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PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS.

CONTRIBUTED BY OFFICERS OF THE ROYAL ENGINEERS,

AND

HON. EAST INDIA COMPANY'S ENGINEERS.

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PREFACE.

As I have been appointed to perform the duty of editing the Professional Papers, I have endeavoured to render this volume as portable as possible, in accordance with the opinion generally expressed at the Meeting of the Corps in February, 1854, (although the unexpected length of the valuable paper at the end of it has rendered it more bulky than was originally intended); yet it must not be forgotten that, as the Officers, both of the Royal Engineers and East India Company's Engineers, are employed in a great variety of duties, *equally varied information* should be collected for them to enable them to take advantage of the latest improvements in all branches, so that every operation which they may have to direct may be performed *in the best manner possible;* and I hope that officers of every rank in both services will therefore assist in rendering the experience which they acquire useful to the rest, by sending accounts of what they observe and consider remarkable, (whether resulting in success or failure) as their contributions to future volumes, accompanied by drawings, if possible on a scale adapted to the work and with the dimensions marked on them, so that what is required to be represented may be made known with a due regard to cost and portability.

The results of experience in the *operations of war* are, however, what we must consider most valuable, and the subscribers will therefore rejoice to see in this volume some records of the experiments made at the Royal Engineer Establishment at Chatham, whither both officers and men naturally look for information relative to the improvements made in carrying on their duties before an enemy; and whilst we may expect soon to obtain detailed accounts of those operations which have been lately carried on against the Russians in Europe, we may hope that our brother officers whose duties are confined to Asia, but who have hitherto had more constant practice in the field than ourselves, (recollecting that we have all studied the subject together at Chatham) will continue to take a prominent part in adding to our knowledge of it when opportunity offers, so that all may unite in increasing our efficiency as Military Engineers.

P. J. BAINBRIGGE,

Captain, Royal Engineers.

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SKETCH OF THE ORIGIN AND PROGRESS OF THE BRITISH TRIGONOMETRICAL SURVEY.

BY LIEUTENANT COLONEL PORTLOCK,

R.E., F.R. AND G.S., F.R.A.S., AND M.R.I.A., ETC.

HAVING followed General Colby to the last scene of exhibition of that personal energy which was so remarkable a feature in his character as a practical geodesist, the narrative must be retraced back to the epoch when Major Colby was required to extend the operations of the British survey to Ireland: and in order to estimate correctly the magnitude and the difficulties of the task thus imposed upon him, it is necessary to compare together the objects of the previously existing and of the projected surveys, and to consider what means were then available for, or suitable to, the purposes of the prospective work.

It is not until civilization has made considerable progress, and the value both of time and labor has begun to be estimated with scrupulous precision, that the importance of good maps can be fully appreciated. Until then the bold huntsman or the hardy peasant pursues his way over rough and dangerous tracks, regardless both of the labor and of the difficulties of his journey; but when at last by the pressure of an increasing population and the multiplication of its wants, men are taught to economise every moment of their own time, and of the labor of their horses and cattle, as being an element of production, the loss of which must be attended by a corresponding loss in the productive value of their property, they cannot long be blind to the importance of such maps as will guide them in laying out their roads and their canals, or assist them in studying the physical condition and the local peculiarities of the country they inhabit and the soil they cultivate. The successful execution however of extensive national maps depends on certain scientific principles which have been founded on an accurate knowledge of the figure of the earth, and it is not therefore surprising that the production of really good or accurate maps should have been reserved for an age of scientific excellence. In this country, indeed, as has been already shewn, a great scientific operation, simple in its details but grand in its results; namely, the triangulation for determining the length of an arc of the meridian, as an element in estimating the figure of the earth, was the precursor of the national survey, and supplied the necessary data for combining together the surveys or plans of detached portions of the earth's surface, and for projecting them correctly as one whole in the map of an extensive country. This first survey, commenced as it was in detached fragments, had for its object a general representation only of the country, and though the field work was plotted on the scale of two inches to a mile, the map itself was engraved and published on a scale of one inch to a mile, which was manifestly insufficient for practical purposes; for though in a favorably situated district, such as Wales, a map on this scale, sketched and shaded with the skill of a Dawson, may have proved sufficient for the geologist in tracing out the great features of the ground, a similar map in a country of less marked reliefs would have proved inadequate even to so limited an object. Beautiful therefore as maps upon this scale have been, and can be made; and valuable as they are to the traveller, to the general student of a country, or even to the road maker, they are not sufficient for the wants which have grown out of the modern refinements in agriculture and the improved modes of general communication, or have been consequent on the pressure of an increasing population. Waste of time and waste of space can no longer be tolerated, and hence it is that the value of minutely detailed maps has at length been felt and acknowledged. Nor was it only in the object of the work, that the early survey differed from the survey as it now is; it differed from it also in the principle of its execution. The original survey having been grafted, as it were, upon an independent scientific work, was local, and detached in order of performance, and as the importance of a great national survey was at first only partly recognised, the annual parliamentary grant voted for it was small, and the work proceeded under all the disadvantages of a slowly protracted survey, an interrupted publication of unconnected maps, and a tone of shading and style of execution varying, though improving, in its progress. Subsequently, indeed, the work was viewed as a whole, and every care was taken after the publication of the map of Lincolnshire to revise the first published maps, to lower their depth of shade, and put them in harmony with the last; but still the defect of a system, in which every successive map represents a portion of the country in a different condition from the preceding one, must cling to this great work, until at a future period it shall undergo a general revision, undertaken simultaneously over the whole country, and be thus rendered a faithful record of the condition of the country at some one definite epoch.

The British survey had just passed into the transition state between a collection of detached and not very harmonious works, and a work executed on uniform principles as one whole; and the maps had assumed, under the immediate superintendence of Lieut.-Colonel (then Captain) Mudge, R.E., and Lieut.-Colonel (then Lieutenant) Dawson, R.E., who were ably assisted by the intelligence and artistic skill of Mr. Baker, the chief engraver, that purity of style and just graduation of shade, which have raised them to the first rank amongst the most beautiful specimens of topography of the present age, when the attention of Government was powerfully directed to the wants of Ireland, hitherto overlooked as regarded the national survey. The object however of the Irish Members of Parliament was not to require the extension of the British survey and British map to Ireland, but to ask for a work which should serve as a basis for a general valuation and be practically useful in the adjustment of the local burthens of taxation, and it is therefore evident that they had adopted a much more sensible view of the advantages of an accurate survey and map than had hitherto been taken by their English brethren, the reason of this superiority of judgment being fairly ascribable to the fact that Ireland was already in possession of a survey of no mean character; one, indeed, which, considering the time of its execution, must be considerered a work of very great merit.

The history of the survey of Ireland, commonly called "The Down Survey," by Dr. William Petty, A.D. 1655-6, edited for the Irish Archæological Society by Major (now Lieut.-Colonel) Thomas Askew Larcom, R.E., one of its most distinguished members, enables the enquirer to study the object and peculiarities of that remarkable work, and to perceive the natural connection between it and the modern Ordnance survey of Ireland; and this work of a friend and brother officer will therefore be freely used for that purpose.

The great objects of the Down survey were the measurement and the distribution of forfeited lands; but as the ancient people of Ireland had been persecuted and despoiled before the time of Cromwell, so also had surveys for similar objects been previously found necessary. The surveys of Tipperary taken in the time of the Earl of Strafford (1639), and called the Strafford survey, were of this kind, and under the sanction of the Lord Deputy and Council, were adopted by Dr. Petty, who however undertook to introduce all such amendments as time had rendered necessary, for "it was considered that many houses and improvements were now demolished, which were, anno 1639, standing; and many wet grounds, heretofore pasturable, now become wholly bog, with other like alterations, which might have proved a grievance to the army, and consequently a review was thought necessary." In a Report on the Strafford survey made by Mr. Benjamin Worsley, Surveyor-General, and Mr. Miles Simner to the Commissioners of the Commonwealth it is thus described, "We have perused certain small books bound up in parchment, and entituled: No. 1, Barony of Ikerine; 2, Eliogarty; 3, Kilnemauagh; 4, Kilnelongar; 5, Ileagh; 6, Upper Ormond; 7, Lower Ormond; 8, Arra; 9, Owny Mulrian; 10, Ownybeg. On the outside of which books are set down likewise the names of the parishes respectively belonging to that baroney. In the inside of the books, before every parish, are set downe the names of the jurors, being generally six in number, and underneath the said names, this memorandum within, that they being all duly sworne upon the holy Evangelists, have set forth the bounds and meares, names and by-names, of all the quarters, plow-lands, and other denominations of lands lying in the parish, together with all the owners and proprietors of the said lands, their names and by-names, and to the said information have at the end thereof subscribed their names.

In the next place is sett downe the names of the surveyors who admeasured the said parish, with this memorandum, that each sworne admeasurer for the parish doeth present, uppon his oath the true quantities and qualities of all the several lands lying in the parish to be as followe, and to the said presentment hath, at the end hereoff, subscribed his name.

The method and proceeding in the description of every parish is as followeth :—

1st. The number of surrounds made by the instruments, in each parish respectively, is sett downe, together with the quantity of land contained in each surround, according to the denominations, as one plowland, $\frac{1}{2}$, $\frac{1}{3}$ or $\frac{1}{4}$ of a plowland, &c.

2nd. A description of each surround, more particular, according to the name of the land so surrounded; the quality of the said land as arable, pasture, meadow, timber-wood, shrubby wood, and bogg; and this again into waste and into that which holds a proportion as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ or $\frac{1}{5}$ in value, as we conceive to that which is profitable and good; 4th. The names of the proprietor or proprietors who have lands within the said towne soe called or distinguished, or a note of the said lands itts being in controversy; 5th. the quantity of acres in the said towne distinguished according to the quality; 6th. the number of reference, both to the county map, to the baroney, and to the parish map.

3rd. At the end of each surround is an observation made of what castles, houses, mills, or other edifices, as also what mines or other emoluments were found upon it.

Wee further humbly certifie that, besides the sayd bookes, wee find a very fair county map, containing the several barronyes before described to be admeasured: as alsoe other smaller maps of particular barronyes, and of particular parishes, most of which, soe far as wee can discover, are very entire and perfect. The said plotts or maps expressing alsoe the quality of the said land, whether arable, pasture or meadow, &c., and how the same is respectively situated in each land." These extracts give a most favourable view of this section of a survey in the early part of the seventeenth century, and of the common sense objects it was intended to fulfil.

Such as the Strafford survey was, Dr. Petty adopted it, having first employed Dr. Patrick Raggett to go over it carefully, comparing the ancient measurings with his own new test measurements, and Dr. Raggett thus reports the results of his investigations. "I, Patricke Raggett, of Thurles, in the county of Tipperary, having been duely sworne, doe hereby certifie that the barronyes of Balleboy, Kilcarsy, *and others* on the King's County, have by myselfe or sufficient assignes and partners, been surveyed and admeasured according to the printed instructions given unto me by Dr. William Petty, viz., by returning the true quantity, quality, figure, situation, name, proprietors, bounds and buildings uppon, and of all and every the parcells and surrounds of lands directed to be admeasured, together with the names of the mearesmen, and of their dwellings, who shewed the said lands. And have reviewed, examined, and compared the survey and admeasurement of the barronyes of Upper Ormond, Lower Ormond, of Owney and Arra, of Owneybeg, and the territories of Kilnemanagh and Kilnelongurty, in the county of Tipperary, by surrounding and tracing over the meares of all and every denomination of land within the said barronyes, by the help and with the assistance of a jury of the country, and doe attest the same to have been well performed, according to the best of my care, skill, knowledge, and information. Given under my hand, this 10th January, 1655.—PAT RAGGET."

In this instance, however, as will generally be the case, the adaptation of old work to new, proved far more troublesome and very nearly as expensive as an entirely new survey would have been. It appears indeed that Mr. Worsley, the Surveyor-General had shunned the use of these previous surveys when engaged on the new survey, before the undertaking of that work by Dr. Petty, and that one motive at least for their adoption by the Doctor was to avoid the disputes which might have grown out of a comparison between two distinct surveys, for it is said, "that the Doctor understood that the books of reference which were wanting were gotten into the hands of some of those officers whose lots were like to fall in Tipperary, who, in case of disagreement (between the new survey now to be made and that already in being) to their disadvantage, would oppose that very reputeable survey of Strafford sorely against the Doctor's." After all the trouble of examining the Strafford survey and comparing it with the civil survey, as well as of reconciling the names and distributions of land, and the expense of a review of the work by Patricke Ragget, "the said old survey did not yield much advantage to the Doctor uppon the whole matter, that is, uppon downe admeasurement and subdivision, taken both together, there having been soe much ventured to try it by the above mentioned previous examination and reviews. So that, in briefe, this old survey gave the Doctor only an occasion to play at hazard, and he had the good fortune to win, though not one hundred pounds." He, however, escaped much litigation by fusing the Strafford survey into his own, and that doubtless reconciled him to a measure of which he manifestly disapproved.

The condition of the topography of Ireland anterior to the epoch now under examination is thus summed up by Lieut.-Colonel Larcom: "Before the time of Petty, except the material compiled into the early maps of Ireland by Boazio, Ortelius, Norden, Blaeu, and others, the only detailed surveys of any magnitude were those of the King's and Queen's Counties, about 1630; the county of Londonderry, by Raven; and the Strafford survey. Worsley was carrying on the surveys for grants and forfeitures, which have been sufficiently adverted to already as 'grosse surrounds;' but it remained for Dr. Petty to originate the idea of connecting the separate operations, into a general survey of the three provinces which were not comprised in the Strafford survey. His great step was making territorial and natural boundaries the main objects, instead of estate boundaries alone; because the former were permanent and enduring, the latter in their nature fluctuating, and destined to change by the very purpose for which the survey itself was made."

The object which had rendered such surveys, as the last enumerated in this passage, necessary, was one of the age, and continued unaltered notwithstanding the change in the character and persons of the governing body of the state. In the reign of Charles I. the Earl of Strafford, when Lord Deputy of Ireland, directed those surveys of Irish forfeited estates to be made which subsequently bore his name, and again in the great rebellion of 1641 a new motive for forfeiture was discovered, and new surveys became necessary. The lands thus obtained by forfeiture were neither retained as Crown property, nor transferred by royal grant from one great proprietor to another, but were in part allotted to the soldiers in lieu of their arrears of pay, and in part to those adventurers who had been induced to contribute large sums of money towards the expenses of this international war. Such had been the projected arrangement of the Monarchy; and it was not only adopted by the Protectorate of Cromwell, but extended so as to include the subsequent arrears of the soldiery; the people of Ireland receiving at that time about the same treatment, and being equally an object of legalised prey, whether governed by monarchists or by republicans.

The preamble of the Act for the "Satisfaction of the Adventurers for Lands in Ireland, and of the Arrears due to the Soldiery there, and of other publique debts," is thus worded: "Whereas, many well-affected persons, bodies politique and corporate, did subscribe and pay, in, upon several acts and ordinances of the late Parliament, divers considerable sums of money by way of adventure towards the suppression of the late horrid rebellion of Ireland, which said sums of money were, by the said acts and ordinances, appointed to be satisfied by several proportions of the lands of the rebels there, as soon as the said rebellion should be appeased; and whereas also several other great sums of money are grown due, and in arrear unto the officers and soldiers who have been employed in reducing the said rebels, and to sundry other persons, either for arrears yet unsatisfied, of moneys lent, or provisions or other supplies furnished for the publique service; and, whereas, by the blessing of God upon the forces of the Commonwealth, the said rebels are subdued, and the said rebellion is appeased and ended, and it is hereby declared to be appeased and ended;" so that it may be readily conceived that the motives for confiscation must have been very powerful, when the land and other real property were destined to replace money in the payment of the troops, and in other public transactions: nor did the land of Ireland pay alone for the cost of its own conquest, as may be judged from the following passage of the act, "And be it further enacted by the authority aforesaid, that in case the moyety of the said ten counties shall not be sufficient to satisfie the debt of the said adventurers, then the remainder thereof shall be satisfied by such lands as are forfeited in the county of Louth within the province of Leinster, excepting the barrony of Atherdee, and what shall be defective in the other moyety of the said ten counties, to satisfie the arrears of the army in Ireland, that have accrued and grown due since the fifth of June, 1649, together with such other arrears as became due unto them for *their service in England* before the said fifth day of June, 1649, shall be made up and satisfied unto them out of the surplusage of the moyety of the ten counties allotted to the adventurers, in case any such surplusage shall appear to be, and out of the county of Louth, or out of the forfeited lands of other counties in Ireland"—by which passage it appears that arrears of pay due for service in England were also liquidated in Irish land.

It is unnecessary to dwell longer on this painful part of the subject, as it will be readily understood from what has been said that no ordinary caution was required in the survey of land which was about to be distributed amongst so many eager, and as regards the soldiers, either already or about to be disbanded, literally hungry claimants; whilst therefore the act of 1652 entitled, "An Act for the settling of Ireland," created the necessity for a survey, provision was made for its execution by the act of 1653, by the order of council which that act confirmed, and by the instructions drawn up by the commissioners which it approved. The work was undertaken by Mr. Benjamin Worsley, who had come from England for the purpose and was appointed Surveyor-General, and that portion done under his directions bears the double name of Civille and Grosse survey which is thus explained by Lieut.-Colonel Larcom, "In regard to the designations Civille and Grosse survey, which occur so frequently, it will be seen that the Civille survey was the terrier or list of forfeited lands, prepared under the commissioners appointed by the commission of 1st June, and Act of 26th September, 1653. The Grosse survey was the designation by which the surveys ordered by the above commission are referred to in the acts;" and it may be added that the word survey in its most ample, and most satisfactory sense should never be confined to the mere topographical delineation of a country, or the simple field work connected with it, but should embrace, as in this case, the preliminary operations of the examination and determination of boundaries, and the subsequent collection of illustrative statistical information of every branch and kind. This was the view of the subject taken by Sir W. Petty, although he was unable to realise his wishes in respect to the latter portion of the enquiry to their full extent, and such was the enlightened view of the true objects of a survey with which General Colby commenced the Irish survey, though he too was not permitted to carry out the noble design in its integrity.

The work was in full progress under Mr. Worsley, when Sir William, then Dr. Petty, who had come to Ireland in 1652, as Physician to the forces and to the household and family of the Lieutenant General, being a man of extraordinary acuteness of intellect and energy of character, came forward to impeach and condemn the manner in which the survey was then conducted, and to offer to undertake on his own part its completion on sounder principles and in a much shorter time. The acrimonious disputings between Mr. Worsley and Dr Petty, and the complaints of the surveyors who had been employed by Mr. Worsley, which necessarily followed this bold and startling proposition, do not require to be here detailed, as the Council was at length convinced of the wisdom of Dr. Petty's proposals, and his offer being accepted, the remarkable work called "The Down Survey" from "its topographical details being all laid down by admeasurement on maps" or as "the survey laid down" was the result. In briefly detailing some of the arrangements of the Down Survey, and the civille and grosse survey which preceded it, they will occasionally be compared with corresponding arrangements of the Ordnance Survey, and the justice of the following remarks of Lieut-Colonel Larcom will be fully appreciated; "Generally, in regard to all, nay, to each and every of them, it is not beside the subject to say that there is not one of these precautions which was not found indispensable in the similar work of the Ordnance survey, and it is even more remarkable that clear directions on the same points were laid down also in the similar instructions prepared by the able director of that work, Colonel, since General, Colby, who, it is needless to say, had never seen or heard of the archives and documents we are now consulting and printing. Many of the instructions of Dr. Petty and Colonel Colby might be printed in parallel columns, so remarkably have the same circumstances produced the same results, from minds very similar in some respects to each other." Sir W. Petty, must indeed, by any historian of the Ordnance survey of Ireland, be considered its progenitor as a great practical work, just as General Roy was its progenitor as a work of science.

Objects.—The object of the Down survey has been clearly stated; namely, as a basis for the distribution of the forfeited lands amongst the adventurers and soldiers, who had either by money or in person contributed towards the expulsion of the old proprietors and the quelling of the rebellion which had led to the forfeitures. The object of the Ordnance survey was to provide a basis for the equitable adjustment of local taxation. The Committee of the House of Commons of 1824 thus reports: "The surface of Ireland consists of about 20,000,000 acres in English measurement, divided into 4 provinces, 32 counties at large, 8 counties of cities, towns, or other independent local jurisdictions, 252 baronies, about 2,400 parishes, and a further civil subdivision, generally known as townlands, but bearing different names in the several counties in Ireland. These sub-denominations, which may be generally expressed by the word townland, are the ancient and recognised divisions of the country; they form the basis of the Down survey; they have been long used in the apportionment and collection of country and parochial rates. It is obvious, that if a baronial or even a parochial subdivision were alone to be effected, sufficient data would not be furnished for the apportionment of the local taxes; and if, on the other hand, a survey by fields were to be undertaken, as in France and Bavaria, the expense of such a work would be augmented, and its completion postponed. A survey by townlands appears to your committee to be the rational medium between these two extremes; sufficiently close for practical purposes, without aiming at any extreme minuteness of detail." The Down survey, for many years had been unfitted to supply the wants of the public in respect to taxation. In its original state it consisted of 31 folio volumes of survey maps of lands forfeited by the rebellion of 1641. The respective baronies on a small scale, including as well as they could the denominations of lands therein; and upon a more useful and extensive scale, the various denominations contained in the space of the respective parishes, a folio sheet being added to each parish, describing its site, bounds, particular denominations, content, forfeiter's names. Of these volumes, many were nearly and some totally destroyed by a fire, which took place in 1711; and though it was proposed to supply the deficiency thus created by a copy made by General Vallancey of a set of the maps which Sir W. Petty had copied for his own use from the originals, and which, having been captured by a French privateer when on their passage to England, had been lodged in the King's library at Paris, the parliament had never ventured to give legality to this copy, which only extended to the baronial maps, even as evidence of boundaries; Mr. Handcocke remarking in his evidence that "General Vallancey's copy is a transcript of the copy of the original baronial maps only, defective of every other likeness or means of information, too minute in many instances to afford the strong contour by which original boundaries, if defaced by time, could be accurately defined; too confined sometimes in space to declare the quantity, or ascertain landmarks, such as castles, churches, &c., &c.; in some instances and very many indeed, erroneous and differing from the originals as to figure, but totally deficient as to every other source of information afforded by the originals. To authenticate them generally and entirely as records, might be dangerous; partially, where the originals have been destroyed, some use may be safely made of them; but, in no instances should they be admitted to serve as proofs on trials of boundaries, unless where none of the originals can be had." And if, defective, from its now imperfect condition, even as an indicator of territorial boundaries, how much more so must it have been as a guide to the determination of the quantity and value of land, when it is remembered that though a great, nay, a wonderful work, for the period of its execution, and from the extraordinary fact that it had been completed in about two years, it was not founded upon a scientific basis, nor calculated to represent the altered condition of the country after the lapse of nearly two centuries, nor to meet the exigencies of an improved agricultural and social system.

To supply at least some of that information necessary for an equitable adjustment of local burthens which could no longer be derived from the Down survey, several county maps had been constructed on various scales and of very different degrees of merit, but as such works could not be achieved as parts of one great whole, and therefore be stamped as legal documents of reference by one uniform authority, they were of little or no influence in abating the evil complained of, and in consequence the various assessments were made in the most irregular manner, sometimes from old county books or keys which were arranged when the relative value of the land was quite different, and sometimes in a still more loose and arbitrary manner. In the County of Limerick the whole assessment upon the county was first divided amongst the baronies, proportionably to the number of acres in each, but without reference to the comparative value of the land, and this principle was again followed in apportioning the baronial assessment amongst the townlands, so that the rate levied when estimated in proportion to the actual annual value or return of the land, was ruinously unequal, 100 acres of the most inferior land paying as much as 100 of the very best. In the County of Waterford, the Treasurer, Edward Roberts, Esq., stated, that "The county is divided into 489½ ploughlands, of which each barony contains a different number; for instance, the Barony of Glanaheiry 14, and that of Decies without 122; so that if £10,000 be presented on the county at large, that sum is divided by 489½, and each barony bears its proportion according to the number of ploughlands therein. Here it will be observed, that though the tax on the ploughland itself was collected by the acre, the allotment was made without any reference to the number of acres in the townland, or to their value, a custom, as Mr. Roberts remarks "fraught with much injustice; for instance, there is in the Barony of Coshmore, one ploughland, containing upwards of 8000 acres of which 2000 are arable land, and another ploughland, which contains only 180 acres, and both these ploughlands bear an equal share of the tax charged on the barony." In the County of Wexford the treasurer stated, "There is no general scale followed by the baronial collectors for apportioning the cess on the several sub-denominations within their baronies, as *each barony* has a *different modus* of ascertaining the same from custom, time immemorial." Mr. Daniel Mussenden stated that "they applied differently in different baronies in the same county; they applied by the townland in my neighbourhood in two baronies I am concerned in. The townlands are very unequal in size; they probably were of the same value when that division of the country was made, of which we know nothing; but from the improvements of the county they are now very unequal." Even where the Down survey had been adhered to, as in Tipperary, it had failed to secure equitable adjustment, as it had originally only professed to make the one great general distinction between profitable and unprofitable land, and therefore was no longer a fair representation of the relative capabilities of the land to support taxation. A magistrate of the county, Thomas Lanigan, Esq., stated "The money is levied by a very erroneous and unfair mode of calculating the taxes by the Down survey. We are supposed to be taxed by the acre, but it is a very unfair survey. I know some persons who do not pay half the taxes they ought, and others who pay much more." Doubtless the unfairness here referred to was not connected with the original accuracy of the survey, but with the great alteration in the relative condition of lands which must have taken place in so long a time, and were similar in character to that referred to by Mr. Leslie, member for the county of Monaghan, in his evidence. "The applotment is laid on by what we call the townland; the townland differs much in quantity; the applotment was made in the reign of William the Third; it was then regulated according to the value of the land, consequently land at that time not so valuable has since become very valuable, and paid scarcely anything in proportion, so that the tax is now very unequal." Indeed the Right Honble. Denis Browne, afterwards Lord Oranmore, describes the taxation of Mayo, as *ridiculously unequal*, and gives as an example the case of "Mr. Harry King who has a farm from which he gets no rent, because by some strange jumble the whole tax of a great part of the district is thrown upon it; and there is a large surface of fine land adjoining it, which pays nothing." Such then was the irregularity and injustice of the local taxation on land in Ireland, when the imperial parliament was urged, by its most influential members, to remedy the evil by a general survey and valuation of that country. The great analogy therefore between the Down survey and this newly projected survey is in the fact, that they were both planned for practical objects connected with the land, whilst in other respects, though there were many points of resemblance as to the details of the operation, there were also equally striking features of disagreement: the Down survey being a collection of maps, not capable of being combined into one whole, and the Ordnance survey one great map of the whole country, though for convenience divided into a number of parts; the Down survey, whilst delineating the territorial boundaries, adopting the one great distinction between profitable and unprofitable land, as the only one required for the mere purpose of distributing the forfeited estates amongst soldiers and others, and the Ordnance survey, whilst delineating the boundaries in a similar manner, but with that more scrupulous accuracy which was necessary to render the map a fitting basis for the minute valuation required in the nineteenth century, by the improved agricultural and commercial condition of the country, applying all the resources of modern science to make it equal as a great topographical work to any survey or map undertaken by any European or other government.

SCALE.—In determining the scale of a map it would appear to be easy to adjust it to the representation of every thing intended to be embraced by the survey, either as boundaries or as objects; and yet the example of the Ordnance survey proves how difficult it is to bring all opinions into harmony even upon a matter of such apparent simplicity. For the Down survey, Sir W. Petty adopted the scale of 40 perches to the inch for the first great plot from which the content in acres was to be estimated, and for a large barony plot the scale of 80 perches to the inch, these latter plots being reduced into maps of various scales according to the size, so that each barony might be brought into one sheet of paper. The committee on the Down survey reported (1813) "We find that the existing parts of the Down survey consist of two sets of maps; one set containing a map of each barony into which the several counties are divided, and the other a separate map of each parish. These baronial maps are in general on a scale of 160 perches to an inch, but in some the scale is as small as 320 perches to an inch. The parochial maps existing are in general on a scale of 80.

but some on a scale of 40 perches, to an inch. From the difference of the scale on which the baronial and parochial maps are formed, there are in almost all, if not in every one, of the parochial maps, numerous names of denominations of lands, which are not mentioned in the baronial maps of the existing Down survey, the baronial maps noticing only the parishes, and most considerable denominations of the lands." A somewhat similar arrangement was adopted in the Ordnance survey of Ireland, as the index maps of counties are drawn upon scales varying with their magnitude, so as to include the county in one sheet, whilst the general townland map is of one uniform scale throughout. The scale adopted for the Irish Townland survey was 6 inches to the mile, a scale which had been previously tried in the English survey, as was thus stated by General (then Major) Colby, in his evidence before the select committee of 1824; "The English survey commenced upon a scale of six inches to a mile, on which scale the map of Kent was originally plotted, and it is now carried on in the scale of two inches to a mile," and he added in reply to a question, whether such a scale was sufficiently large to represent distinct divisions of land varying in size from 50 to 300 acres, "I should think it would represent those divisions very completely." From this extract it does not appear that General Colby had previously proposed a scale for the Irish survey; but in his reply merely expressed an opinion on a scale then suggested to him by the committee. The evidence of Mr. Richard Griffith, the well known civil engineer and geologist, was however more positive in its character. The direct question was put to him; "What scale would you propose for the maps that are to be executed by the surveyor for the purpose of valuation?" and his reply was equally explicit, "I should recommend the scale to be six inches to a statute mile, but in the survey of towns or villages, or townlands immediately adjoining, where portions of acres are of great value, I think it would be necessary to lay down the map on a scale of 20 inches to a mile; but these should be considered only as supplemental maps to the others, for every townland should be laid down on the scale of six inches to a mile," so that the adoption of that scale may be fairly ascribed to the confidence justly reposed in Mr. Griffith by the committee, and it may be added that his recommendation of auxiliary maps of towns, &c. on a larger scale, has been also carried into effect. As the value of the Down survey was tested and established by its successful application to the purpose for which it was designed, namely, the distribution of the forfeited lands, so has also the value of the Ordnance survey of Ireland been proved by a similar successful application to the valuation of the land; and in like manner its collateral utility to the engineer and agriculturist has been acknowledged by some of the most able men who have actually tried it, and thereby acquired a right to express an opinion on its merits or its defects. Still however the experience of the Irish map has not served to decide the question as to scale generally, either as regards England or Scotland, and evidence has been given of the most conflicting kind before successive committees of the House of Commons by men of apparently equal scientific eminence, some of whom have desired no other kind of map than the one so long in progress in England upon the scale of *one* inch to a mile, whilst others have recommended the whole survey to be plotted on the scale of 24 inches to a mile, and the map drawn on a scale of 12 inches to a mile. It is not intended to attempt in this memoir to reconcile these differences of opinion, though Colonel Hall, late superintendent of the survey, and immediate successor to General Colby in that important charge, has suggested the following compromise in his very able report. "The scale most adapted for general engineering and statistical purposes is the six inch; increasing or decreasing this scale diminishes the *general* applicability of the map," and "after a very full consideration of the whole of the purposes for which public maps are now and may be hereafter required, I am decidedly of opinion that the 12 inch is the best scale to be adopted for a general map of all the arable rural districts of the kingdom; villages and towns to be an exceptional scale of 2 feet, 5 feet and 10 feet to a mile according to the nature of the place." These opinions may not appear quite consistent with each other, but Colonel Hall evidently means that he prefers a 6 inch map, if intended only to serve the general objects of engineering and agricultural improvements, and a 12 inch, if intended to supply the place of estate maps. Without doubt every unnecessary increase of the scale is a cause of additional labour, whilst it adds to the difficulty of executing the work; and though this may be indifferent to one who is merely called upon to use detached maps for some specific object, the person who has to superintend the construction of one general map of a country must speedily recognise the difficulty of combining together such a multitude of sheets of paper, each of which embraces a mere minute fragment of the country. Colonel Hall, therefore, whilst maintaining that such large plots are not necessary, recommends that, if prepared, they should at once be placed on copper, as the only mode of securing them from the distortions and changes consequent on hygrometrical causes.

A comparison, however, between the scales of the two great Irish surveys, the Down survey of Sir W. Petty and the Ordnance townland survey, suggests at least some reason for doubting whether the scale adopted for the latter work was really the best for the purpose, and whether it would not have been even wiser to adopt the same scale for the Ordnance map as had been adopted by Sir W. Petty for the Down survey, namely a scale of 40 perches to an inch or 8 inches to a mile; this scale representing 22 yards or 66 feet by $\frac{1}{10}$ of an inch and being therefore sufficient to exhibit the minutest building as the $\frac{1}{10}$ could be readily subdivided into 2 and even into 4 parts, whilst the advantage would have been even greater in respect to the acreage, as a square inch would have represented the $\frac{1}{64}$ part of a mile or 10 acres, and $\frac{1}{10}$ of an inch square $\frac{1}{10}$ of an acre, a subdivison sufficiently minute for most purposes. The facility of estimating areas which such a scale affords is therefore manifest, and at the same time it puts a survey in relation to the measures always adopted in agricultural operations, the perch and the chain; whilst 24 or 32 inches to a mile might still be adopted as a scale for cities or important towns.

These remarks have hitherto had no reference to the more general question of a proportional scale suitable for all countries; which, however, deserves at least a brief notice as there cannot be a doubt that the selection of some definite proportion for the more general map of every country, such as the one inch map in England, would be very convenient by enabling a student to read, as to distances, the map of any country in the measures of his own: and even in the larger maps, where a scale of well known units must necessarily be adopted, as the readiest way of meeting the wants of the practical man, a proportional scale should also be given, as for example, a scale of 24 inches to a mile or $\frac{1}{2640}$, 12 inches or $\frac{1}{5280}$, 8 inches or $\frac{1}{7920}$, 6 inches or $\frac{1}{10560}$, 2 inches or $\frac{1}{31680}$, 1 inch or $\frac{1}{63360}$.

In the preceding proportional scales, the fractions are all inconvenient for general application, as they are not resolvable into a finite decimal fraction. For example, the 8-inch scale is represented proportionately by the decimal ·00012626, &c.; the 6-inch by ·0000946969, &c.; the 2-inch by ·0000315656, &c.; the 1-inch by ·00001578282, &c.; the 12-inch by ·000189393, and the 24-inch by ·00037878, &c.: numbers which cannot even be approximately adjusted to a finite decimal proportion, for should the decimal in the 8-inch be assumed to be ·00012, it would represent a unit scale of 7·6 inches to the mile, or 8·24 inches if assumed to be ·00013, neither of which would be attended with the practical advantage of the 8-inch scale in respect to areas in acres; and, again, in the 6-inch, if the approximate decimal ·00009 were adopted it would represent a unit scale of 5·7 inches to the mile, or in the 2-inch, where the approximation would be nearer, ·00003 would represent a scale of 1·9 inch to the mile. If therefore it be deemed indispensable, as it undoubtedly is philosophical, to consider every line in a map as bearing a definite proportion to the distance it represents, the ordinary duodecimal scales have the disadvantage of requiring, in every case, a long multiplication by the denominator of the fraction representing the proportion, in order to reduce the measured line on the map to the measured line on the surface of the earth which it represents. To replace them therefore it has been proposed to adopt a scale of $\frac{1}{2500}$ for rural districts, and $\frac{1}{500}$ for towns, equivalent respectively to scales of 25·34 inches, and 126·72 inches or 10 feet 6·72 inches per mile; these scales being those adopted in France and Belgium, where they are so readily applicable to the decimal metrical scales of those countries, and being also very easy of application to any form of unit scale, the fraction $\frac{1}{2500}$ being represented by the decimal ·0004, and the fraction $\frac{1}{500}$ by the decimal ·002; so that any distance measured on the map is at once reduced to the true distance in space by multiplying it by 10,000 and dividing the product by 4 on the one scale, or by multiplying by 1000 and dividing by 2 on the other; as, for example, 5 inches on the map are equal to $\frac{50000}{4} = 12500$ inches, and 2 feet on the other scale are equal to $\frac{2000}{2} = 1000$ feet.

Notwithstanding however the ease with which this proportional scale may be used in estimating distances, some of the most scientific men in the country have differed in opinion as to its advantages and disadvantages. As stated by Professor Piazzi Smyth, it is *not* a decimal scale, and therefore not entitled to the prestige attaching to that name. Nor is there any good reason for preferring the French metrical system to a decimal system founded on our own yard, as the metre can only be considered an approximation to a natural standard, and must be practically determined at any time by reference to a standard bar, *assumed to be* the $\frac{1}{10000000}$ part of the earth's quadrant, just in the same way as the length of a yard would be determined by reference to a standard bar, stamped as a true yard by authority. For the purposes indeed to which maps on so large a scale as those now under discussion are likely to be applied, there seems little advantage in forcing a uniformity between the maps of other countries and those of our own, as it is highly improbable that an Englishman would ever find it necessary to consult so large a foreign map, or *vice versa;* but with maps of a smaller scale it would indeed be highly desirable that the same proportional scale should be adopted for all countries.

The one practical disadvantage, that the result is not at once given in measures which convey to the mind a distinct notion of distance, such as 1, 2, 6, 8, 12, &c., inches do, in those scales in which they respectively represent a mile, can be easily obviated by printing, on each sheet of the map, scales divided according to the received measures of this and some other countries. The Astronomer Royal proposed proportional scales of $\frac{1}{600}$ and $\frac{1}{3000}$ as more available with our measures for the large maps, but the Government has provisionally adopted the scales of $\frac{1}{500}$ and $\frac{1}{2500}$, and so far as distances are concerned the regret will be that a more purely decimal scale could not have been contrived, as it may fairly be asserted that, after all, the image of distance conveyed to the mind by the word "mile" is extremely vague, and varies with almost every person, the pedestrian and the equestrian, for example, viewing it under very different aspects. In small scale maps where estimates of distance are made in reference to the time of journeys, the mile is indeed a useful unit of comparison, but in the large scale maps the objects of reference will far more frequently be connected with feet and yards, or links and chains; and as the great advantage of such maps is, that they are at once adapted to all the purposes of minute registration and to all the wants of the farmer, care should be taken to render their use for such purposes as easy as possible. Whatever then may be the result of the present effort to introduce a decimal division in all measures, it is probable that the acre will still continue the unit for land measurement, and if so, some assistance should be given to the farmer in determining at sight his acreage; which might be done by engraving on the large maps vertical and horizontal lines forming by their intersection squares of ten acres. In the scale of 8 inches to the mile, every square inch would thus represent 10 acres; in that of 16 inches, the square of 2 inches; in that of 24, the square of 3 inches; and in that of 32, the square of 4 inches; whilst squares of $\frac{1}{10}$, $\frac{2}{10}$, $\frac{3}{10}$, $\frac{4}{10}$ of an inch would respectively represent $\frac{1}{10}$ of an acre; so that, presuming the squares of ten acres were represented on the map, every farmer would be able to subdivide his land with the utmost ease and precision, and adjust the several portions to the rotation of his crops,—the maps thus truly becoming agricultural. The same object would of course be attained on any proportional scale in respect to the 10 acres, by engraving the squares, but here the farmer would require to subdivide the lines of the squares into ten parts for subdivision into $\frac{1}{10}$ths of an acre, though this might be also done by the engraver at the margin lines of the map.

This important section of the subject may be summed up in the following manner:—

1. *The scale of* 1 *inch to a mile* has been found suitable for the purposes of a general map, and more especially so where the surface of the country is marked by strong reliefs, which can be brought out effectively by shading. The feeling of the public is decidedly in favor of the completion of this map for the whole United Kingdom. Viewed as a proportion scale it is inconveniently represented by the fraction $\frac{1}{63360}$, and might be therefore replaced with advantage by a scale of $\frac{1}{60000}$, corresponding to a scale of 1·056 inch, which for ordinary itinerary purposes might be approximately and conveniently read by allowing 20 miles to 21 inches, the error being only one mile in 110. A proportion of $\frac{1}{50000}$ would perhaps be still better, as being at once reducible to the decimal ·00002: it corresponds to 1·267 inch or nearly $1\frac{1}{4}$ inch per mile, so that every 5 inches would correspond to 4 miles, or 20 miles to 25 inches, the error being about one mile in 80, and is therefore a very desirable scale, independently of its simple relation to the proportion $\frac{1}{2500}$ adopted for the large maps, from which it is derived by muitiplication by $\frac{1}{20}$.

2. *The scale of* 6 *inches to a mile* has been found sufficient for all the purposes of the townland survey of Ireland, but it must be remembered that it was intended by General Colby to serve merely as a representation of the data required for valuation and taxation, not as the means of obtaining those data; and in consequence that it exhibits the area of the townlands as obtained by direct calculation from the distances measured on the ground and not from paper measurements. Even in respect to boundaries, as will be seen hereafter, General Colby introduced a written description of them, resembling what was formerly called a survey, in contradistinction to a map, and which would materially assist in clearing up difficulties or settling disputes. The Committee of the House of Commons of 1824 expressly excluded from their consideration the question of estate or property maps, and there can be little doubt therefore that the scale adopted was a judicious selection for the objects it was intended to fulfil. Had General Colby been required to provide for the wants of registration by producing a map on which distances of 4 or 5 feet might be determined by paper measurement, and to supply to the proprietor or farmer detached property maps, he would unquestionably have selected a larger scale; but as the case stood, he

adopted a moderate scale for portability's sake, marked upon the maps the areas with the utmost possible precision, preserved accurate written descriptions or records of the boundaries, and added to the maps a large amount of collateral information in altitudes, which had never been before contemplated. Whatever therefore may be said by civil engineers or surveyors of the superior advantage to them of larger maps, to General Colby must be awarded the honor of first endeavouring to make the great national map available for all such practical purposes. The nearest convenient proportional scale would be $\frac{1}{10000}$, corresponding to 6·336 inches per mile.

3. *The 8-inch scale*, as well as its multiples, 16, 24, &c. is admirably suited to land measurement, 1 inch, 2 inches, 3 inches square representing 10 acres, and $\frac{1}{10}$, $\frac{2}{10}$, $\frac{3}{10}$ of an inch square $\frac{1}{10}$ of an acre. It was the scale of the Down Survey.

4. *A scale of 3 chains to the inch*, or 26⅔ inches to the mile has been advocated by several surveyors as being in frequent use with them; but with respect to the measurement of land or determination of acreage, the scale of 4 chains to the inch or 20 inches to the mile, or 5 chains to the inch or 16 inches to the mile, appears preferable; a square inch on the first representing 1·6 acre, and on the second 2½ acres.

5. *The proportional scale of* $\frac{1}{2500}$, has the advantage that a square inch is so nearly equal to one acre, that it may be practically assumed to be equal.

6. Mr. James Saunders has proposed a scale of 28·8 inches to the mile, in connection with a decimal division founded on the yard as a unit. In this system the yard would be divided into 100 parts or chains, and each chain into 100 links, the proportion being $\frac{1}{2200}$; so that 22 chains in the field would be equal to one link on the paper, and one square yard on the paper to 1000 acres. As the yard is the only standard measure of England, it seems only reasonable that it should be made the basis of any future decimal system of measures, and this mode of dividing it into 10, 100, 1000 parts has also much in its favor as regards the measurement of land.

7. Finally it may be said, that if a proportional scale be desirable for very large scale maps, which can rarely have any but a very local application, it is far more so for small scale maps; in the one case there can be rarely any necessity for the comparison of distant localities, in the other such comparisons may be frequently necessary. In the small scale map the unit of comparison will be large, as the mile, the kilometre, the werst, &c.; whilst in the large scale map, the unit will be some familiar measure of less extent, such as the chain or the perch; and as the persons who use such large scale maps, for agricultural and other purposes, are not generally acquainted with the theory of proportional scales, it is desirable to assist them not only by engraved scales, but also by the system here recommended of ten acre squares, each side of which would be equal to 10 chains, and therefore at once suggest to the person using the map a convenient and well-known unit of comparison.

MODE OF DETERMINING BOUNDARIES.—*In the Down Survey* this very important operation was confided to the director of the survey, Dr. Petty, who was required by his instructions, " to have if possible such bounders as shall be recommended by the jury that gave information to the Commissioners of Civil Survey, causing them to be either sworn, or subscribe before good witness, unto the truth of the bounds they shall shew unto you. Where the meares are not certainly known, but two are offered as likely to be them, then you will take notice of both, viz., of the most likely by admeasurement, and of the other by estimate, making extraordinary marks at all such places, and recommending them to the country, and expressing the controversy about the said meares in your respective returns."

In the *Ordnance Survey* the responsibility of determining the townland boundaries was even greater, as they had become, almost universally, the boundaries of property, and the value of that property had so greatly increased; nor was the difficulty to be expected chiefly in well cultivated and valuable districts, as it may be presumed that such boundaries had been constantly kept in view and were therefore easy of recognition, but rather in the wilder and mountainous districts where the boundaries had been preserved more by tradition than practical knowledge, and where, of course, the appeal would be answered differently by different parties. The writer of this Memoir was, for example, waited upon by the agent of a great proprietor, with the intention of convincing him that his employer was right in claiming a portion of a barren mountain summit, whilst his adversary declared that it was on his side of the boundary; and the agent appeared much disappointed on finding that the Ordnance officers were to be engaged in the actual survey of the boundaries when determined, and not in discovering or determining them. Military men were indeed little fitted for entering into such disputes, and Major Colby was therefore most wisely disinclined to undertake this part of the work, which was confided to a special boundary department under Mr. Griffiths, as commissioner. The admirable manner in which the boundary department performed its duty, and the value of that harmony between proprietors, who had been before disputing about mere trifles, which was one of the results of the prudence and patience which were exhibited in the enquiries of its members, cannot be overrated; and when the Ordnance surveyors commenced their own labours, they found almost all difficulties removed and disputes settled. Still, however, precaution was necessary to guard the Ordnance from any charge of error, consequent not upon erroneous surveying, but on previous error due to an imperfect determination of the boundary; and to this point Major Colby directed his especial attention. First, then there was the Boundary Note Book, in which the officer receiving the boundary made brief entries of every particular connected with it, verifying and establishing satisfactorily the several marks made by the meresman, and taking the utmost precaution to avoid the possibility of any deviation in the survey from the boundaries pointed out. To this book appeal could at any time have been made in defence of the accuracy of the survey, and the blame, if any, would have been ascribed to the right person; but, though without doubt, such references were sometimes necessary, they were extremely rare.

After the survey had been completed the boundaries were again minutely described in the *Boundary Register*, accurate distances and bearings being now substituted for the approximate data of the Boundary Note book, and it may be fairly said that this book is a document of the highest importance, as it will afford at any future period the means of tracing out the boundaries, even should the natural evidences of them, such as fences or streams of water, &c., have either been removed or have altered their courses. This description of written survey is quite in conformity with the practise of the Down and other ancient surveys, and in many cases would prove the only mode of arriving at truth, as for an example, in the case of a question as to which side of a fence had been the boundary—and the establishment of such checks and records must be considered a striking example of the forethought with which Major Colby entered upon the organisation of a survey, so widely different in its requirements, from any of the surveys with which he was then acquainted.

NAMES.—*In the Down survey*, it was expressly declared by an ordinance of the Protector's Council, that "all counties, baronies, and places returned or certified in or by, miswritten, or wrong names, shall be enjoyed by those whose lots are or shall be on such counties, baronies, or places, as if they had been returned or certified by their true and proper names; and Lieut.-Colonel Larcom quotes from the records then in the custody of the late Sir William Betham, a memorandum of an order from King Charles, which goes beyond this tacit recognition of carelessness, and enjoins the corruption or change of the ancient names by stating that the "barbarous and uncouth names of places" in Ireland much retard the reformation of the country, and directing "the Lord Lieutenant and council to change such names into others more suitable to the English tongue, annexing the ancient names in every grant so altered." These directions were embodied in the acts of explanation, but we may well sympathise with Lieut.-Col. Larcom when he observes that, "few persons will now be found to regret that the change of names thus authorised and ordered was not generally carried into effect." In the *Ordnance Survey* the importance of a correct determination of names was felt and fully appreciated, and "Name Books" were established by Major Colby, in which the officers entered the names, according to the best information they could acquire; but the enquiry did not rest here, but became the subject of the most careful antiquarian research. Lieut.-Colonel Larcom, who took so active a part in this and other branches of the survey, observes in respect to names, that, "as for the orthography of the names engraved on the maps of the Ordnance survey, the different spellings and *alias* names of every townland were collected from all accessible documents, some (where the names were ancient) of very great antiquity; and finally, local inquiry and examination were made by an Irish scholar on the spot, to render the name ultimately adopted as nearly as possible consistent with the ancient orthography. This information being all classified and arranged in proper descriptive books forms a large collection of documents, which, being preserved with the records of the survey, may be at any time referred to or published; and as there is scarcely any more fertile source of confusion than uncertainty of nomenclature, it may be hoped that, as the boundaries of the Ordnance survey are recognised by several Acts of Parliament, the names now engraved on the authorised maps of that survey, may also become generally adopted in all legal and authentic papers." Had the Survey Memoir, commenced with so much promise in the Memoir of Templemore, been extended to the whole country, these names would, without doubt, have been published in connection with their meanings as interpreted by Dr. Donovan, and have shed much light on the earlier history of the country. Accustomed, indeed, as we are, to the use of names which have, during the lapse of ages, gradually undergone so many changes as to have lost all resemblance to their originals, we are too apt to undervalue the importance of clearing away the disguise and tracing out the real and graphic name which lies beneath it, and is in itself a record of some local peculiarity or some historic fact. General Colby was no antiquarian, and the attention he directed to this special object is therefore a strong example of the sound good sense and judgment he exhibited even in subjects to which he had not previously directed his attention.

Mode of Surveying.—In the early surveys the system was that of simple "surrounds," as it was called, the perimeter of the ground being measured by a chain, aided by the compass or circumferentor, and the area being determined by measuring the figure of the ground, when plotted on paper. Such a system could afford no check against the errors so likely to occur in measuring the perimeter, as the work might close pretty well at the end and yet be affected by many intermediate though compensating errors. In the 11th Article therefore of the instructions issued by Dr. Petty to his surveyors, he enjoined them, "by intersections, to determine the true place of all townes, churches, castles, knowne houses, hills, raths, &c., within each respective surround, and to be frequent in making such observations, for the better examining and correcting your works;" and thus a system of checks was introduced to guard against the possible distortions of the measured perimeter. In the 5th

Article of his additional instructions, Dr. Petty provided even for a check upon the truthfulness of the Field-Books as he directs, "as to the trueth of the field-books, you shall, as often as you see occasion, cause some angles or sides, or both, to be measured (unknowne to the measurer unto whome the measuring thereoff is allotted), thereby to examine any sophistication of the said field-books;" and in the 6th, he directs that "the common lines of each barrony are to be run together by two distinct measurers at once, their respective servants keeping double reckoning of the chains alsoe;" whilst in the 7th, he explains the mode of applying the checks in plotting; thus, "as often as conveniently you can, you shall protract your large surrounds before you doe the inworke of the same; neither shall you allow of such inward lines as you have taken by intersection from the outmeares, untill the said outmeares bee approved of by protraction; and when you shall correct any worke by tyeing lines, you are to select and run for that purpose such lines as may alsoe subdivide the said great denomination into its several properties and qualities, according to the rule aforegiven."

These instructions manifest a great improvement in the mode of survey, as compared with the "surrounds," which had been before used without any system of cross or traverse checking. In the Ordnance Survey, "surrounds" when necessary for the measurement of roads, &c., became secondary, and dependant on the internal triangulation, as in this work a complete and regular triangulation was established, from the great triangles depending upon and proceeding from a base line measured, as will be hereafter shewn, with all the precision of modern science, down, through various gradations, to the minor triangles, the sides of which were required to be measured with the chain. In such a system as this, all must depend upon the fidelity with which the field work has been executed and recorded; and the most effectual mode to ensure such fidelity, was to separate the duty of calculating, and of protracting the angles and lines, from that of observing and measuring—the one devolving on the field parties, and the other on the office computers and draughtsmen. Some misconception seems to exist in the minds of surveyors as to the advantage of this division of labour; which, indeed, they have looked upon as derogatory to their profession, inasmuch as it degrades, in their estimation, a surveyor to the rank of a mere mechanic. In such cases the ordinary pride of man being enlisted against the judgment of a man of science, has, as might have been expected, produced many partial and much exaggerated opinions, the error of which becomes apparent on the very slightest examination. Beginning, then, with the great triangulation, it is evident that the field observer can seldom do more, in the way of calculation, than roughly work up the data of the few triangles he requires for protracting his own general diagram. He sends then his observation book, with a diagram explanatory of the approximate positions of the objects, to the computer, and if the latter experience any difficulty in making use of either of these documents, the fault must be ascribed to the observer, who has either wrongly exhibited the objects on his diagram, or has made mistakes in observing or recording their angular positions. To every one accustomed to the observation of distant terrestrial objects, the difficulty of recognising with certainty every member of a cluster of mountains, of which the relative positions change in respect to every observing station, must be familiar; and though this difficulty may be greatly diminished by the point-fixer furnishing the observer with a rough diagram of all the objects of importance surrounding the station he is erecting, and marking upon it when possible, the lines of direction to the several observing stations, there must occasionally occur misnomers which the calculator and protractor will as readily detect, as the observer would have done, had he been also the calculator. The advantage indeed of being able to proceed simultaneously with observations and calculations, and thus to detect errors or to suggest deficiencies, at the earliest possible moment, is so great, that no one acquainted with the practical working of the Ordnance Survey will doubt the wisdom of separating the office of calculation from that of the observer. In the minor triangulation the necessity of such an arrangement was still more manifest, as the increased number of observers would have led to great confusion, had it been attempted to carry out the calculations individually. When the survey commenced in Ireland, a district arrangement was established; each district, five in number, being placed under a captain, under whose direction it was intended that the district triangulation should be conducted, whilst the divisional, a still minor triangulation, was entrusted to the lieutenants acting under him. There was thus a gradation of work, as of instruments, the primary distances determined by the work of the great theodolite of Ramsden, or in immediate connection with it, being furnished to the district captain by the officer conducting the primary triangulation, and the divisional officers being supplied with their initial distances, determined by the observation of 12-inch theodolites, mounted on Bond's repeating tables, by the district captain; when the divisional officer proceeded to perfect his minor triangulation, as the true basis for the chain measurement, by observations made with 7 and 8-inch theodolites.

For some time this system was adhered to, but it soon became evident that as each officer framed his triangulation in reference solely to his own wants, the junction work, common to two districts, often became intricate and confused; and this was even more strikingly the case with the altitudes of common points, when determined by independent observers working from opposite directions, and from distinct data. In 1833, therefore, Colonel Colby determined that the secondary triangulation should be conducted as one whole, and intrusted to the writer of this memoir the task of forming and superintending a department for that purpose, the completion of the great triangulation having left him disposable for this new service. To effect such a change at a time when the district surveys were beginning to advance with considerable rapidity, involving, as it did, the creation and training of a corps of observers, was a task of considerable difficulty and anxiety, giving rise at first to many complaints on the part of the district and division officers; but all difficulties were soon overcome, and as the number of observers increased, the demand upon them increased also, as it became a race between the two branches of the work, the triangulation department struggling to anticipate the wants of the districts, and the districts to run ahead of the triangulation,—whilst the rivalry, amicable though it was, consequent on their separation, rendered each department a check upon the working of the other. In a very few years, the triangulation department was able to supply data in distances and altitudes for the chain survey of three or four millions of acres per annum, the division officers interpolating such additional triangles from their own observations, as might be found necessary to check the chain lines connected with internal or townland boundaries, or to complete the content survey. The calculation of so large an amount of work, produced from the simultaneous observations of 30 or 40 observers, could only be carried on successfully by a well organized body of computers, for here at least no one could doubt the impossibility of connecting calculation with observations, and this object was attained by the establishment of a second computing office, in the country, in addition to that already existing in Dublin, so that it might be moved occasionally and kept as central to the field work as possible. Simple as these arrangements now appear, the establishment of such a system, at a time when every moment was in itself precious and the chance of retarding a work on the progress of which public opinion had been much awakened and expressed was at least a formidable risk to undertake, may be taken as another example of that firmness of character which so much distinguished General Colby, and which rendered him philosophically calm amidst clamour, however loudly, or censure, however unfeelingly expressed, so long as his judgment was satisfied as to the wisdom of his plans and the rectitude of his determination.

For the actual content survey, measurement by the chain closed the graduated series of operations, checking, and being checked by, the minor triangulation, and affording the materials for calculating the area of the townlands. In this respect, the difference between the Down and Ordnance Surveys is very great, as the former, like some modern surveys, depended for its areas on measurements from paper, whilst in the Ordnance Survey of Ireland, the actual measured lines were entered in calculation books, framed on a prescribed form, and thus used directly for the determination of acreage. This feature of the survey does not appear to have attracted the notice it deserves, in the many discussions which have since taken place as to the proper scale of surveys for valuation, or other practical purposes. When the survey was first commenced, many schemes were proposed for calculating the area, some depending on measurements, either from the paper itself or from a trace previously taken on glass graduated into squares, and some on the principle of substituting weighing for measuring, by tracing the boundaries on thin lead plates rolled of a definite thickness, so as to give a certain proportion between the weight and number of acres. Ingenious as some of these plans were, they would have introduced into the determination of acreage; first, the chances of error consequent, in protraction, on changing the natural scale of measurement in the field into the artificial scale of the map; secondly, the probable errors of measuring lines on paper; and thirdly, as regards weighing, the errors which must have attended the use of plates of metal from the inequalities of thickness, which however minute, must have materially affected the accuracy of the results. General Colby therefore determined to obtain the acreage from the lines actually measured on the ground, and thereby to reduce the possible error in its amount to a comparatively minute quantity depending on the possible error of chain measurements. By this arrangement, the maps on the six inch scale have become practically useful to proprietors and farmers, to an extent which only those who have used them can fully appreciate; and the reason of this is evident, as the acreage marked on every townland, being determined with almost absolute accuracy, the subdivision of the townland for farming purposes only requires the proportional division of a known and certain quantity of acres, and is liable only to error in determining that proportion; as, for example, suppose a townland divided into squares of any convenient size, or covered by a glass so divided, it would be only necessary to compare the number of squares occupied or covered by any field or substance with the total number of squares occupied by the whole townland, in order at once by a simple operation to ascertain the acreage of the field. If, in the six inch map, the square of the glass or other transparent measuring plate be made $\frac{1}{100}$ of an inch, it would represent on that scale about ·18 of an acre, and it may therefore be readily understood how accurately the acreage of the subdivisions may be determined; the acreage of the whole having been previously given, as a quantity practically free from error.

When the Irish survey was first projected, a valuation of the land, with a view to the more just allocation of taxation, was the main or rather its sole object, and for this purpose alone an engraved and published map would not have been necessary, as a few copies of the plots of the survey might have sufficed for the wants of the valuations. General Colby however, not only foresaw the inconvenience of such a narrow system, as it would then have been impossible that every farmer should check, if he thought fit, the accuracy of assessments made upon him, but he also anticipated the great advantages which would result from the use of such a map for agricultural, engineering, and many other purposes, and he therefore, though still looking forward to the extension to Ireland of the one inch map, successfully urged the publication of the 6 inch map, so that he must always be remembered as the author of the first great practical national map in this country.

ALTITUDES.—The 13th article of Sir W. Petty's instructions refers to this important subject, in these words: "You shall measure the height of all notoriouse high hills and mountains, describing their feet and manner of rising, together with their names and true places." This was as much as could have been expected, at the time of the Down survey, and little more had been done in the British survey than the determination of the heights of the principal mountain or hill stations; but in the Irish survey, General Colby introduced a new system, by spreading altitudes over the whole face of the map, as well on low as on high ground. For this purpose, the principal stations were fixed in altitude with great precision, partly by direct observation to referring objects at once close to them and the sea, and partly by levelling from the sea line to the referring objects. From the principal stations the heights of secondary points, either hill stations, church towers, or other easily recognizable objects were then deduced; and these, in turn, became initial points for the districts and divisions. Finally, the measurement of the chain lines between stations, the altitudes of which had been determined by triangulation, afforded the means of fixing the levels of a vast number of intermediate points, and thus of placing, at every step, a known altitude mark within a convenient distance for reference. The "Field Levelling Book," and the corresponding calculation books provided for the calculation and record of these subsidiary altitudes in a systematic form, and a comparison of the results from the two trigonometrical altitudes, on which they were based, afforded a check upon their accuracy. Perhaps no published maps have ever been supplied so copiously with altitudes, determined in such a manner as to be practically useful for farming and engineering purposes, and many able judges have acknowledged the assistance they have derived from them. In considering this subject, however, it is right to remember that the success of the system depends on the accuracy of the primary initial altitudes, and on the mode of deducing the secondary and other altitudes from them; so that it becomes interesting to trace out the steps by which the altitudes of the Irish survey have been brought to their present high degree of accuracy.

In Great Britain, as before observed, the height of certain hills, or other stations near the sea, were determined partly by angles of elevation and depression, and partly by levelling from the low water mark of spring tides. These altitudes were then used for obtaining others, either by reciprocal observations, using two stations, or simply by elevation or depressions from one station only. Such observations required, of course, two corrections, namely, that for curvature and that for refraction, the one constant and certain, the other variable and uncertain. From several reciprocal observations in England, it had been concluded that the refraction was about $\frac{1}{12}$ of the arcal distance between the objects, and this amount of refraction therefore was adopted and constantly used in correcting observations for elevation or depression. In the first instance, the same correction was applied to the observations of the Divis mountain, near Belfast, which was the first great observing station of the Irish survey, and the first primary initial altitude, and many secondary altitudes, such as the bands or other distinguishing marks of Antrim and other church towers. Supposing the instrument supplied with adequate means for taking the angles of elevation and depression, the value of the resulting altitudes would necessarily depend on the unchangeableness of the proportional correction for refraction, and on the accuracy of the horizontal distances to be used in calculation. In respect to the distances, their accuracy was certain to be far within the limits of required accuracy; but as regards the correction for refraction, the same certainty could not be expected, and in proportion as it deviated from the assumed ratio of $\frac{1}{12}$ of the arcal distance, so would the calculated diverge from the true altitudes, the difference increasing as the distance increased from the observing station. Hence, as a natural result, there was often a difference of 5 or 6 feet in the amount of error of secondary stations, and in consequence the common points of adjoining districts were found to differ widely in altitude from each other, when determined from independent secondary stations, the altitudes of which had been supplied from the great triangulation. This inadequacy of the system of the British survey for determining altitudes with the precision required in a practical work, was almost immediately discovered, in consequence of a comparison of the reciprocal observations of Divis, taken by General Colby, and of Knocklayd, also in Antrim, taken by the author, when it was found that a refraction not of $\frac{1}{12}$th, but of $\frac{1}{14}$ was required to harmonize the results of the two sets of observations when used separately; and as this amount was subject to very great variation, sometimes approximating to $\frac{1}{12}$, and sometimes approaching $\frac{1}{16}$, a system of standard heights was introduced so as to get rid of the errors due to uncertain refraction.

In this system, the altitudes of points near the sea in various directions were determined with precision, and these were used as points of reference; the refraction at the observing station being deduced from the known heights of the observing and observed stations, as it was necessarily equal to the difference between the observed angle of depression or elevation, and the angle which would actually give the known difference of altitude between the two stations. The refraction thus obtained was used in determining the altitudes of any other stations nearly in the same direction; and so on with other standard heights, as it was found that the amount of refraction was not constant in all directions at the same time, being much affected by local circumstances. It was not, however, always possible to have a standard point of altitude in the required direction, and hence, notwithstanding the improvement in the altitudes effected by this simple arrangement, it became necessary to abandon the determination of altitudes by observations from distant stations, and to restrain the limits of observation, even by the great theodolite, to distances of about 10 miles as the maximum; and the necessity of such limitations in respect to distance, may be judged from the following simple illustration. From the station of Culeagh, the Mayo mountains were visible over the intervening Leitrim ridge, and the double peak of a small mountain was a very remarkable object. Now, from the peculiarity of its form, this mountain might be observed, according to the refraction, sometimes as a single conical peak, and sometimes as having two peaks, one being higher than the other, whilst on other occasions it was cut off entirely from the observer's station by the intervening ridge. Another system was therefore adopted: initial bases of altitude were fixed with great care along the eastern and western shores, and observing points were selected, running in lines directly from the one side of the island to the other. These points were distant from each other from 8 to 10 miles, and reciprocal observations were taken between each successive pair; but as a further check, a subsidiary station was selected between each pair of the observing stations, and was observed from the stations east and west of it. By this arrangement, the difference of altitude deduced from the reciprocal observations of the observing stations, which might have been affected by some change in the amount of refraction of one or the other, was brought into comparison with the same difference as deduced from observations made to the intermediate or subsidiary station which being comparatively so near to each of the pair of stations, would be very little affected by any small variation in the refractions. The first line of altitude observations of this description, was adopted by the author to connect the heights of the Antrim and Londonderry surveys, and to reduce the junction points of adjacent districts to harmony. It ran obliquely from the eastern coast of Antrim to the northern coast of Derry, and was most effectual in giving to the altitudes of those counties a high degree of accuracy, although the observations were taken with an instrument of less size, and very difficult of manipulation. The author afterwards carried several similar lines across the country, using the great theodolite as the observing instrument; and it may fairly be said that the altitudes were excellent, although affected by the error consequent on the use of the low water line of spring tides as the zero of altitude. This had been the referring line in the British survey, but General Colby, who had encouraged every step taken to improve the altitudes, readily abandoned it for the more correct mean tidal line, and perfected the survey altitudes, by having other lines of altitudes determined by careful levelling with the spirit level. In every survey, these two modes should be used in conjunction with each other, lines of initial altitudes being first determined by the spirit level, and these lines connected together by traversing lines of altitudes, determined in the way which has been explained.

The primary and secondary altitudes being thus reduced to a uniform standard of accuracy, the subsidiary and chain line altitudes became also safe points of reference for practical operations of drainage, of road making, &c.; and it is at this point that some would have had the progress of improvement stop: but General Colby was not blind to the advancement of topographical science on the Continent, and was ready, therefore, to introduce into the British survey and map any of the improvements which had been adopted there. Looking then at the early sheets of the Irish map, the engineer will be struck by the vast amount of data expressed upon them in regard to altitudes, and may also trace, in many cases, the gradual rise of a hill, by following the course of a chain line, and noticing the successive levels marked along it; but in others, he will find it a painful task to unravel the confused web of levels scattered over the map, or to deduce from them any notion of the features of the country. In a map of moderate size, such as the one inch, in England, some description of shading would of course assist in reducing levels to order, or would even supply their place; and to this object General Colby gave much attention at the commencement of the Irish survey, visiting all the mountain chains, and after a careful consideration of the features of the country, ordering a general map to be drawn, so as to afford a graduated scale of shading to be used subsequently in the inch map, the necessity and preparation for which were never absent from his mind. To a map however on so large a scale as the 6 inch, ordinary shading was inapplicable, and General Colby therefore, in the first instance, left the reader of the map dependent solely on the engraved altitudes. In 1837 and 1838, however, the data of the survey were called into practical use, in aid of another great public object, namely, the determination of the best lines of railway for Ireland; as in that country, so often underrated and even contemned in regard to its supposed want of utilitarian habits, the wise example was set to its more confident sister country, of making the railways parts of one general system, and not a set of isolated and disconnected systems. Commissioners were therefore appointed, using the statement of Lieutenant (now Lieutenant Colonel) Larcom, "in 1837 and 1838, to report on the most advantageous lines for railways in Ireland, and other matters connected therewith: a general map of the kingdom was deemed necessary, and Lieutenant Larcom was entrusted with the preparation of such a map. On this map the various lines of railway proposed by private parties, as well as those recommended by the Commissioners, were to be laid down, and the map was also to be the means of exhibiting, for the first time, the geology of the whole island, by Mr. Griffiths. The Ordnance survey had extended over only one-third of the country, but the triangulation was complete for the whole island. By the aid of this, the principal latitudes and longitudes were computed, and a net work prepared, by which the detail of the Ordnance survey and the various local surveys—some published, many fragmentary and in M.S.—were connected. An outline map was thus completed, but, for geological purposes it was also necessary that the mountain ranges and features of the ground should be delineated. For this purpose, such material as existed was collected and combined, after which persons practised in that branch of topography were dispatched to the principal localities—either where the information was most defective, or where the greatest accuracy was required. From the drawings and enlarged sketches of these parties the original work was corrected, and ultimately a map on the scale of 4 miles to the inch was drawn and engraved. It is believed that this was the first general map of any country in Europe, on which the ground was completely delineated as one whole; and as yet it is the only such map of Ireland. Made, as it was, in much haste, and from very imperfect material, its accuracy could be only comparative, being limited, of course, to that which the original material possessed, with such aid from compilation as careful collation and comparison could supply, with the valuable materials of the Ordnance triangulation for its general basis. It was deemed satisfactory, and the Commissioners by a letter, forwarded through the Treasury, to the Master General of the Ordnance, dated 18th March, 1839, acknowledged the assistance it had afforded them."

CONTOURS.—" It was in connection with this map that Lieutenant Larcom was led to consider the importance and the practicability of adopting the continental system of contours, for exhibiting the third co-ordinate of topographic delineation—the altitude. At his instance, experiments were tried, and an officer, Lieut. Bennett, set apart for that duty, which, as the outline plans were then considerably advanced, it was proposed, in the first instance, to make the basis of the general map for delineation of ground. The experiment was successful, and the system was at length deliberately adopted; and provided it be not carried into needless details, it will become a most valuable improvement on the former system."

The introduction then by General Colby, on the recommendation of Lieut.-Colonel Larcom, of contour lines on the 6 inch map was a most important improvement, and such still appears to be the opinion of persons practically acquainted with the working of the Irish map; but, like every new invention or proposed improvement, whether referring to a better system of farming or surveying, it has been strongly opposed and condemned by some men of great influence, and of commanding talents in other subjects, though manifestly imperfectly acquainted with the principles of topographical science. It would be impossible to detail, in this memoir, all the arguments urged for or against contours, by the several witnesses examined before the Committees of the House of Commons, but it will be easy to shew that whatever may have appeared to be their force, it would indeed be a retrograde movement to abandon this characteristic feature of a national survey and map, which ought to be framed on the opinions of the scientific men of the world, so as to embrace every possible improvement, and not on the partial views of those who think only of their own wants, and from habit cling to the imperfect modes to which they have been accustomed; as it is still, and ever will be, difficult to convince persons, whose minds have not been fully trained, that crude experiments seldom lead to useful results, and that the experience gained with defective instruments can never be urged as an argument, against the advantages which an enlightened theory foretells as the consequence of improved systems and instruments. Contour lines are familiarly illustrated by the horizontal traces left by the sea upon the rocks of the coast, on the recession of the tide, and geometrically they are the orthographic projection upon some horizontal plane of comparison, such as the plane of mean tidal altitude, of the successive lines of intersection with the surface of the ground of a plane parallel to the plane of comparison, and raised successively above it, to such intervals of distance as may be determined upon, whether of 10, 20, 30, or more feet. Now, it is probable that every one would admit the advantage of being able to trace out either a line of some definite level from the levels actually marked on the map, or of being able to judge from such levels the amount of fall or rise between any two points; but when the difficulty and labour of poring over the numbers, and searching out those required, are removed by *contour* lines, the additional aid thus afforded is undervalued, and would be rejected; and this arises from the little information on the subject possessed in this country, although in 1818 it was determined by the Bureau de Cadastre that the general topographical survey of France should be delineated on the plan of contours.

In respect to very large maps, the contours become a substitute for shading; and in small maps they are the proper basis for field sketching and shading, as they at once impress upon the mind, by their inflections, the true forms of the ground, and powerfully correct the errors which are unavoidable in simple sketching, from the constant changes in the intensity and direction of shadows; and from the extreme difficulty in determining the modulations of the surface where there is no marked shadow, or where the shadow falls in the wrong direction. To the eye, however, acquainted with contours, the plan becomes a model, and though shading is a pleasing addition from the pictorial effect it produces, it adds little to the real practical value of the map. It is most unfortunate that the beautiful maps of Wales, engraved from the sketches of Mr. Dawson, have served to support the argument against contours, and in favor of shading alone for hill sketching; although it may be asserted safely, that were even his son Lieut. Colonel Dawson, so able a pupil of his father, to attempt to reproduce the same maps from his own sketches, he would succeed only as regarded some very striking features, but would assuredly fail in all minor or less marked details. The beauty of a map is, indeed, too often dependant on the skill of the artist, rather than on the fidelity of the surveyor; and it is certain that the only way to secure accuracy in the representation of a country is to control the artist by the shackles of geometry, and hence that contour lines alone, as geometrical facts, will enable two sketchers to bring out corresponding results in sketching the same countries.

These remarks, of course, apply only to contours determined accurately by instruments, and not to contours put in by the eye, as the latter depart from geometrical precision and partake of the inaccuracy of sketching; though as a general rule, the sketcher should accustom himself to reduce the ground before him mentally into contours, as he will thereby acquire much more correctness of eye in the delineation of its features. It is probable that the introduction of sketched contours into the map has in some degree strengthened the objections of the opponents of the system; for though the effect of shading is produced by the multiplication of the contour lines, it becomes difficult to distinguish the geometrical contours from the others, and equally so, from the general confusion, to use the contour lines for practical purposes. Restricting, however, the contours to those which have been determined instrumentally, and limiting their numbers according to the scale, so that they shall be clearly distinguished, one from the other, they produce a facility in using the maps for agricultural and engineering works, which no amount of simple levels scattered over the surface, nor shading however artistic, can confer upon them.

Notwithstanding, indeed, the great opposition raised against the introduction of this foreign system into our topography, it may be said that contours have already gained ground in this country, as may be shown, even by the amount of change of opinion exhibited by the two successive Committees of the House of Commons, the first in 1851, recommending absolutely or unconditionally, "That the system of contouring be abandoned." Whereas, the Committee of 1854, report—

1. "That the levels as above described having been provided, contour lines to a certain extent would be an useful addition to a map on the six inch scale, and *well worth* an outlay of five shillings per lineal mile, this being the cost of contouring, as estimated by Captain Gosset, on the assumption that the levels above mentioned have been previously obtained and recorded; these contour lines should be instrumentally traced with accuracy, and the system of interpolating contour lines should be abandoned.

2. "That contour lines selected from those obtained for the large surveys (if of a different colour) would be an useful addition to the one inch map; but on maps of a larger scale, of 24 or 26 inches, they would be inexpedient."

This latter resolution would have been better had it directed that the contour lines should be introduced into the plans, for the one inch, before the hill sketching, as a necessary element for that branch of the work, and not simply added as a supplementary feature. The map of London and its vicinity, contoured by Mr. Mylne, will be exhibited at the Paris exhibition, and prove that a highly intellectual member of that most talented body, the Civil Engineers, has not been backward to recognise the value of contours; and I may add that the Ordnance contoured map of a large country town was actually used by one of that body, to frame his plan and estimate for its sewerage, so that he became a competitor for the premium offered for the best plan, without having ever set his foot within the town. The names I withhold, as the prize had not been adjudged when my friend mentioned the circumstance to me; but one such fact is of more value than many arguments in proving the practical importance of contour lines on maps.

Military Organization.—Sir W. Petty, much to the displeasure of the surveyors of his time, employed the soldiers, who were available for such an object, on his survey, and this drew forth a remonstrance from several of the surveyors, to the effect that Sir W. Petty had, in their absence whilst engaged on the survey, put in his tender for the survey, and then instead of employing these surveyors upon his work, he had declined to hearken to their propositions, "but upon very hard and unreasonable terms, which they could not accept." The surveyors then went on to say, that had the "Doctor had any more new, certaine, and expeditious way of survey than hitherto had been known or practiced, there had been just grounds for our yielding to the Doctor's terms; but, instead thereof, we find him informing the private soldiers, whose labour he may hire at an easie rate, in the ordinary and common method, where it plainly appeares that the Doctor, by his undertaking, hath not out done the surveyors; for, in his proposalls, there is nothing considerable but his time and price. As for the time, we shall make it evidently appear, by undeniable arguments, that the whole worke will be performed by the surveyors now employed by your lordships within the time agreed upon; and for the price, we are content to accept of less than the Doctor hath proposed, not doubting but that we, who have had experience already in the work, shall be better able to perform the same than such who are raw and inexperienced, though taught by the Doctor." But, to this and all the other objections Sir W. Petty replied. 1st. "That he looked upon soldiers only as hardy men, and fitter than most others for the difficulties previously mentioned, that other men of the like qualifications would serve as well; and in fine, that he cared not for using soldiers otherwise; and for many such could be had together without much staying for others. 2ndly. That it was easy to discover whether soldiers would returne false work on purpose, to the injury of the state. 3rdly. These men being designed only for field work, could abuse the state only in the length of their chaine, which would alsoe discover itselfe. 4thly. That no soldier could tell where his own, or any friend's of his, lott should fall, nor whether he should at all measure the land that should be his owne or his friends; soe as all the soldiers, and indeed all the other surveyors, must with much art universally combine to justifie any one person."

The employment of soldiers was adopted by General Colby, on far more enlarged principles than those stated by Sir W. Petty, though it is highly probable that the latter was restrained by prudential motives from expressing all his reasons for prefering military men, though requiring to be trained for the work, to the civil surveyors of his time. General Colby thought that the habits of order and discipline, acquired by soldiers, were very essential elements in the character of men required to work out the minute details of a great work, which could only be rendered successful by the most harmonious action of all its parts. In the survey of Great Britain he had already exhibited a tendency in this direction, by much increasing the number of officers employed, and from the first he determined that the organization of the Irish survey should be military. To assist him therefore in the control of his officers, he selected Major (now Col. Sir Wm. Reid, Governor of Malta) as the local superintendent, and applied for Mountjoy House or Barrack, in the Phœnix Park, as a residence for the Superintendent, and as an office for the Survey; he named captains to command, and subalterns to serve in the districts, who were at once appointed by the Duke of Wellington on his recommendation alone; and he urged successfully an augmentation of the Sappers and Miners to fill up the subordinate ranks of the survey force. It was not however as hardy, or even as well disciplined men, that he desired to have the Sappers; he required that they should be instructed and well trained men, and for this purpose the new companies, raised for the survey, were placed under Lieut. (now Col.) Streatfield, of the Engineers, and carefully instructed at Chatham, under his superintendence, in Practical Geometry and the elementary principles of Surveying. These men proved most important auxiliaries to the survey, as they formed a nucleus around which the less trained country people, including many accustomed to the more simple operations of a survey, could be collected and formed into one well disciplined body. The Sappers were not however useful only as chainmen, or even as observers with the smaller theodolites; but were valuable assistants in the drawing and calculating offices, and were ultimately employed on the triangulation of Scotland, as observers with the great theodolite. They proved also equally skilful observers with the zenith sector, as may be seen by reference to the last published volume of zenith distances of stars, which contains a mass of observations of great interest and value to the survey, most of which were the work of the Sappers. In addition also to these services, extensive as they were, they supplied some excellent engravers to the map department, so that it may be fairly said, that much of the facility of execution and success of the survey must be attributed to the employment of this valuable class of soldiers; and it should also be remembered that, though General Colby followed the example of Sir W. Petty in the use of soldiers, he went far beyond him in his estimate of their utility; and by adopting a judicious preliminary training, was enabled to avail himself of their services in some of the most difficult and responsible operations of the survey. These two great men thought and acted, as it were, on the same primary idea and plan; but whilst Sir W. Petty saw before him the crude topographical works of the 17th century, and was an improver of that date, General Colby laboured in the 19th, a century of scientific discovery, and endeavoured to give to his work a character of completeness suitable to such an age. It would be easy to follow the parallel further by enumerating the great collateral objects which Sir W. Petty and General Colby had in view, as being of equal importance with the survey itself; but to this point it will be necessary to refer again, in describing the more purely scientific operations of the survey, and it will be therefore enough here to conclude the comparison with the following passage by Lieut.-Col. Larcom, who, after speaking of the 'briefe account of the most materiall passages relating to the Down survey' a manuscript preserved in the record branch of the office of Paymaster of Civil Services in Ireland, observes, "It was the good fortune of the Editor, nearly 200 years later, to see similar foresight and arrangements exercised on a far larger scale in another survey of Ireland, by one who possessed many of the qualities which distinguished Sir W. Petty, and who also succeeded in carrying his great work to a successful close, under circumstances and obstructions, many of which bear a striking analogy to those which the history will shew to have attended the Down survey. This may give the narrative a peculiar value to those who are conversant with the more modern survey, but it will show to all the importance, nay, the necessity of clearly scanning a work as a whole before entering upon it, and that similar circumstances will perhaps, in all ages, produce similar measures, though each be perfect independent of the others." It is indeed, in this latter quality of grasping, as a whole, the minor details as well as the greater results, that General Colby was more especially distinguished in planning his scheme for the survey, and the Author, who passed many hours in freely discussing every arrangement, as it presented itself to the mind of General Colby and was thrown by him, as it were, freely down as a gauntlet of challenge, can testify to the clearness of his judgment and quickness of his perception in devising a system, which combined in every branch the most careful field entry with an equally careful office record; and which introduced every precaution against error in the field in surveying, and yet checked it at every step by protraction in the office; and in planning and perfecting a map, which at once should maintain a high standing amongst the best topographical works of the age, and be rich in all the elements of practical application.

Office Arrangements.—It will be readily imagined that a work of such magnitude as the survey of Ireland upon a six inch scale could not have been undertaken successfully, without such office arrangements at head-quarters as should secure uniformity and efficiency of direction in the first place; and in the second, the means of rapidly collating together the materials received from the districts, preparing them for the engraver, and finally engraving them. The organization of the map office at the Tower, though doubtless equal to the demands upon it of a one-inch survey, never extending at any one time over a large space of country and therefore not calling a great number of persons into employment, would have been totally inefficient for such a work as the Irish survey. One of the first objects therefore of General Colby had been to secure a proper building for the proposed office; and when Sir Wm. Reid, after having seen the military organization completed, left the survey, he placed in charge of the office one who was competent to form and superintend such a system of management as should ensure order, celerity, and certainty of action, and, above all, a due subordination in all branches of the work. In making his choice also of such a person, General Colby had to keep in view the collateral objects which were so wisely associated in his mind with the legally prescribed one, namely, the statistical, antiquarian, geological, and natural history surveys of the country, and he therefore exhibited his usual accuracy of judgment, when he appointed Lieut. (now Lieut.-Col.) Larcom to the office, for assuredly all those who have visited the survey office, in the Phœnix Park, in the days of its active operations; have gone through its calculating, protracting, engraving, and printing establishments; have seen the application of the electrotype process to the multiplication of the engraved copper plates; and have relaxed their minds afterwards, by a peep into the museum, arranged, it is true, under the direction of another officer, but still indebted for much of its success to Lieut. Col. Larcom's judgment and taste, must remember that office as a remarkable example of order and efficiency; and those who have not seen the Mountjoy office, may still study it in the survey office at Southampton, of which it was the prototype.

The magnitude and variety of the objects undertaken by this office may be best explained by another quotation from Lieut.-Col. Larcom's statement to the Inspector General of Fortifications, as follows: "It would not be possible in any moderate space to describe fully the numerous branches of duty accumulated at the focus of so great a work as the "General Survey of Ireland," the first occasion on which a topographical department was formed for the Ordnance. A few officers of Artillery or Engineers, and a separate corps of draftsmen, with other civilians had been employed on surveys; separate artists had before engraved maps for publication, and much had been combined in the English Map Office at the Tower; but it remained for Gen. Colby, in Ireland, to create a topographic branch of the Engineer department in all its gradations, combining in one body the Astronomical and Geodesic operations; the territorial surveys for particular national or public purposes; the general topographic delineation of country; and the engraving, printing, and publishing such surveys and delineations, on any scale, or in any manner the particular service might require; and, not only to execute such a work in Ireland, but to combine with, and engraft upon it, from time to time, such extensions or modifications, as the wants of the country, or the advance of science or discovery, might require, to keep *au courant* with every branch of knowledge, and embody all which could be made available to the great work, of which several examples will occur in this memorandum. Such also, in regard to Geology and Natural History, was its application under Capt. Portlock, to productive industry, with many similar or cognate pursuits to which the survey has given rise, or for which it has afforded facilities. For such a department no organization before existed, but at the close of the survey of Ireland it had been satisfactorily accomplished, and the Ordnance possessed a topographic corps, which would bear comparison with that of any country in Europe, embracing, in addition to the officers of engineers, three companies of sappers, and a numerous extra body of civilians."

"Of the departments more immediately confided to Lieut. Larcom, the several branches may perhaps be briefly described.

I. The examination of the original plans was divided into the five separate operations connected with the plans. 1st. The plotting, or construction from the field work. 2nd. The registering of contents or areas. 3rd. The orthography. 4th. The details of drawing, both outline and ornamental. 5th. The figures of altitude.

II. The draftsmen were: 1st. For general service. 2nd. For reducing to the smaller scale for Ordnance and general maps. 3rd. The drawing of those smaller maps, and selecting and inserting the names and details of topography."

"III. The computers formed the link of connection between the orginal plan and the engraving. This department was chiefly devoted to the calculation of the rectangular co-ordinates which fixed the position of the numerous trigonometrical points within each sheet of the townland survey, by which the construction of each sheet became independent of those around it, the triangulation itself being furnished by the general trigonometrical department. This system of projection was admirably devised by Colonel Colby to render the correctness of engraved maps independent of the expansion and contraction of the paper on which the plans were drawn, with similar sources of error from occasional discrepancy in the district triangulations. It was in fact a re-construction of the maps on the copper itself, which it is believed had not been adopted before in any national survey. The better to carry out this project, a new mode of transferring the detail plans themselves to the copper was also devised, viz., by tracing them with a peculiar ink on transparent paper in small portions, and combining these fragments together by aid of the new network of points. Another advantage resulted from the substitution of this method for the former practice of pencilling the plan and rubbing it on the wax ground; viz., that instead of the thick and indefinite line, caused by the sulphur, with which, in all pencils, the plumbago is mixed, combining rapidly with the copper, the charcoal of the ink remained sharp and definite for any length of time, so that instead of working from hand to hand with each of the engravers, a number of plates could be kept ready prepared for them, and thus the large number of those artists (from 50 to 60), were kept constantly supplied: these three several subdivisions of this work—the computing, the tracing, and the transferring, each of which occupied steadily from 4 to 5 or 6 persons, under one head computer,—being able to provide sheets for the engravers at the same average rate at which the engravers finished and passed them to the printers, viz., 2 in 3 days."

"By this department also the meteorological observations were conducted. It was at first hoped that such observations could have been collected from all parts of the country, and methodized and reduced at head quarters. This was not carried out, but observations of the principal instruments were made and recorded at the office itself in an observatory constructed for the purpose. They were conducted with regularity through the whole length of a Julian period, and it is hoped when published they may yet prove an useful addition to that branch of science, more especially as regards the dew point and tension of vapour, in respect to which will probably be found the greatest peculiarity of the Irish climate."

"IV. The engraving of so extensive a survey was also without precedent, and required correspondent changes in the system and arrangements of that branch. In this, as in the original plans, it was no longer a question of making a single engraving; it was necessary to divide the operation into its processes, and provide or train a sufficient number of persons possessing skill or qualification required for each. Independently of the rapidity which would thus be gained, it was evident there was no other way in which uniformity could be attained over some two thousand plates, to which number it was probable the whole work would extend. Already it has been stated that the transfer to the copper, which is usually the work of the engraver himself, had been provided for in the previous branch. Great facility, as well as correctness, was soon found to result from this. The great divisions of map engraving, viz., outline, writing, and ornament, were next subdivided, and mechanical aid introduced into every part which was susceptible of it. The difference between cultivated and barren ground was expressed by a rolling machine instead of by hand, the numerous figures of altitude, and trees of particular classes were inserted by punches, instead of being separately engraved. The like application of machinery produced a very beautiful mode of representing the sand, beach, and water, which before were the work of separate and highly paid artists. Ultimately, a number, averaging sixty, of engravers were daily at work, the whole body being regulated with the precision of a machine, rather than of a body composed of many individuals possessed, in various degrees, of artistic skill, and the result was perfectly successful."

"In connection with the engraving, it would be improper to omit the early introduction of electrotype, which within a few months of its first discovery was made available for the purposes of the survey. It was apprehended that the early plates must sooner or later begin to exhibit the effects of the immense number of maps printed from them, and to guard against such effects, more especially on the more complicated and expensive plates, matrices were taken from them, preserving all the freshness of the original, for the creation of as many duplicate plates as might be at any time required. There was much difficulty in this from the great size of the plates, and this was first overcome on the survey. The practice has now become common, but it is nowhere better done, even at this day, than by the apparatus of the survey office. From the manipulations and experiments of Mr. Dalgleish in the laboratory, it there took the form of manufacture in immense vats of acid, containing fifteen hundred gallons each, with proportionate magnitude in the rest of the apparatus. Other applications of this beautiful science to the purposes of the survey soon occurred, such as obtaining great facility and economy in insertion of corrections or revisions in the plates by merely taking a matrix, and erasing the parts, which it was desired to replace, from it, instead of from the original plate. This has been explained in a Paper by Lieut. Col. Larcom, in the "Aide Memoire," and need not be further adverted to here."

"V. The printing of the maps from the copper plates, was at first an expensive operation. A single printer was employed, on the terms usually paid in private establishments; *i. e.* he was paid so much for every impression printed, all ink, paper, and materials being provided for him. The price paid to him was ninepence for each impression; but when the system of examination, computing and engraving, was matured, and the progress of the survey in the country had attained rapidity, this price became enormous, and it was resolved to attempt in this branch also the system of division of labour, which in the others had proved so advantageous. For this purpose, a few sappers of superior intelligence were selected, and trained each to one part of the operation. Its great divisions were, 1st, inking the plate and cleaning off the ink; 2nd, damping the paper; and, 3rd, passing it through the press; but each of these had to be studied in its details. In the first, the best ink being required, the charcoal of vine stalks was obtained from Frankfort; the oil was burnt in a peculiar way to drive off the superfluous watery portion; and a careful manipulation adopted for charging the delicate parts of the engraving. To this one set of men were devoted; another set were instructed in the delicate handling of the plate in cleaning, which, instead of the system, usual at that time of rubbing the plate with whiting by the bare hand, the tendency of which was rapidly to wear out the plate itself, was performed thenceforth by a process practised in Paris, and described in the Memorial Topographique, merely by fine muslin and alkaline solution. This saved nearly all the friction and wear, and was most successful; to this indeed, and to the care of these men, is to be attributed the very small injury which the plates sustained from the unparallelled number of impressions which were taken from them. It combined, in fact, the durability of steel plates, with the facility of correction, which is the chief recommendation of copper. The damping of the paper and passing it through the press was the final operation, which required care in the one process, with force and strength in the other. After this, the sheets were placed in milled glazed boards, under great pressure, to smooth and dry. These operations were all in progress together, the numbers employed in each being such that there should be no waiting in either, and the ultimate result was, that instead of twenty or thirty impressions in a day, the numbers taken frequently amounted to many hundreds, while the price was reduced from ninepence to one penny each, exclusive of material, which was, of course, the same in both cases."

"Perhaps it may not be out of place here to advert to a class of work, which subsequently became of importance, and the full results of which are yet to be seen. This arose, in the first instance, merely from the desire to ascertain a correct orthography for the numerous names of places, more especially parishes and townlands, which alone amount to nearly 70,000, to be engraved on the face of the maps. These names were commonly of Irish origin, and frequently of great antiquity. Lieut. Larcom first began himself to study the Irish language, and investigate the names as they arose, but this was obviously insufficient, except to give him the means of devising a general system of research and controlling those who were to work upon it. This was ultimately accomplished by a party of persons employed for the purpose, and the operation consisted simply in reading all the sources of information, and extracting everything which bore on the names of the several localities. Many of these were in Latin, many in Irish, contained frequently in MS. charters and grants. When all had been collected that libraries and records could furnish, an investigation by a qualified Irish scholar was made on the ground, where by additional inquiries, conversation with the old inhabitants, and examination of the locality, little difficulty was experienced in discovering the meaning of the name, and its correct orthography. But it was not deemed proper, in all cases, to revert to the ancient spelling, now frequently obsolete: the practice, when this information had been obtained, was to adopt that one among the modern modes of spelling, which was most consistent with the ancient orthography. The documents thus collected form in themselves a most valuable topographic library, such perhaps as no country in Europe possesses in the same condensed form. It subsequently became the basis of the historical branch of a Memoir, which it was proposed should accompany the maps, as it must be obvious that to trace all the changes which the name of a place has gone through, by studying all the works in which mention of it occurs, is, in fact, to pass in review the whole history of the place."

"Of late also, it has attracted the attention of legal men, in connection with the recent acts for Registration of Deeds, as preserving the *alias* names of the various places, which in conveyances of property or investigation of titles is usually a fertile source of confusion and delay. For this purpose, these documents may yet be found to possess a high public value, more especially when the Ordnance maps shall be used for the registry of real property, as by the recent act has been enjoined."

"In addition to the special charge of the department for engraving and publishing the maps, Capt. Larcom performed also the duties of adjutant or brigade-major, being the sole officer permanently attached to Colonel Colby, at head-quarters. The force employed on the survey of Ireland was on an average about 20 officers, 200 sappers, and 2,000 civilians, from 1828 to 1846, when the last county was completed, and the greater part of the force removed to England. The whole correspondence of the survey, both civil and military, within itself, and with the various authorities of the Ordnance and the government, as well as the accounts of an expenditure amounting to £720,000, passed through the office during the whole time."

To many the above extract may appear to relate rather to Lieut.-Col. Larcom, than to Gen Colby, but such is not the case. Gen. Colby did indeed avail himself of the services of one so able; but he was, at the same time, always present to aid him by his advice and judgment: and though, as a man of enlightened and liberal mind, he willingly listened to the suggestions or examined the projects of those serving under him, he was equally able and ready to point out their fallacy, or to explain their inapplicability; so that, in this, as in every other branch of the work, he is entitled not only to claim respect for the judgment he exhibited in the selection of his officers, and for the extreme liberality with which, forgetful of self, he allowed every one to work out an honourable name for himself; but also to have awarded to him the high honour of having planned such a work as the survey of Ireland, watched over the arrangements required in its progress, and secured its success by controlling the development of its organization in all its parts, and directing, either in person or by letter, all its operations; for when we look with admiration at this, or any other work, seen as a completed whole, and give praise to those portions of it which appear so excellent, we ought not to forget how much, which would have been either relatively or absolutely bad, had been rejected and thrown aside, through the instrumentality of that superior mind and powerful will, which presided over and controlled the whole work.

J. E. P.

(*To be continued in the next Volume.*)

PROFESSIONAL PAPERS.

PAPER I.

Report on the Disputed Boundary between Canada and New Brunswick. By Major Robinson, Royal Engineers.

PRELIMINARY REMARKS.

It will be seen by the following papers and report, that whilst Major Robinson and Captain Henderson, of the Royal Engineers, were employed in British North America for the purpose of exploring and reporting on the best direction for a line of railway between Halifax and Quebec, their attention was at the same time directed to the subject of a long-pending dispute as to the common boundary line between the provinces of Canada and New Brunswick.

The dispute was as old nearly as the latter province itself, which was formed into a distinct government in the year 1784.

The primary cause of it was the very general, or rather the vague and indefinite, manner in which the boundaries of Canada were described in the Royal Proclamation of the 7th of October, 1763, when it was formed for the first time into a British province out of the possessions then recently conquered from the French.

The Quebec Act, which was an Act of Parliament passed in June 1774 to remedy some of the defects and omissions of the Royal Proclamation, did not, unfortunately, more clearly define the "southern boundary of Canada," which was the term afterwards employed in defining the northern boundary of New Brunswick.

In the summer of 1785, being but a very short time after the formation of New Brunswick into a distinct government, it appears the Surveyors-General of Canada and New Brunswick were in correspondence, and disputing as to the limits and extent of their respective provinces between the Upper St. John's River, the Lake Temiscouata and the River St. Lawrence.

In 1787 they were appointed to meet each other in the territory in dispute, with a view to agree upon and mark out the boundary, on the route of communication then existing between the two provinces.

The Surveyor-General of Canada was instructed to guide himself by the description given of the boundaries in the commissions of Lord Dorchester, then Captain-General and Governor-in-Chief of the three provinces of Canada, New Brunswick, and Nova-Scotia. The Surveyor-General of New Brunswick was instructed by the Lieutenant-Governor to guide himself by the Act of Parliament (1774) for establishing the province of Quebec.

In consequence the two Surveyors-General set off, and met each other *en route* near the mouth of the Madawaska River, at its junction with the Upper St. John.

There was no agreement, however, between them. The Canadian Surveyor-General requested him of New Brunswick to *go back* with him thirty-five miles, to fix the boundary at the Grand Falls; whilst the latter requested the former to *go on* with him about fifty miles, to fix it on the height of land overlooking the River St. Lawrence.

The question, in consequence, remained unsettled, but it soon became merged entirely, and was directed to remain in abeyance by Imperial authority until the much more important boundary dispute, which was then going on between Great Britain and the United States, should be terminated.

This great dispute, respecting the north-eastern boundary of the United States with the British provinces of Canada and New Brunswick, is now matter of history.

Arising out of the treaty made in the year 1783 with the United States, it was not settled until the year 1842, when a compromise was agreed to, and the question set at rest by dividing, as nearly as could be, the territory in dispute equally between the contending parties.

During its continuance volumes of angry diplomatic correspondence were written, commission after commission of inquiry and exploration was appointed; and more than once war was imminent between Great Britain and the United States of America in consequence of it, the whole of which might have been avoided, if the statesmen or diplomatists of those days, who drew up the Royal Proclamation in 1763, and framed the Boundary Article in the Treaty of 1783 with the United States, had adopted more generally the use of parallels of latitude, and due north or south lines, or meridians of longitude.

In new countries, where the inhabitants are few and scattered, and their physical geography imperfectly known, no better principle can be adopted.

A parallel of latitude, or a due east and west line, is capable of being marked on the ground with the greatest accuracy.

So also can a due north or south line, provided some initial point for its commencement be given.

A second of latitude is equal to 101 feet on the earth's surface, and with good instruments and time to repeat the observations, the limit of error might be brought to about that quantity.

But if a meridian of longitude from Greenwich, or from any other distant meridian have to be fixed, the limit of error will be greatly increased.

Probably two observers would differ as much as a mile or two, or even more, in determining the longitude of any fixed point astronomically.

In new or partially explored countries, such a difference is of little consequence.

The difficulty is only in establishing the initial point for a due north or south line.

The mouth of a large river is a vague definition, but still more the source; there may be a hundred streams contributing to the one main stream, and lying, in regard to its mouth, in very opposite directions.

A river boundary, from this cause, may soon become questionable and uncertain.

Chains of mountains are not always continuous, but become broken and interrupted, ramifying and separating into smaller branches, until all distinctive character may be lost.

Hence originated the long-pending disputes in question.

When that between Great Britain and the United States was happily terminated by the Treaty of Washington, in 1842, and while the Commissioners were tracing the new boundary fixed by it upon the ground, the old dispute between Canada and New Brunswick was revived.

Each province appealed to the Imperial Government, and hence arose the following joint report and proposed plan of settlement by the officers of engineers and their legal commissioner, Mr. Johnston, appointed under Mr. Secretary Gladstone's letter of the 2nd July, 1846.

To this boundary New Brunswick expressed her ready acquiescence, but Canada protested against it.

After a considerable delay, arising from various causes, Lord Grey suggested a plan to decide the dispute by arbitration, according to which, Thomas Falconer was chosen arbitrator by and on behalf of the province of Canada, Travers Twiss, Esq., D.C.L., was selected by and on behalf of New Brunswick, and the Right Hon. Stephen Lushington, Judge of the Admiralty Court, was chosen by them as third arbitrator, or umpire, for the decision of the question.

Early in 1851 the arbitrators met in London, and after examining and considering the documents and reports submitted to them, two of them made a report and suggested a boundary line.

Mr. Falconer, the arbitrator on the part of Canada, refused to join in it.

The Government, however, adopted the report of the majority, and an Act of the Imperial Parliament was passed in August, 1851, by which the boundaries were defined strictly according to their decision, and a dispute of nearly seventy years' duration set at rest, it is to be hoped never to be revived.

The boundary line thus recommended by the arbitrators, and adopted by the Government, differs from that of the Commissioners; the former giving to Canada, as a matter of feeling, what the latter stated they would have done but for fear of making a complicated boundary: viz. the entire seignories of Madawaska and Temiscouata, and compensating for it to New Brunswick by the addition of a portion to the eastward of the river Kedgwick.

The line is, in consequence, less simple than that recommended by them, and will be more expensive to trace out on the ground. Some doubts may also arise in determining the points where the tangents to the highlands occur.

The line is otherwise unobjectionable.

WILLIAM ROBINSON,
Capt. Royal Engineers, Br.-Major.

June 14, 1852.

The preliminary remarks above are reprinted, as they are required to explain the Report and accompanying documents which follow, and which did not appear in Vol. 3.—Ed.

Copy of Instructions from the RIGHT HON. W. E. GLADSTONE *to* CAPTAIN PIPON *and* LIEUTENANT HENDERSON.

GENTLEMEN, *Downing Street, July 2nd.* 1846.

In the prosecution of the enquiry with which you have been charged respecting the line of the proposed railway connecting the different provinces of British North America, you will probably be brought into the immediate vicinity of the territory, which, since the Treaty of Washington, has been in dispute between the provinces of Canada and New Brunswick. The adjustment of that dispute by any mutual consent of the parties to it having proved impracticable, I have considered how far such an adjustment might be effected by the arbitrament of Her Majesty's Government in this country. But the remoteness of the locality, and the conflict of so many voluminous statements and proofs, to the right understanding of which some knowledge of that locality is indispensable, have convinced me that the reconcilement of these differences could not be so effected. The only resource which has remained, is, that of committing to competent persons on the spot the duty of pursuing the inquiry, and of reporting for the assistance of Her Majesty's Government their joint opinions on the practical course it may be fit to take.

To you, therefore, as Her Majesty's Commissioners for the purpose, I propose to intrust this investigation, the Master-General and Board of Ordnance having expressed to me their assent to your acceptance and discharge of that employment. I have also instructed the Lieutenant-Governor of Nova Scotia to offer to Mr. Johnstone, the Attorney-General of that province, the office of your colleague as legal Commissioner. Assuming his acquiescence in the proposal, I have now briefly to indicate what will be the objects of your and his joint inquiry, and what the duty which will devolve on you and on him

After actually inspecting the territory in dispute (as far as any such inspection may be requisite, either for your thorough understanding of the reports hitherto made on the subject, or for clearing up any ambiguities in them), you will prepare such plans and maps of the country as may be sufficient for the full explanation of the controversy. That duty performed, you will next consider with Mr. Johnstone whether any line can be drawn for the demarcation of the two provinces which would satisfy the strict legal claims of each. If you should find it impossible to discover such a line, the three Commissioners will then consider how a line could be drawn which would combine the greatest amount of practical convenience to both provinces, with the least amount of practical inconvenience to either. You will, at the same time, advert to such interests (if any such there be) as the empire at large may have in the adjustment of this question.

The three Commissioners will then prepare and transmit to Her Majesty's Secretary of State having the department of the colonies, the result of their inquiries, and a report of their conclusions on both of these questions, supported by such proofs and arguments as may appear to them, collectively, to be necessary in support of those conclusions.

You will keep a distinct account of all the expenses which you may incur in the execution of this duty.

The Governor of Canada, and the Lieutenant-Governor of New Brunswick, will afford you all the aid and facilities in their power in your discharge of this duty. I enclose, for your information, a copy of the instruction which I have addressed to them for this purpose.

I have, &c.,

(Signed) W. E. GLADSTONE.

Captain Pipon and Lieutenant Henderson.
&c. &c. &c.

Copy of a Despatch from EARL GREY *to* GOVERNOR-GENERAL THE EARL OF ELGIN AND KINCARDINE.

Downing Street, August 26th, 1848.

MY LORD,

I have the honour to transmit to your Lordship the accompanying copy of a Report, and its Appendix, which has been drawn up by the Commissioners appointed by the Queen to investigate and report upon the respective claims of Canada and New Brunswick to the territory ceded to Great Britain by the Treaty of Washington.

I shall abstain from submitting this Report to the consideration of her Majesty until I shall have learned the opinion which the authorities in Canada and New Brunswick entertain upon it; but I trust that both provinces will regard the result of this enquiry as satisfactory, and as fairly determining upon their respective claims.

I have, &c.,

(Signed) GREY.

The Earl of Elgin and Kincardine,
&c. &c. &c.

P.S. The copies of the maps referred to in the accompanying Report are now in course of preparation, and will be forwarded to you as soon as they are completed.

REPORT.

Halifax, Nova Scotia, July 20th, 1848.

MY LORD,

On the 2nd July 1846, the Right Hon. W. E. Gladstone, then Her Majesty's Secretary of State for the Colonies, appointed the late Captain Pipon and Captain Henderson of the corps of Royal Engineers, Her Majesty's Commissioners for prosecuting the exploration and scientific investigation judged necessary for the adjustment of differences existing between Canada and New Brunswick in relation to the territory which, since the Treaty of Washington, has been in dispute between those provinces; and the Right Honourable Secretary at the same time nominated Mr. Johnstone, the then Attorney-General of Nova Scotia, to be the colleague of Captain Pipon and Captain Henderson as legal Commissioner.

The Secretary of State, in indicating the duties that would devolve respectively on these Commissioners, instructed Captain Pipon and Captain Henderson that, after actually inspecting the territory in dispute as far as such inspection should be requisite, they should prepare such plans and maps of the country as might be sufficient for the full explanation of the controversy; and that duty being performed, they were directed to consider with Mr. Johnstone whether any line could be drawn for the demarcation of the two provinces which would satisfy the strict legal claims of each. Should it be found impossible to discover such a line, the three Commissioners were then to consider how a line could be drawn combining the greatest amount of practical convenience to both provinces with the least amount of practical inconvenience to either, adverting at the same time to such interests, if any such there were, as the empire at large might have in the adjustment of that question. And the three Commissioners were instructed to prepare and transmit to Her Majesty's Secretary of State, having the Department of the Colonies, the result of their inquiries and a report of their conclusions on both of these questions, sustained by such proofs and arguments as may appear to them collectively to be necessary in support of those conclusions.

Under the authority and instructions thus communicated, Captains Pipon and Henderson in the summer of 1846, pursued their preliminary topographical surveys, until, by the untimely death of the former officer,* the whole duty devolved on Captain Henderson.

In the summer of 1847, Major Robinson (appointed by Her Majesty's Government to succeed Captain Pipon) and Captain Henderson continued the needful explorations; and these officers, having returned to Halifax, have been, during the last winter and spring, engaged in preparing the maps and other delineations requisite for the explanation of the subject.

Mr. Johnstone has been in correspondence and personal communication with the Commissioners as circumstances required; and being in Montreal in the autumn of last year on public business, he availed himself of the occasion to obtain, in personal conference, the views of Mr. Papineau, then the head of the Land Department in Canada, and formerly one of the Commissioners for settling this controversy, who, by command of Lord Metcalfe, visited Fredericton in July 1845.

On his return Mr. Johnstone pursued the route by way of Fredericton and St. John, for the purpose of enjoying a like advantage in New Brunswick; and he had the benefit of meeting and conversing with, on the same subject, Mr. Baillie, the Surveyor-General and Commissioner of Crown Lands of that province, who had been appointed a Commissioner on the part of New Brunswick, in 1844, for meeting a Commissioner from Canada with a view to the adjustment of the dispute.

The map and other papers proper for the full explanation of the controversy having been completed by Major Robinson and Captain Henderson, the three Commissioners have met and considered the subject, and they have the honour now to report the result of their deliberations in the order directed by Mr. Gladstone.

1st. On the question whether any line can be drawn for the demarcation of the two provinces which would satisfy the strict legal claims of each.

In prosecuting this branch of the inquiry it seems proper, in consequence of arguments that have been advanced in the course of the controversy, to offer the preliminary observation that the object of the investigation being to ascertain the boundaries appointed to the provinces after they came under the dominion of Great Britain, the question is not controlled by any previously-existing extent of territory or jurisdiction.

The Proclamation of 7th October, 1763, is therefore the first subject of examination, and forms the foundation of the titles to be considered. By this instrument the Government of Quebec is declared to be bounded "on the Labrador Coast by the River St. John, and from thence by a line to be drawn from the head of that river through the Lake St. John to the south end of the Lake Nepissin, from whence the said line, crossing the River St. Lawrence and the Lake Champlain in 45 degrees of north latitude, passes along the highlands which divide the rivers that empty themselves into the River St. Lawrence from those which fall into the sea, and also along the north coast of the Bay des Chaleurs and the coast of the Gulf of St. Lawrence to Cape Rosiers, and from thence, crossing the mouth of the River St. Lawrence by the west end of the Island of Anticosti, terminates at the aforesaid River St. John."

No reference being here made to the previously-existing limits of the territory or jurisdiction of Canada as held or exercised by the French, or to the real or supposed extent of Acadia, or any territory or colony previously possessed or claimed by Great Britain, and the British Crown having unquestionable authority to subdivide in any manner it saw fit the territories then recently ceded to it, the province of Quebec could neither be extended beyond or circumscribed within the limits assigned to it by the Proclamation, except by authority of the Sovereign or Parliament of Great Britain.

* Captain Pipon was drowned during the performance of this duty in the River Ristigouche, October 28, 1846.—Ed.

In June 1774, the Quebec Act, 14 Geo. III., chap. 83, was passed, with the declared object among other things, of remedying omissions and inconveniences that had been felt in the operation of the Proclamation.

It does not profess to substitute any boundaries for the province of Quebec in place of those defined in the Proclamation, nor does it declare the limits by which that province had been or was to be bounded. It enacts that certain territories, islands, and countries should be, "during His Majesty's pleasure, annexed to and made part and parcel of the province of Quebec as created and established by the Royal Proclamation of the 7th October, 1763.

The Proclamation therefore, modified by the Act, remained in full vigour.

The description of the territories mentioned in the Act commences in the following manner: "bounded on the south by a line from the Bay of Chaleurs along the highlands which divide the rivers that empty themselves into the River St. Lawrence from those which fall into the sea to a point in 45 degrees of northern latitude on the east bank of the River Connecticut, keeping the same latitude directly west through the Lake Champlain," &c. &c.

The description terminates without bringing this line back to its place of beginning; and the north coast of the Bay of Chaleurs, one of the boundaries under the Proclamation, necessarily continued under the same authority to be so after the Act.

On examination it will be perceived that no alteration in the limits of the province of Quebec from those established under the Proclamation was made by the Act, or could have been designed, and that the difference in the two descriptions is immaterial. The Act reverses the course followed in the Proclamation: it names a point at which the line meets the 45th degree of north latitude, on which the Proclamation is silent, and mentions as a boundary on the south a line from the Bay of Chaleurs along the highlands, while in the Proclamation the connexion between the bay and the highlands is left to implication.

The title of New Brunswick may be considered as commencing with the Commission to Montague Wilson, Esq., as Governor of Nova Scotia, dated 21st November, 1763, being only a few weeks after the Proclamation; and from the nearness of these dates it may be assumed that the laying off of the two provinces of Quebec and Nova Scotia were simultaneous Acts.

In this Commission the boundaries are stated thus:—

"To the northward our said province (of Nova Scotia) shall be bounded by the southern boundary of our province of Quebec as far as the western extremity of the Bay des Chaleurs, to the eastward by the said Bay and the Gulf of St. Lawrence, and to the westward, although our said province hath anciently extended and doth of right extend as far as the River Pentagoet or Penobscot, it shall be bounded by a line drawn from Cape Sable across the entrance of the Bay of Fundy to the mouth of the River St. Croix, by the said river to its source, and by a line drawn due north from thence to the southern boundary of our colony of Quebec."

In the year 1784, Nova Scotia was divided, and the province of New Brunswick erected out of it.

The new province, as appears from the Commissions of the Governors at an early period, was defined as follows: "bounded on the westward by the mouth of the River St. Croix, by the said river to its source, and by a line drawn due north from thence to the southern boundary of our province of Quebec, to the northward by the said boundary as far as the western extremity of the Bay des Chaleurs, to the eastward by the said bay and the Gulf of St. Lawrence to the bay called Bay Verte, &c."

The strict legal rights of the two provinces being dependant on the terms and just construction of the Proclamation, and the Quebec Act explained by the Commission to Governor Wilmot, it is necessary to examine with precision the mode in which the boundaries are described, that, by the language of the documents, qualified by the nature and condition of the subject, the intention of the Government and the legitimate meaning of its declarations and acts may be ascertained.

The following conditions result from the several descriptions when considered together :—

1st. That Canada shall be bounded by the north coast of the Bay of Chaleurs as far as its western extremity, to which Nova Scotia is specifically stated to reach.

2nd. On the the south side, by a line from such western extremity along certain highlands to the 45th degree of north latitude, at a point on the eastern bank of the Connecticut River.

3rd. That those highlands shall be "the highlands which divide the rivers that empty themselves into the River St. Lawrence from those which fall into the sea."

Had no inherent characteristic been selected to mark the highlands that were designed to form the demarcation between Canada and the adjoining possessions of the Crown, the descriptions contain nothing else which could ensure a boundary capable of being ascertained through an unexplored and wilderness country, the interior of which was almost unknown, extending over the great distance that separates the Bay of Chaleurs from the Connecticut River, and an object deemed by the Government of no small importance would have been placed at the hazard of conjecture or accidental coincidences, and made subject to very great risk, if not the almost certainty of failure.

The physical attribute of the highlands was therefore the only security employed for attaining the needful certainty.

It may be reasonably presumed that in addition to this advantage another benefit was contemplated from the peculiar nature of the boundary, namely, the giving to each province jurisdiction over the whole course of such rivers as emptied themselves within it, a convenience likely to be much regarded at a time when, in the absence of roads, the facilities of water-carriage directed the course of settlement. This presumption is the more probable, as the object of securing a certain definite boundary might have been effected by the ordinary means of lines running by magnetic courses or between given points; the latter object could only be attained in the mode that was adopted.

It has been seen that the Proclamation and Act speak of "the highlands" dividing the rivers falling into the St. Lawrence from those falling into the sea, as of certain not conjectural existence, and it cannot be imagined that the Government did not apprehend the import and consequences of its own act; or however little may have been known with accuracy of the course and relative bearing in connexion with other objects of the highlands or the interior of the country, that it did not possess or suppose itself to possess adequate information of the River St. Lawrence and the Bays of Chaleur and Fundy, and the rivers emptying themselves into them, and the general elevation of the land, to justify their assumption that such a boundary might safely be relied on, to say nothing of the intrinsic probability from natural causes that a range of highlands, fulfiling the condition, existed.

While, however, it may be well believed that the description was framed on a conviction that certainty and convenience were secured by a boundary dependant on its physical character, yet whatever may have been the notions and opinions that led to the selection of a line thus distinguished, or whatever may have been thus distinguished, or whatever may have been the ideas prevalent (if any were entertained) as to the actual location of the highlands, or their position relatively to other circumstances or features of the country, the Act of the Government in unconditionally adopting that boundary was decisive and clear, and the legal claims of the provinces can now only be governed by the plain meaning and legal construction of the documents by which the title is created; and it is believed that no exposition can be conducted on sound principles that does not demand in the construction of these documents that the controlling and distinguishing element in the boundary shall be its division of the rivers that discharge their waters in the opposite directions indicated in the Proclamation and Act, and that to this paramount consideration points less important for effecting the general objects shall be held subordinate.

Whatever line, therefore, shall be found substantially to answer the description these documents give of the boundaries of the provinces, must control the legal claims of Canada and New Brunswick. Whether a boundary of that character actually existed was a question demanding for its solution exploration and scientific research.

At this point, then, it is that appeal must be made to the topographical result of the labours of those Commissioners to whom the exploration and research directed under Mr. Gladstone's Despatch were committed; and from the observations made and the knowledge acquired in the fulfilment of this duty, they have felt no hesitation in pronouncing as their clear and decided opinion that highlands do exist which separate the rivers that empty themselves into the River St. Lawrence from those that fall into the sea; that these highlands connect themselves continuously by highlands with the north coast of the Bay of Chaleurs at its western extremity, and reach the 45th degree of north latitude at the eastern branch of the Connecticut River, thus essentially fulfilling the several requirements of the Proclamation, Act of Parliament, and Commissions for the southern boundary of Canada, and laying the foundation for establishing the strict legal claims of the two provinces.

On the accompanying map,* prepared by Major Robinson and Captain Henderson, this line is coloured green, and it will be seen that the northern highlands, claimed by New Brunswick, are adopted, and the line contended for by Canada as her southern boundary is rejected.

The determination and confidence with which the claims of both provinces have been supported, and the arguments which on behalf of Canada have been used in support of the boundary to which that province thinks herself entitled, call for some consideration of the principal objections that have been urged on her part against the northern highlands, which this report presents to your Lordship as forming the southern boundary of Canada under the terms of the Proclamation and the Quebec Act.

In this view some of the observations that have been already offered have been made, which otherwise would have been deemed unnecessary.

In attempting to avert the application of the fundamental principle on which the northern highlands are preferred, and the southern range repudiated, namely, the necessity that the boundary heights should divide the rivers that empty into the St. Lawrence from those that fall into the sea, the advocates of the Canadian claims have intimated that the word "sea" in the Proclamation and Act might be read "Atlantic Ocean," and the conditions of the description be held to be adequately satisfied by highlands possessing the required qualification as far east from the 45th degree north latitude as the due north line and the St. Croix River.

It is difficult to apprehend the ground on which an exposition is proposed, so little in harmony with the letter and the apparent spirit of the written instruments to which it is applied, whether considered in relation to the nature of their subject or the policy of their framers.

* See table of references on the map.—Ed.

The territories to be affected by the contemplated division from the Connecticut River to Chaleur Bay were bounded towards the north by the River St. Lawrence, and towards the south and east by the Atlantic Ocean and Bay of Fundy, and the Gulf of St. Lawrence, and the Bay of Chaleurs.

In speaking of a division of the waters flowing into the St. Lawrence from those flowing in an opposite direction, the word "sea" was alike appropriate throughout the whole course of the line; the term "Atlantic Ocean" could only apply to a part of the boundary.

The subject therefore in itself furnishes no warrant for departure from the plain meaning of the language used.

So, also, as the whole of these territories were British in 1763, and no reason has been assigned, and none can be easily imagined, for subjecting one portion of the country bordering on the line to a policy different from that applied to another, nearly as extensive, the objects of the Government, as legitimately deducible from its language and acts, and the nature of the subject, seem as little to favour this construction.

But further, although it must reasonably be presumed from the dates that the boundaries of Nova Scotia were under consideration when those of Quebec were determined upon, yet the construction under review renders inappropriate and inapplicable throughout the whole extent of Nova Scotia that peculiar qualification of the boundary which it has been seen gave to the description its only certainty, and effected an object of policy which it may be reasonably supposed the Government had in view.

It seems likewise to be a violent improbability that for no assignable reason a boundary should have been given to Nova Scotia so extensive as from the Bay of Chaleurs to the due north line, which could only be ascertained and tested by a quality discoverable alone out of her limits far to the west.

For so great a departure from the language, plain meaning, and natural construction of written instruments, some reason of a constraining power may justly be required. None can be found.

The treaty of 1783, and the supposed intentions of the British Government, as evinced by the treaty, and as subsequently manifested in negotiating its execution, have been appealed to in this connexion.

But as the Proclamation and Governor Wilmot's Commission passed nearly twenty years previously, neither the treaty nor what occurred under it could affect the condition of the description throughout that long interval of time, and the title existing then must have continued the same in its inherent nature afterwards.

The treaty, too, was made when the circumstances were greatly altered.

A foreign and independent party was introduced, and the subject was less extended than that over which the Proclamation had operation, and it was contracted just to that extent which made the term "Atlantic Ocean" appropriate, for the territory to be defined under the treaty extended no further east than did that ocean.

An argument against the line along the northern range of highlands, which has been much relied on (and which appears to be the only intrinsic objection) is derived from the language of the Act of 1774, in the commencement of the description, "bounded on the south by a line from the Bay of Chaleurs along the highlands that divide the rivers that empty themselves," &c.

The objection turns chiefly on the words "on the south," as connected with the course of the line claimed by New Brunswick for some distance from its commencement at the bay.

It will be best understood by an extract from one of the most able papers in support of the Canadian claims, where it is said,—

"The words of the Act of 1774, 'bounded on the south by a line from the Baie des Chaleurs along the highlands which divide the rivers that empty themselves,' &c. would never be supposed to have been intended to direct that from the Baie des Chaleurs a line should be run in a direction almost north for a distance of from 35 to 40 miles ere the commencement of the southern boundary of Quebec could be found, for this line from the Baie des Chaleurs to the highlands would form a western and not a southern boundary for the province of Canada."

The same objection has been very elaborately argued by another Canadian Commissioner, who has reiterated it in a variety of forms, and deduced from it many inferences. The objection seems to overlook the nature of the subject, viz., the boundaries of an unexplored country of great extent, of which the interior geographical relations were unknown, and treats the supposed intentions of Government and the import of its language as if controlling lines of small extent, the result of actual survey or accurate and minute knowledge.

This mode of exposition would introduce more serious objections than this; for instance, the Bay of Chaleurs, in 1763 and since, was called in the Governor's commissions an eastern boundary of Nova Scotia and New Brunswick, whereas it is the northern limit.

Again, the line itself so much controverted and now under consideration, from the earliest to the present time, is called the south boundary of Quebec and Canada and the northern of Nova Scotia and New Brunswick, and on that description this objection is founded. Yet Canada, not less than New Brunswick, offers, as adequately fulfilling this designation, a range of highlands which on its own maps exhibits not only deviations from a west course as palpable as that now objected to, but which, even in its general course, is far from giving a south boundary.

The Proclamation of 1763, however, furnishes a key to the meaning of its framers in this particular, by clearly exhibiting their intention to confine the description of the boundaries to definite objects known or assumed to exist, leaving the intermediate details necessary for uniting the line of which they were ignorant to be supplied as the country should become more perfectly known.

This significantly appears both in the course of the line from the St Lawrence to the highlands and from the highlands to the north coast of the Bay of Chaleurs.

In the latter case, which is the point under consideration, the expression is "passing along the highlands which divide, &c., and also along the north coast of the Baie des Chaleurs."

The governing objects being, consequently, these highlands and the north coast of the Bay of Chaleurs, the description, by necessary implication, required that they should be united. The exact method of uniting them was evidently a matter of detail, but it seems in every way probable that the framers of the Proclamation were aware of the existence of the very remarkable highlands at the north-west extremity of the Bay of Chaleurs (upwards of 2,000 feet in height), and which from an inspection of Mitchell's map, which appears to have been used by them officially, are represented as the continuation of the range of highlands dividing the waters of the St. Lawrence from those flowing to the sea.

The Act of 1774 could contemplate no alteration, because the highlands were the same as in the Proclamation, and the relative position to the Bay of Chaleurs was necessarily unchangeable. The difference of language was such as arose from commencing at the Bay of Chaleurs, and from introducing what was supposed to be the the general course of the highlands in the whole distance between that bay and the 45° of latitude.

But as the objection could only avail to defeat this line, without having power to substitute another not conformed to the description, and as the point on which it arises is obviously one of little moment, and the main objects of the description are plainly expressed and capable of being defined, were it necessary to bend and control this uncertain and immaterial point in the description, to preserve the operation of the certain and essential, the just rules of exposition would, it is conceived, in such a case allow this license.

It seems, however, in the present instance, unnecesary to depart from the strict rules of interpretation.

A line dividing the sources of rivers falling in opposite directions could not be assumed to be a line free from many windings; and the term "bounded on the south," applied to such a line running through an extent of country stretching from the Bay of Chaleurs to the Connecticut, could not be used strictly, or be intended to describe a direct line.

If so, the particular part of the line in which deviations might occur, or their nature and extent, must be deemed immaterial, and be treated as incidents inseparable from such a boundary, of which its framers must be presumed to have been well aware, their general objects being secured by the ascertained points of commencement and termination.

Major Robinson and Captain Henderson having visited the Bay of Chaleurs, and explored the country both north to the St. Lawrence and south of it into the interior of New Brunswick, and given due consideration to what, in their opinion, were the intentions of the framers of the Proclamation and Act, and the amount of knowledge they may be reasonably supposed to have possessed of the bay, have given it as their opinion that the highlands of Tracadiegash, which rise abruptly at what to all intents and purposes is the western extremity of the Bay of Chaleurs to an elevation of some 2,000 feet, best fulfil the language and intentions of the Proclamation, &c., and that the line may be traced from thence in a north-westerly direction, neither cutting nor intersecting any rivers, for about 45 miles through an elevated country, when it may be considered as meeting the more specific range of north highlands, which from thence runs westwardly for a comparatively short space, where it turns to the south, and continues that course for a very considerable distance, until it is brought into the vicinity of the due north line.

The exact locality of the western extremity of the Bay of Chaleurs, as mentioned in the Quebec Act, does not appear to the Commissioners to require to be sought for with the precision which has been insisted on both by Canadian and New Brunswick Commissioners.

No accurate survey had been made of the bay at the time the Proclamation was issued, and therefore it cannot be supposed that any precise spot was intended by the introduction of the term 'western extremity.'

The existence of the mountain range of Tracadiegash highlands must have been perfectly well known to those who had visited the bay, and it is to be remarked that in sailing up it they appear rising like a wall, completely closing it in, and forming its western extremity. The shape of the bay, as laid down on Mitchell's map, justifies the conclusion that this was the idea then entertained.

Another objection to which great importance has been attached is derived from the treaty of 1783.

From the mention of the north-west angle of Nova Scotia, in connexion with the line between Great Britain and the United States, the understood identity of this line and the south boundary of Canada is assumed, and from the subsequent assertion of Great Britain that the southern range of highlands formed the Treaty line, the deduction is drawn that this line is the true southern boundary of the old province of Quebec.

Many authorities seem opposed to this view.

British official agents employed in negotiating the line with the United States refused to admit the identity of the provincial with the Treaty line, and required that the north-west angle should be ascertained by first determining the highlands described in the Treaty, and the rivers they divide.

Colonel Mudge and Mr. Featherstonhaugh have exposed the fallacy of attempting to determine the true range of highlands from a previous assumption of the north-west angle of Nova Scotia.

In the first statement on the part of Great Britain, according to the provisions of the Convention concluded between Great Britain and the United States on the 29th September, 1827, for regulating the reference to arbitration of the disputed points of boundary under the Fifth Article of the Treaty of Ghent, it is stated (page 23), after detailing the evidence of Simon Herbert, of the Madawaska settlement, that "this last-cited evidence proves an actual jurisdiction over this territory since the Treaty of 1783, by the British province of New Brunswick. The claims of this province and Canada with respect to this and other parts of the territory in this quarter are conflicting *inter se*, and show the uncertainty of their respective boundaries, which, in fact, have never been settled, and may require the interference of the mother-country to adjust; but these conflicting inter-colonial claims, which have arisen since the Treaty of 1783, are altogether irrelevant to the present controversy between Great Britain and the United States as a foreign power, and under that Treaty. Whether under the one province or the other the possession is British."

The Canadian Commissioners, whose argument is under consideration, themselves concede that it compels the adoption of a boundary between the due north line and the Bay of Chaleur, not comformable with the Proclamation and Act of 1774.

Apparently in view of a difficulty resulting from that fact, the British Commissioners before named have given their opinion "that the Acts of the British Government touching the partitionment of lands between the provinces of New Brunswick and Lower Canada are not appropriate matters for discussion in the dispute with the United States."

The converse seems here to be at least as applicable.

Great Britain and the United States, by a modified arrangement of the dispute, have felt the true position of the highlands, and of the north-west angle of Nova Scotia yet undecided.

Besides, nothing that has been advanced by the Canadian Commissioners, however correct it otherwise might be, can warrant the conclusion that the opinion of the British Government, as supposed to be expressed in the treaty, and as afterwards advanced in discussion with the United States was authoritative between the colonies. For as the treaty was not designed to alter, and had not force to alter the colonial boundaries (which remains to be ascertained after the treaty by the same distinctive features as before) if, in fact, the line of highlands claimed by Great Britain as the boundary with the United States was not the ancient provincial boundry, a mistaken assumption on that point could not affect the latter boundary. Nor, if the true position of the north-west angle, as capable of being ascertained, should prove inconsistent with the indicia, of the highlands between Great Britain and the United States as described in the treaty, could it be proper for the mere purpose of removing a discrepancy arising from the introduction (very needless it would seem to have been) of the north-west angle into the treaty, either on the one part to change the true position of that angle, or on the other to substitute other highlands for those marked out by the treaty.

Lastly. The institution of the present Commission, and the instructions to explore the territory in dispute, and to consider whether any line could be drawn for the demarcation of the two provinces which would satisfy the strict legal claims of each, is decisive that Her Majesty's Government does not consider those claims to be concluded by the treaty of 1783, or by anything that has taken place under it.

The Commissioners are therefore unable to perceive that they should fulfil their duty by surrendering to this objection the convictions they derive from the topographical evidence before them as applicable to the documents by which the boundary was originally established.

They consider their duty to be to discover, if it can be discovered, the line between the two provinces according to the terms of the Proclamation, the Quebec Act, and the Governors' Commissions; and by adopting the distinguishing characteristic of the highlands mentioned in the Proclamation and Act, as a controlling fact in the description, they best show their deference to the example of the Imperial Government, as they thereby conform to the same principle that the British Government maintained in its controversy with the United States, and which, as applicable to the line then in question, and the language of the treaty, well justified the claim of Great Britain when disembarrassed from connexion with the north-west angle of Nova Scotia.

Much on both sides has been written of the possession taken, and the jurisdiction exercised by the two provinces.

These can have little effect on the question of title, for the same difference of opinion that now agitates the two provinces on this subject existed as early as 1785, and it is clear they have not been adjusted or waived from that time to the present.

The following extract of a letter from the Surveyor-General of New Brunswick to the Surveyor-General of Quebec, dated at St. John, N. B., 21st June, 1785, given in the Appendix to one of the Canadian Commissioners' Reports, explains the controversy as it then stood:—"By your letter you seem to think that the Tamasquata Lake, and the discharge therefrom (or the Madawaska River) fall into your province, surely some great mistake or misinformation must occasion this idea. New Brunswick is bounded on the northward by the bounds or line settled by Act of Parliament between Nova Scotia and Canada, which Act expressly mentions the line between those provinces is to run on the height of land separating those rivers that fall into the St. Lawrence from those that fall into the sea; therefore the Tamasquata waters discharging themselves by the Madawaska into the St.John, and by that river into the sea, renders the business so clear that your error can only originate from a want of knowledge of our limits, or not having lately perused the Acts describing the bounds of your province."

Two years afterwards ineffectual efforts appear to have been made by the Provincial Governments to adjust the boundary. At that time the Canadian Surveyor-General endeavoured to establish a line from the Bay Chaleur to the Great Falls of the River St. John, and thence westward; while the Surveyor-General of New Brunswick insisted on commencing at the Portage between the River St. Lawrence and the Lake Temiscouta for the purpose of examining which way the waters inclined on the heights there that their course might determine the boundary.

Thus New Brunswick contended for the same principle, and claimed from it the same result in 1785 as she does now, and as it has been deemed imperative to adopt in this Report; and the Government of Quebec sought a boundary much further south than the sister province would admit, although considerably to the north of that subsequently, and now claimed by Canada.

Concessions of land and jurisdiction exercised by Canada under the French, and since 1763 under the colonial government, have been urged in opposition to the north line of highlands.

Any argument drawn from the Acts of the French Government has been anticipated in a preliminary observation.

The exercises of authority since the proclamation are met by corresponding Acts on the part of New Brunswick. Her measures of appropriation and of jurisdiction between the Restigouche and the south highlands, and to the west of the due north line have been, especially of latter years, as extensive, continued, and decisive as those maintained by Canada south of the north highlands.

These Acts on either side, therefore, prove nothing on this branch of the subject beyond ignorance of the true boundary or a mutual spirit of appropriation under conflicting titles.

But it might be urged that although concessions of land and the exercise of jurisdiction by the French Government were admitted to confer no title, they yet furnished a motive calculated to influence the British Government which should be considered as interpreting its Acts.

This may be admitted to be true under some circumstances and to a certain extent, and if, in fact, it were shown that in 1763 there were many Canadian settlers who would have been separated from the Quebec Government by the north highlands, and if any other line of highlands could be found which would in any adequate degree satisfy the terms of the Proclamation and Act, the suggestion would be entitled to serious consideration.

Neither of these facts, however, appear.

The Proclamation placed under the jurisdiction of Quebec the fishermen of Gaspé and the settlers on the southern bank of the St. Lawrence and its tributaries; but if there were inhabitants on the south coast of the Bay of Chaleurs, they were as distinctly retained under Nova Scotia.

A letter of the Surveyor-General of Quebec in 1787 shows that the country about the Tamascouta Lake and Madawaska River was then unsettled.

The inhabitants located near the Great Falls of the River St. John are mentioned as Acadians; they therefore originally may have been Nova Scotian rather than Canadian subjects, and nothing in the communication creates the impression that they were settled there before 1763.

It is more than probable that the Government believed the means they adopted to be the best for the purpose of placing under Canadian jurisdiction, as far as was practicable, all the inhabitants and concessions of lands known to belong to Canada. Nor is there any reason to believe that the extent to which they may have failed in this result was sufficient to have justified or would have occasioned the abandonment of a line recommended by its general adaptation to the policy of the Government in this respect and in other particulars.

Objections, however, which like this, are founded on the supposed intentions of Government, are obviously of little weight, if their only effect shall be to set aside a boundary that satisfies the Proclamation and Act in their more important requirements unless there be another line more perfect to substitute.

A slight comparison is sufficient to show that the line claimed by Canada cannot support this character.

Indeed, although there have not been wanting advocates of the Canadian claims who go the length of asserting the coincidence of their line with the requirements of the Proclamation and Act, yet it appears from the able Report before referred to (Messrs. Draper and Papineau) that there are others who stop short of this point, and admitting that the line along the southern highlands does not satisfy the terms of the Proclamation and Act, endeavour to bring the northern line into the same predicament.

The line claimed by Canada at its commencement is required to cross from the north coast of the Bay of Chaleurs at its head to the opposite shore. This fact is admitted by the same gentleman whose Report has just been noticed to be at variance with the apparent meaning of the Proclamation and Act. Soon after, as is seen on the maps prepared by another of the Canadian Commissioners, it diverges abruptly to the south for a long distance, giving occasion to an objection similar to that urged against the north line, of making an east instead of a south boundary to Canada, if such an objection were available: and it passes to the due north line, near Mars Hill, on a general south-west course, in which respect, as also in occasional interruptions of continuity, it is as liable to criticism as the north line.

It is, however, in the essential part of the description that the objection to the highlands claimed by Canada becomes, as it is conceived, fatally irreconcilable with the Proclamation and Act, inasmuch as these highlands do not divide the rivers that empty themselves into the St. Lawrence from the rivers that fall in the opposite direction, being in fact themselves separated from the heads of the rivers falling into the St. Lawrence by the large river, the Restigouche, and the valley it passes through.

This boundary, too, divides the St. John River 220 miles below its source, and instead of confining Canada to the St. Lawrence and her tributaries, it would give her a large portion of the St. John, with the Tobique, the Madawaska, and St. Francis, important rivers falling into the St. John, and the Restigouche from its source, with all its numerous and not insignificant tributaries.

On the other hand the north line, after running among highlands from the north coast of the Bay of Chaleurs at its head without crossing its waters, pursues its course along highlands that divide the rivers that empty themselves into the St. Lawrence from those that fall into the sea, to the Metjarmette, where the two lines meet and unitedly run to the Connecticut River at the 45° N. latitude along highlands that continue to fulfil that essential requisite.

Comparing, then, the two boundaries, and in the interpretation of the documents and the application of the facts, avoiding the extremes of verbal severity and unlicensed freedom, the conclusion on the minds of the Commissioners is irresistible, that unless the language of the Proclamation and Act shall be deprived of all distinctive meaning and a plainly expressed intention in harmony with the nature of the subject, and consistent with a rational and probable policy, shall be disregarded, the north range of highlands is the south boundary of the ancient province of Quebec demanded by the Proclamation of 1763 and the Act of 1774.

If this conclusion be not correct, the Proclamation and Act must be considered as having failed of any operation as far as relates to this important boundary, for unquestionably the south highlands cannot satisfy the descriptions either in their letter or spirit.

The observations hitherto have been confined to the south line of Canada; but it is also necessary to inquire into the west boundary of New Brunswick because its settlement affects the question between that province and Canada if the north highlands shall be adopted.

After the due north line from the source of the St. Croix, as it has been adjusted between Great Britain and the United States, has fulfilled its distance, New Brunswick claims to be entitled to remove it further west to the position it would have occupied had it been struck from the western source of the River St. Croix instead of the northern, and where it is contended it ought to have been placed agreeable to the Treaty of 1783.

To sustain this claim, it is asserted that the line with the United States was settled conventionally for quieting controversy, and not according to strict right.

In this view on the part of New Brunswick the Commissioners cannot concur.

The adjustment of the due north line between the United States and Great Britain was the judicial and not conventional act of the Commissioners appointed under the Treaty of Ghent, and it was subsequently acted upon, and has been finally ratified, by both Governments.

Whatever, then, may be individually thought of the correctness of the decision, it cannot practically be questioned by the provinces; but it is conceived that the line must be treated as occupying the true position designed by the Treaty, and concluding the claims of New Brunswick to extend westwardly. Therefore, in answer to the question on which the Commissioners were required by the Right Hon. the Secretary of State first to give their opinion, they have the honour to report that, in their opinion, a line can be drawn for the demarcation of the provinces of Canada and New Brunswick which would satisfy the strict legal claims of each: That is—

Commencing at the point at which the extension of the due north line strikes the north highlands before mentioned, and running along those highlands and reaching the north coast of the Bay des Chaleurs at the highlands of Tracadiegash, agreeably to the accompanying map,* being that part of the line coloured green which lies between the letters A and B.

They further report that a tract of country lies between the north highlands westward of the due north line, and the line of the United States, which, according to the strict legal rights of the two provinces, belongs to neither, being included within the lines marked B C D on the map, and which, in 1763, formed part of the ancient territory of Sagadahock.

The Commissioners deem it their duty further to report, that the line of division which the strict legal rights of the provinces, agreeably to the Proclamation and Act of Parliament and Commissions thus demand, is at variance with the actual possessions of both provinces, and is incompatible with their mutual advantage and convenience.

The inquiry, therefore, which was directed by the Hon. the Secretary of State to be made by the Commissioners if they should find it impossible to discover a line satisfying the legal claims of the provinces, is practically as needful as if that result had followed the investigations under the first branch of the subject.

Mr. Gladstone's directions are, "To consider how a line could be drawn which would combine the greatest amount of practical convenience to both provinces with the least amount of practical inconvenience to either."

Each province has exercised jurisdiction and extended its settlements as far as and along the Restigouche River for a considerable distance from its mouth, which thus has practically become to that extent their boundary, although each has claimed a right to extend its line far beyond.

Any attempt to alter this practical and subsisting division could not fail to be very injurious, without offering the prospect of any adequate benefit, and therefore, in this particular, the legal line of division calls for modification; and it would be proper that a large portion of this territory north of the Restigouche should be confirmed to Canada, although lying to the south of her anciently-defined boundary, and according to that boundary being strictly a portion of New Brunswick.

A considerable portion of the country that lies to the west of the due north line, between the north highlands and the newly-settled United States line, the Commissioners believe would be beneficially and properly assigned to New Brunswick, whether as regards the comparative benefit to the two provinces, or their meritorious claims, or the interest and convenience of the inhabitants.

* This is the Eastern portion of the boundary claimed by New Brunswick, see Table of References on the Map.—*Ed.*

The inhabitants of this portion of the country have chiefly settled under the authority of New Brunswick, and are familiar with the administration of its laws and usages; and the St. John and its tributaries, the Madawaska, and the St. Francis, offer to them, through New Brunswick, the most eligible mode of transport to market for their timber and other products of the country.

Over this territory New Brunswick for many years past has claimed and exercised ownership and jurisdiction; has assisted its inhabitants in distress; and during the struggle with the neighbouring State of Maine on the Boundary question, actively and at much inconvenience and expense maintained her jurisdiction and possession, and by her energy, for many years assisted in frustrating the attempts at actual occupation made by parties from the State of Maine; while Canada, removed from the scene of disquietude, remained passive.

Under these various considerations the Commissioners have mutually agreed to recommend a conventional boundary between the provinces of Canada and New Brunswick, which they believe will, agreeably to the desire of the Secretary of State, combine the greatest amount of practical convenience to both with the least practical inconvenience to either.

The conventional boundary they propose is defined by the following lines: that is to say—

That New Brunswick should be bounded on the west by the boundary of the United States, as traced by the Commissioners of Boundary under the Treaty of Washington, dated August 1842, from the source of the St. Croix to the outlet of the Pohenagamook, thence north-easterly, by prolonging the straight line which has been laid down on the ground as the boundary of the United States, between the Iron Monument at the north-west branch of the River St. John, and the Iron Monument at the said outlet of Lake Pohenagamook, until the line so prolonged shall reach the parallel of 47° 50' of north latitude, thence by a line due east to that branch of the Restigouche River called the Kedgewick or Grande Fourche, then along the centre of its stream to the Restigouche River, then down the centre of the stream of the Restigouche River to its mouth in the Bay of Chaleurs, and then through the middle of the Bay to the Gulf of St. Lawrence, giving to New Brunswick the islands in the said Rivers Kedgewick and Restigouche to its mouth at Dalhousie.

This is a line which may be easily ascertained, defined, and marked with comparatively little expense, and with ease and certainty. It gives to the provinces a convenient form, and confirms to each its possessions and inhabitants; or if there is any exception, it is too inconsiderable for notice in determining a question of this nature: and in every particular, as far as the knowledge and belief of the Commissioners extend, it divides the territory in dispute in the manner likely to be most beneficial as regards the provinces comparatively, and as respects the interest and convenience of the inhabitants.

The territory lying west of the due north line, which the ancient boundary leaves without the strict limits of either province, comprises 4,400 square miles. Of these the proposed conventional line will give 2,300 square miles to New Brunswick, and 2,100 square miles to Canada; and of the tract of country lying to the north of the Restigouche, which lies strictly within the boundaries of New Brunswick, 2,660 square miles are assigned to Canada.

The seigniories of Temiscouta and Madawaska fall within the limits of New Brunswick altogether or very principally.

The Commissioners would have assigned them to Canada, had it been possible to do so without much injury to the general arrangement.

They believe, however, that the inconvenience of separating them from Canada is more nominal than real. The inhabitants are few, not exceeding 20 families of poor, humble settlers.

The tenure of a large portion of these seigniories has been changed to common soccage by legislative enactments at the instance of the owners, and it is believed the proprietors of the remainder will be content with a similar change.

There do not appear to the Commissioners to be any interests which the empire at large has in the settlement of this question.

All which is respectfully submitted by your Lordship's
Most obedient, humble Servants,
WM. ROBINSON, Captain Royal Engineers,
Brevet-Major.
G. W. M. HENDERSON, Captain Royal Engineers.
J. W. JOHNSTONE.

Copy of a Letter from the ARBITRATORS ON THE BOUNDARY QUESTION *to* EARL GREY.

Eaton-place, April, 17, 1851.

MY LORD,

We have the honour to transmit to your Lordship a scheme for settling the boundaries of Canada and New Brunswick, which is approved by both of us. We also send two Maps which will illustrate that scheme.

We have, &c.
STEPHEN LUSHINGTON.
TRAVERS TWISS.

The Right Hon. Earl Grey,
&c. &c. &c.

That New Brunswick shall be bounded on the West by the boundary of the United States, as traced by the Commissioners of Boundary under the treaty of Washington, dated August, 1842, from the source of the St. Croix to a point near the outlet of Lake Pech-la-wee-kaa-conies, or Lake Beau, marked A in the accompanying copy of a part of Plan 17 of the survey of the boundary under the above treaty; thence by a straight line connecting that point with another point to be determined at the distance of one mile due south from the southernmost point of Long Lake; thence by a straight line to be drawn to the southernmost point of the Fiefs Madawaska and Temiscouata, and along the south-eastern boundary of those Fiefs to the south-east angle of the same; thence by a meridional line northwards till it meets a line running east and west, and tangent to the height of land dividing the waters flowing into the River Rimouski from those tributary to the St. John; thence along this tangent line eastward until it meets another meridional line tangent to the height of land, dividing waters flowing into the River Rimouski from those flowing into the Restigouche River, thence along this meridional line to the 48th parallel of latitude, thence along that parallel to the Mistouche River, and thence down the centre of the stream of that river to the Restigouche, thence down the centre of the stream of the Restigouche to its mouth in the Bay of Chaleurs, and thence through the middle of that bay to the Gulf of the St. Lawrence, the islands in the said Rivers Mistouche and Restigouche, to the mouth of the latter river at Dalhousie being given to New Brunswick.

We have, &c.
STEPHEN LUSHINGTON.
TRAVERS TWISS.

Dr. Lushington's Reasons *for the* Opinion *delivered by him in the Preceding Paper.*

Having carefully read the whole of the papers sent to me respecting the question as to the boundaries of Canada and New Brunswick, I came to the conclusion that the Report of Major Robinson, Captain Henderson, and Mr. Johnstone, was one of the most important documents to illustrate the true state of the case. That Report (with the comments subsequently made upon it) was a document of the most recent date. The commissioners appointed to consider the subject were unquestionably of competent skill, so far as related to any question of topographical examination. They, with Mr. Johnstone, had every opportunity of hearing all that previously passed, and weighing the arguments advanced on both sides.

I deemed it necessary to give this Report the most attentive consideration, to test, as far as it was possible, the truth of its premises and the correctness of the deductions formed from these premises. To attain this end I carefully considered all the objections which had been urged against it, and all the views of the subject which had at any time been taken inconsistent with it.

That Report may be divided into three parts:—1st. Statements of topographical facts; 2nd. Of other facts and circumstances; 3rd. Legal and other deductions therefrom.

I do not find that the topographical facts are denied, nor (speaking generally) the other facts, but the principal objections have been raised to the inferences drawn from those facts.

It is admitted on all hands that the Commissioners, in laying down the basis for ascertaining the boundaries between the two provinces, adopted the true grounds, viz., the Royal Proclamation of 1763, the Commission to Governor Wilmot in the same year, and the Act of Parliament passed in 1774, fixing the limits of New Brunswick. The Commissioners were of opinion that the legal line of demarcation was capable of ascertainment, or, in other words, that a line of boundary did exist which might be traced, and which would be in conformity with the main requisitions in the proclamation, commission, and act of parliament.

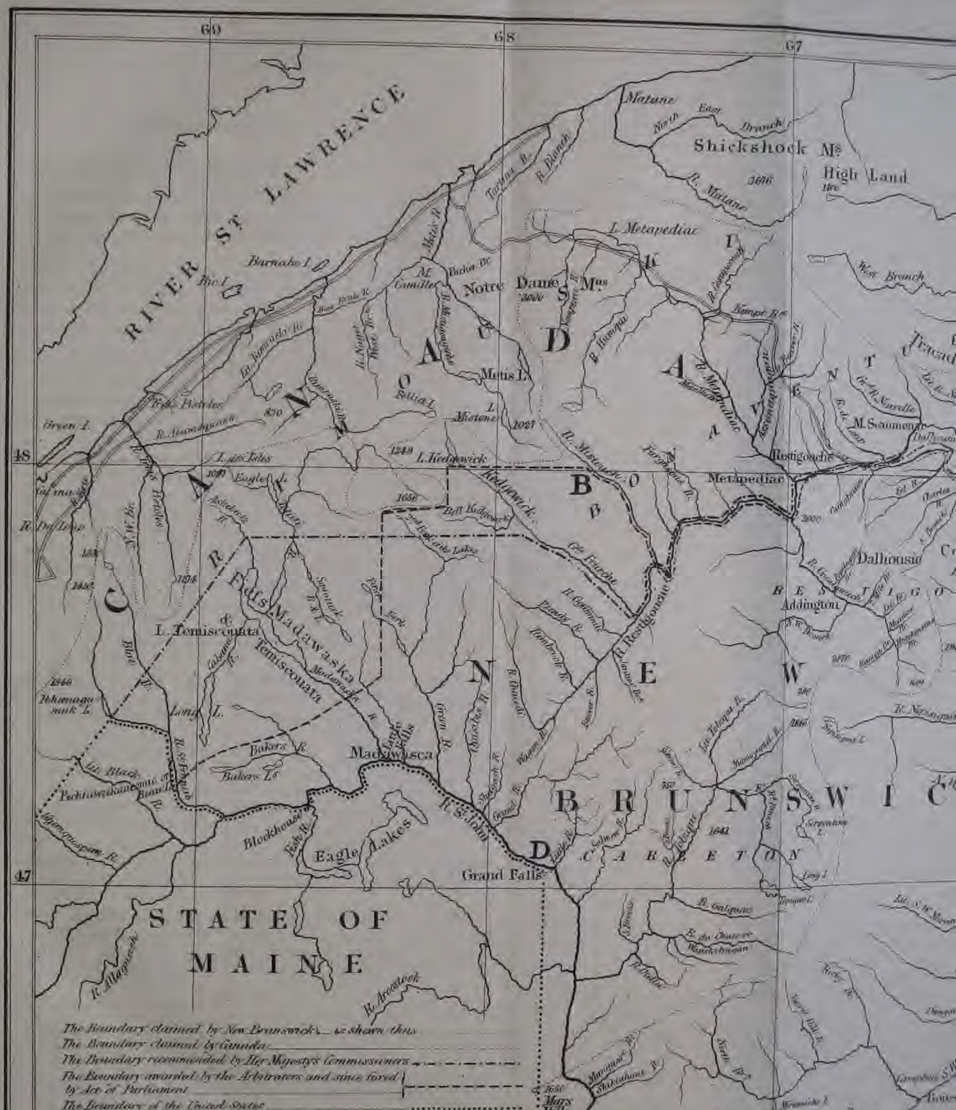
The line so suggested by them was utterly at variance with all the claims preferred on the part of Canada.

The line of the southern mountains suggested by Canada was irreconcilable with the main provisions of the proclamation, commission, and act of parliament, and so obviously so that the position on the part of Canada was abandoned, and not attempted to be urged in the recent discussion with Dr. Twiss and Mr. Falconer.

Whether, however, the Royal Commissioners had discovered the true line, was another and a different proposition. This was denied on the part of Canada, and it was contended that no true line could be discovered. As it is now agreed by all to adopt a conventional line instead of abiding by the true legal limits, the proposition became of less importance; but I think it right to state my opinion that if I had been compelled to say Yes or No as to the true line of demarcation stated by the commissioners, I should, notwithstanding some difficulties, have given my assent to their conclusion.

It was not, as I have said, necessary to prosecute this inquiry to an absolute decision, as all agreed there must be a conventional line; still, the fact of there being a true line of legal demarcation is not wholly foreign to this point.

It appears to me that the Royal Commissioners discharged their duty with great ability—that they weighed with care and impartiality all the facts and arguments adduced on both sides—that their chain of reasoning is just and correct. I was therefore strongly disposed to adopt their conclusions, and in the main to approve of the conventional line suggested by them.



C. Moody Lith. 257 Holborn

W. P. Jackson. Journal Office. Woolwich.

To that line Canada was strongly opposed; New Brunswick had made some objections, but had ultimately acquiesced.

When my co-arbitrators and myself commenced the subject, each of them proposed another conventional line. After several conferences and much discussion on paper, it was found impracticable to modify either of these two lines so as to get an unanimous decision.

It became necessary, therefore, that I should suggest a line myself. I took the line described by the Royal Commissioners as the foundation, and determined not to deviate from it without strong reason.

The Commissioners had stated in their Report that they would have assigned the seigniories of Temiscouata and Madawaska to Canada, had it been possible to do so without much injury to the general arrangement.

On the part of Canada the loss of these fiefs was considered to be a great grievance, not merely on account of intrinsic value, which cannot be great at present, but also as a matter of feeling, and certainly many reasons combined for assigning them to Canada, if it could be done. The Commissioners, too, had strongly expressed this opinion; the difficulty was to find a line which would give the fiefs to Canada, and yet not (to use the words of the report of the Commissioners) do much injury to the general arrangement. I did not think this difficulty wholly insuperable, and endeavoured, to the best of my ability, to chalk out a practicable line giving these fiefs to Canada. I could not, however, feel any confidence in the practicability of this line, for want of local and engineering knowledge; I therefore asked for the assistance of Capt. Simmons, R.E., and to that gentleman I am greatly indebted for the cordial and efficient manner in which he rendered that assistance. I found in him all that could be asked for,—local knowledge, engineering skill, and an earnest disposition to make them available.

The line now proposed to the Colonial Office has been approved by him as practicable and convenient.

Dr. Twiss, on the part of New Brunswick, acquiesced: I entertained some hopes that, as the fiefs of Temiscouata and Madawaska were now to be assigned to Canada, Mr. Falconer might be induced to acquiesce also, but these hopes were not verified.

The line so suggested by me, and approved of by Dr. Twiss, is founded, as far as possible, upon the principle of possession,—a principle laid down by Lord Hardwick in the Baltimore case as the true principle to govern all questions of disputed boundary. This, too, is the basis recommended by Lord Metcalfe.

One of the principal grounds of objection raised by Mr. Falconer was, that the territorial limits of Canada were not extended to the River St. John. It appeared to me that the objection was not tenable—that Canada had no just grounds whatever whereon to maintain this claim—and that, with regard to general policy, it would be very inconvenient to establish two claims to this river which might produce confusion and litigation.

The line agreed upon by Dr. Twiss and myself may be described as a line founded on that of the Royal Commissioners, but modified so as to give Canada the fiefs of Temiscouata and Madawaska, with some slight addition to New Brunswick on the north-east, of little value.

PAPER II.

Continuation of the Remarks on the Military Operations in New Zealand. By Captain Collinson, R.E.

PART III. OPERATIONS IN THE SOUTH.

SECTION I. HISTORY UP TO 1846.

In the former parts of this paper, published in the volume of the Royal Engineers' Professional Papers for 1853, some account has been given of the early history of New Zealand, and of the military operations in the north, during the years 1845 and 1846, which were brought to a conclusion in so complete a manner by the capture of Ruapekapeka in January, 1846, that the northern parts of the colony have never since been seriously disturbed by disputes with the natives. We have now to return to the remaining operations, at Wellington and Wanganui, both in Cook's Straits; the former in 1846, the latter in 1847, and which latter terminated all hostilities between the British and the natives in this colony. The origin of the southern hostilities was different to that of the northern. Heki and his party had been influenced by what may be called political feelings, loss of power, influence, and of revenue; the Southern disputes originated almost wholly in questions about land. These disputes had commenced very soon after the first arrival of the New Zealand Company's colonists in Cook's Straits, and had been gradually becoming more and more serious, but had not yet broken out into open hostility.

As a detailed description of this district, with a map attached, has already been published in the Corps papers, vol. 3. (1850); a summary only of that description will now be given, and that map will be referred to in discussing the Wellington campaign.

Wellington is situated in Port Nicholson, at the south end of the north island, and the whole of that district is filled with a mass of mountain spurs from the Great Tararua range. They run in long narrow ridges 500 to 1,000 feet high, ridges and vallies being all covered with a dense forest, and they extend from Palliser Bay to Kaputi Island* in Cook's Straits, thus enclosing Port Nicholson in a basin of hills, the only valley of any size being that at the head of Port Nicholson, the Hutt (or Heritonga as the natives call it), which is about 15 miles long, and one to two miles broad; and the only parts of the country clear of forest being a few patches near the coast, coloured green on the map.

Beyond these wooded hills, on the east side, lies the broad and grassy valley of the Wairarapa, and on the west side the belt of flat alluvial land, between the sea and the foot of the Tararua range, and extending as far as Cape Egmont.

* See large map in Vol. 3. New Series of Professional Papers.

Between 1841 and 1846 the settlers had penetrated a little into the interior, notwithstanding the opposition of the natives; and had located themselves on the lands assigned to them by the New Zealand Company, some in the Hutt, some at Porirua, and had cleared little spaces in the woods and built wooden huts.

The New Zealand Company had made a cart-road from Wellington, extending into the Hutt valley a few miles, but it was necessarily very difficult of passage, even for the rough carts of the settlers, and there was a bridle path to Porirua, (following nearly the line of the present road), and thence on to the north-west coast by Pukerua, but it was almost impracticable even for the well-appointed settler; with these exceptions, the only way of crossing the country was by the narrow foot-paths of the natives, and beyond these paths it was dangerous and indeed nearly impossible to stray into the thick forest, the underwood of which is choked with creepers thickly interwoven. If it was difficult to move regular troops over the fern plateaux of the North, it was quite impracticable to do so among these wooded hills; added to which, from its very character, still less was known of the country than of the neighbourhood of the Waimate; settlers had been lost in its forest ravines within a mile or two of Wellington.

The natives of this district may be divided into three great tribes; the *Ngatiawas* living in Wellington and about Port Nicholson, and also at Waikanae on the north-west coast, who had always sided with the British, having been well treated by the New Zealand Company. The chief man among them was William King, but the chief most known to the settlers was *Epuni*, one of minor rank.

2nd. The *Ngatitoas*, living at *Porirua* their chiefs were *Puaha* and his brothers, and *Rangihaetaa;* part of this tribe opposed the British under *Rangihaetaa*, and part remained nominally neutral under Puaha.

3rd. The *Ngatiraukawa*, living at Otaki, one of their chiefs was Te Rauperaha, a chief of high standing in New Zealand both for family and talent. This tribe remained neutral, excepting *Te Rauperaha* himself.

After the affair of the Wairau in 1843 (mentioned in part 2 of this paper), there was great alarm throughout all the Southern settlements; at that time there were no troops or organized defences of any kind against the natives, and the settlers began to fear that this evident want of power would encourage the natives to proceed to open hostilities in their opposition to the claims of the New Zealand Company: they petitioned the government for protection, and even discussed the propriety of abandoning the Colony altogether.

It is not intended here to discuss the question of the purchase of lands from the natives by the New Zealand Company; there are, however, two great facts connected with the question, which appear to me most apparent from the records of those events, and which may be mentioned here, as they bear upon the military operations; and these are:—

First.—The want of due consideration towards the native chiefs and concerning the reserves of lands for the natives, on the part of the New Zealand Company's agent.

Second.—The want of power in the local government to control the excited avarice of the natives when the question of the purchase of lands was re-opened before the Crown Commissioners.

With respect to the first, the great chiefs *Rauperaha* and *Rangihaeta* do not appear to have been treated by the New Zealand Company's agent on his first arrival with the consideration due to their influence in the country. They both almost immediately repudiated the sort of bargain they had made with the agent, for the sale of the Hutt, *Porirua* and the *Wairau* districts; now, considering their powerful influence and the existence of the doubt about their claims, it would, doubtless, have been better that the Company's agent should have come to terms with them, which at that time he could have done at one-fourth the cost at which it was finally obliged to be concluded in 1848.

With respect to the second, the discussions before the Crown Land Commissioners (see part 2)—fanned by the Wairau affair, and encouraged by the absence of force in the government,—had excited the opposition of natives from all the neighbouring tribes to an imminent height The settlers, indeed, organized themselves into a militia; but the acting governor, Mr. Shortland, disbanded them, and contented himself with sending a police magistrate (Major Richmond, late of the 80th, and afterwards Superintendent of Wellington) and 53 men of the 96th under Captain Eyton. There is little doubt that the organization of a militia at this time, backed by two or three companies of troops, and accompanied by concessions to the principal chiefs, would have saved the expense of the hundreds of soldiers that were afterwards required; and would, at the same time, have left a better impression of British power on the natives. As it was, the natives continued from 1843 to 1846 making more and more violent oppositon to the settlers. Parties of natives belonging to the *Ngatitoa* tribe and to the *Ngatitama* (a branch from the River Wanganui) acting with the open support of *Rangihaeta* and the secret support of *Rauperaha*, located themselves in the Hutt, and occupied and planted patches which the Company's settlers were just beginning to cultivate,—by way of preserving what they considered their title to those particular patches of Land. Just at this time Governor Grey arrived in H.M.S. Castor (Capt. Graham, C.B.) from the successful campaign of *Ruapekapeka;* he was accompanied by H.M.S. Calliope, Capt. Stanley, and H.M.Stmr. Driver, Comr. Hayes, and a transport, and having with him altogether about 500 men of the 58th, 96th, and 99th regiments, under Lieut.-Col. Hulme, 96th, and the detachment of Royal Artillery just arrived from England under Capt. Henderson, with two 6-pounder field guns, two 4⅖-inch mountain howitzers, and some 6-pounder and 3-pounder rockets; (and not two 3-pounder guns, and two 12-pounder-howitzers, as stated at the end of part 2.) There were previously in Wellington about 180 men of the 58th and 96th. As there were then no barracks in Wellington, the troops were put into hired houses in the town.

The appearance of the governor with this large force produced an effect upon the natives; several influential chiefs wrote to him in terms full of peace, and (like natives) throwing the blame on another tribe, a party from Wanganui, under a chief called *Mamaka*, who had come down to assist his relations, the *Ngatitama*. This apparent support from the natives perhaps deceived the governor, and, roused by the urgent appeals of the settlers, he thought he could frighten the intruding natives out of the Hutt by a demonstration; forgetting all the difficulties that had occurred in the north, from marching troops into the interior, and even at this time so little expecting resistance, that the force marched from Wellington without equipage of any kind, even without great coats or provisions.

The flat part of the valley of the Hutt is about eight miles long and two broad, covered, as before said, with forest. About two miles up it, the New Zealand Company's road crosses the river: here a small stockade, called Fort Richmond, had been erected some time before, and was occupied by a party of the 58th, under Lieut. Rush: two miles further on was a settler's house, called Boulcotts, in a clearing of some 20 acres, and two miles further was another house in another clearing, called the *Taita*.

The natives coming from *Porirua* used the *Poreraho* path, from the head of *Porirua* water, coming out near Boulcotts.

SECTION II. OPERATIONS IN THE HUTT VALLEY.

In pursuance of the governor's aims, on the 24th of February, 400 men of the 58th, 96th, and 99th marched from Wellington into the Hutt valley, to Boulcott's farm, and occupied it. In the evening the artillery were landed from the Driver, at the head of Port Nicholson, and joined the troops. They had been left behind, in consequence of there not being any opposition expected; but the natives showed no symptoms of being intimidated into leaving the Hutt, and no desire to come to terms in the several unsuccessful *koreros* (or conferences) the governor held with them; so the troops bivouacked on the ground, and, in short, it was two months before they finally quitted that post again.

The natives appeared disinclined to make the first attack, but they continued illtreating the settlers and their cultivations as much as before, so the governor had to make another step forward; he proclaimed martial law, and (under the usual fiction of considering the natives as rebels) he sent a herald to inform them of it, and at the same time ordered the Taita farm to be occupied by a company of the 96th; in pursuance of his orders, the troops fired on the natives the next time they appeared, and thus opened the campaign.

In March there were three detachments occupying this little valley; fifty men at Fort Richmond, fifty men at Boulcotts, and about a dozen militia at the Taita; and yet all they effected was to keep their posts and the communication between them, and that was principally owing to the fears of the natives; for surrounded as these posts were, within 100 yards, by thick forest, and defended only by slight stockades, it would have been easy for the natives to have picked off the soldiers almost man by man, without an enemy being seen. So, with the exception of the posts and the road between them, the hostile natives, who were about 200 to 300 strong,* had free access all over the Hutt valley: and thus the governor, instead of producing an effect by his show of force, perhaps taught the southern natives, for the first time, the uselessness of regular troops in such a country. It seems surprising that the governor, who must even then have determined on the admirable system of tactics which he afterwards laid down, could have made an advance that seemed almost a parallel to that of Wairau. His reason was, probably, the expectation of support from the friendly natives, and the incessant appeals of the settlers. They, indeed, tried to persuade him to attack a stronghold that the natives had made at the end of the *Pareraho* path, next to the Hutt river, on a steep spur, with trunks of trees laid horizontally, and to which they retreated every night. This stronghold might have been commanded from the neighbouring spurs, and assaulted in front by a specially-trained body of men. The mistake was in expecting such a system of warfare to be carried on by troops trained to a certain system of discipline and movement very necessary in civilized war, but worse than useless against savages. The governor, in answering this proposition, showed he was fully aware of the difficulty he had got into, for he says,† "The generality of persons in New Zealand, discussing the operations against the natives, forget that there is no analogy between them and the military operations in Europe: if our enemy retire into the dense and almost boundless forest, and our troops pursue them, the simple result is that the enemy are driven further and further into the forest, and the troops, ultimately, after heavy loss, are compelled to retire upon the open country and their supplies; the troops are forced to fight at the greatest disadvantage, whilst the ene-

* As stated by Mr. Servantes. † Blue Book, 1846.

my act at the greatest advantage. I determined—if it was necessary to inflict punishment—to choose my own time and opportunity to strike the blow." The system he recommended (but which he did not fully carry out) will be mentioned hereafter.

The natives did not show themselves in the Hutt valley, and had apparently deserted it, until 3rd April, when a party of them came from Porirua, and murdered a settler called Gillespie, who had settled on a piece of land under dispute. This roused the governor to active measures again; he went round to Porirua in the Driver, with 300 men, with some idea of intercepting the murderers; he saw *Rauperaha* who seemed half inclined to assist in catching them (they belonged to the *Wanganui* tribe and not to *Rauperaha's*.) *Rangihaeata* would not appear, and although he had nothing to do with the murder, yet he protected the murderers, and now for the first time took an active part in the campaign, by leaving *Taupo* pah, where he and *Rauperaha* had been living together, and going with his followers to *Pauatahanui* at the head of Porirua water, where he commenced a strong war pah. Rauperaha, with his proverbial subtlety, kept on good terms with the British, and consented to give up Paremata-point in Porirua harbour for a military station.

About this time Lieutenant-Colonel Hulme returned to Auckland, and Major Last 99th, took command of the troops in the South.

On the 9th April, 220 men, under Major Last, were sent round by sea to Porirua, and after lying a week under Mana island from stress of weather, they landed and pitched their tents on *Paremata* point. The governor's object in establishing this post was to cut off the communication of the natives by the *Pareraho* path with the Hutt Valley, and thereby he hoped to reduce them to want of food, as they had eaten up all their supplies in the Hutt Valley; and also to keep up his own communication with the neutral natives up the coast. He would never have succeeded in capturing any natives by forming such posts, because, although the *Pareraho* path was the ordinary line of communication with the Hutt, still the mountains at the back were passable to natives; and although the natives up the coast seemed disposed at the least to be neutral, still they were too much afraid of *Rangihaeata* to intercept him if he retreated; and the troops would have been of no more use half a mile from their posts, than they were in the middle of the Hutt. Nevertheless it was an excellent movement as a base for further operations, and it had some effect on the natives, as was shown by an intercepted letter of *Mamaku* to his friends at *Wanganui*, stating that he could not retreat (he was then at *Ohariu* on the coast west of Wellington) because the natives on the coast would not let them pass by land, and the *Pakeha* (or foreigner) had blocked up the way by sea.

The actual site of the *Porirua* post was well chosen, it was an old whaling station on a low sandy point near the mouth of the Bay, accessible to small craft by sea, and from it by boats to the head of the harbour; the ferry for the path to the north-west coast was here also. But the stockade should have been placed on a small hill at the back commanding the low point. There was however a want of pre-arrangement in the formation of the post; the following extract from Mr. Power's "Sketches in New Zealand" will best explain this, he was the commissariat officer in charge:—"When first the soldiers came to *Porirua* there was no accommodation whatever for them. They were landed on the beach in winter, and for some time were exposed to unparalleled privation and misery. They built huts for themselves of fern, flax, or reeds, as soon as they could, and were for some weeks engaged from morning till night in felling timber and dragging it through the bush to the water's edge, and rafting it to the camp. Often after toiling from dawn till dark, they would have to turn out and get under arms several times in the night, on an alarm from the sentries. For several weeks there were few men who ever had dry clothing on by day or by night.

The only land communication with Wellington was by a forest path so bad that all supplies had to be sent by sea." It is true that to overcome such difficulties forms a part of the soldier's duty in campaigning, and well does he get through them when he is encouraged by the presence of an enemy; but in New Zealand these difficulties were greater than ordinary, and the encouraging enemy was never to be seen; the ordinary duties of marching and encamping were indeed the principal features of these operations.

There was considerable labour and difficulty in stockading the *Paremata* post. They had to cross the water to get timber; they had few tools of any description, and what they had were borrowed from the colonial road parties, as the officer com-commanding would not incur the responsibility of purchasing them; and the only artificers were such as could be procured out of the Regiments. Major Marlow, R.E., was in the south for a short time about this time, but he was obliged to return to Auckland, and during this campaign there was no Engineer Department to carry on any of the works. And yet if ever an Engineer Department with a force of well organized and well equipped Sappers was required, it was certainly in such a country and on such an occasion as this. The consequence of this want of men and tools, was that all the stockades, though displaying great ingenuity, were built of small low timbers hardly bullet proof, very irregular in shape and of very small size.

The communication also between the *Paremata* post and Wellington was very bad. Although only fifteen miles, it was a very hard day's labour to march it, and it was a matter of surprise to all engaged that the natives did not take advantage of the forest path, to cut off the small parties of men that used to go between the stations; they might have cut off the communication by land with the greatest ease. And this shows the immense advantage of having steam communication by sea, in campaigning in such a country. Even the circumstance of the engines of H.M. steamer Driver being out of order, was felt to be a considerable loss to the service.

In order to protect the communication as far as possible, a party of militia were established in "Clifford's Stockade," half way on the path from Wellington to *Porirua*.

During April and May the troops were employed stockading their various positions in the Hutt and at *Porirua;* and *Rangihaeta*, it appears, also took advantage of this period of inactivity to construct his pah at *Pauatahanui*, or *Patanui*. It was only four miles from the military post of *Paremata*, and three officers made a very daring reconnoissance of it early in May. Captain Laye, 58th; Lieutenant Yelverton, Royal Artillery; and Mr. McKillop, of H.M.S. Calliope, went in a small boat to the head of the harbour a little before daylight, and landing, actually got up to the very palisades of the pah, before they were discovered, and then they had to escape under close fire. This reconnaissance, however bold, brought no advantageous result: it merely showed that if a suitable force had been at hand, it would have been perfectly practicable to have surprised *Rangihaeata* in his pah.

About this time Governor Grey, having resolved to remain passive during the winter, returned to Auckland. He left with the officer commanding a memorandum describing the line of policy he wished to be observed towards the natives during the winter, which contains maxims for all wars with savages so excellent, and so completely in accordance with those I have endeavoured to deduce from the northern campaigns, that the following extracts from it are here given.

He first describes the previous state of the country about Wellington, and says,* "that British authority was impotent a few miles from the town; that the natives were robbing and murdering and driving off settlers, insulting the authorities, and

* Blue Book, 1846.

resisting by force; that the events in the north had rendered them still more confident in their own powers and resources. But that since the arrival of the troops the hostile natives had been compelled to fall back a little; that wherever the troops had planted themselves they had held their ground; still in their immediate vicinity the natives were robbing and plundering where they pleased: and owing to the impracticable nature of the country, and the want of allies, of information, and of a properly organized police force, not one of them had been taken. But he hoped that now, with a strong military force and a police, the Government would be able to take up and protect a certain line of country."

—— "Evidently therefore if this is a country to be occupied by British settlers, it is not sufficient that Government should conquer and remain in military possession of a certain portion. The aboriginal inhabitants are so numerous and well armed, that no force could efficiently protect shepherds and agriculturists scattered through the country.

"The civil government must therefore support the military with a police; to obtain information, to explore and open up lines of communication, and to assist in the transport of military stores; the total want of the means of doing which would alone prevent any distant military operations being successful. At present the civil government only possess a few constables to watch a hundred miles of country, and mediate between 5000 English and as many savages; hence the great object is to delay hostilities to obtain time to establish them."

"Therefore we should have no military operations with small detachments, but simply hold possession of our post at Porirua and the Hutt; organize the police establishments required, and open lines of road to the coast, and then in the summer act along the coast with the allied natives."

This system of tactics, to employ the local police force on the active service in the interior, supported by the regular troops moving on lines of well connected posts, is in my opinion the one true efficient system to be employed against all savages, in whatever part of the world it may be. The misfortune in New Zealand was that it was never fully carried out. The police force was organized and found to answer exceedingly well, but it was far too small to perform the services required under the above system. There were only about 100 police and militia together. The police consisted of half English and half natives, and were armed with musquets and bayonets, and dressed in an appropriate rough blue dress; they were under two English colonists, Major Durie (who had served in Spain) and Mr. Strode. The militia were armed, but they were too undisciplined to be of service in the field; a militia in such a country would only be serviceable to hold certain posts; but for that they would have been very serviceable; and there does not appear any good reason why a large militia force should not have been raised at this time, as had been frequently recommended by the various Secretaries of State. There was no fear then as there had been before, of exciting the natives, the natives were already excited; the settlers were willing, for besides the paid militia, there were two corps of volunteers in Wellington who kept regular guard; and there were arms, for the native allies were supplied with them.

In case there should be any disturbance in New Zealand again, the above principles for carrying on a war with the natives, will be found to be equally applicable. For although the circle of settlement has been much extended, and information has now been obtained about all parts of the colony, still there would be the same difficulty in moving troops; and even at this time there is no better force organized for carrying out Governor Grey's system than there was at the time he wrote. The regular troops have been reduced to the strength of one full regiment, as he said they could be; but the police force, which he expected would have been increased and paid for out of colonial funds, has been rather reduced; and it is to be feared that under the representative constitution lately given to the colony, it is less likely to be increased than before; for the settlers are more likely to run the risk of the accident, terrible as it may be, than to pay a small annual insurance to prevent it.

In May the roads mentioned by the Governor in his memorandum were commenced; these roads will be noticed more at length hereafter; the parties of soldiers employed on that from Wellington to Porirua, lived in stockades along the line, and worked under arms; but they were never molested by the hostile natives.

The natives, however, did not allow the troops to remain passive during the winter as Governor Grey proposed; they found that the troops were less powerful than they expected, and they began to return to the Hutt, and worked up their courage sufficiently to attack the post at Boulcott's farm which was quite unprotected. This post consisted of two wooden houses, about 100 yards apart, in a clearing near the river; the troops (50 men of the 58th under Lieutenant Page,) were placed in these houses and in a tent between them, with hardly any protection. On the 16th May, half an hour before daylight, a party of about 70, under the Wanganui Chief *Mamaku*, stole across the river, fired a volley into the tent, and then rushed in. At the first surprise the soldiers fell back upon the principal wooden building, which had a sort of stockade round it, and then sallied out and commenced a skirmishing fire, driving the natives back a short distance. On the arrival of a reinforcement of fifty men from Fort Richmond, the natives retreated altogether. There were four soldiers killed and five wounded, and only one enemy wounded. It was here that a bugler of the 58th, sounding the alarm, had his arm broken by a tomahawk, he took his bugle in the other hand and sounded again; he was then killed.

It was the evident weakness of this post that invited this attack and made it so successful. The men at the post did what they could to make it defensible, but there was no regular system observed for making all these posts defensible; they were not even allowed intrenching tools; though the posts were in the middle of a forest supposed to be occupied by the enemy, and moreover (as *Maories* never can carry out an operation without previous discussion,) it had been reported several times before, that some such attack was going to be made.

The sudden and successful outbreak gave more confidence to the natives than anything during the war; *Mamaku* boasted of it as a victory. The settlers were proportionably alarmed; those who had hitherto stuck to their lands, now crowded into Wellington; and such was the fear and ignorance concerning the natives, that an attack on Wellington was daily expected. Major Richmond raised about 200 volunteers and militia, and some houses were put into a sort of defensible state as places of refuge. The militia and volunteers were too hastily organised, and the defences far too slight, to have been of much use if the place had been attacked: but if Captain Fitzroy had embodied the militia of the whole country in his time, they would have been sufficiently trained by this time to have assisted materially in the defence of Wellington.

The alarms here and at Auckland, and the total want of any plan of defence for either place, ought to be a lesson to Surveyor-Generals of young colonies in laying out towns, to take the defences of it a little more into consideration than they are in the habit of doing. Although these two towns were intended to be the chief and pioneer settlements in a colony filled with armed savages, there was no proper provision in either of them for places of arms, places of refuge, or posts of defence. And yet it would be very practicable in planning a town, to dispose the public buildings, such as offices, custom-houses, police-stations, &c., and to construct them in such a way as to make them not only more ornamental and equally useful in their ordinary capacity, but also much more available as defences in times of disturbance.

Major Richmond also issued 200 musquets to the native allies under *Epuni* of the *Ngatiawas*. This, Governor Grey observed, was a dangerous precedent; he had before declined the offer of the natives up the coast to rise in support of the Government. The natives (as he says) cannot be sufficiently depended on to be armed, and the excitement caused by raising one tribe against another would be more difficult to allay than the original disturbance.

After the affair at Boulcotts the natives began to show themselves in the Hutt again, and in June they murdered another settler called Rush. There was some old quarrel between him and his murderers, for the *Maories*, even in war time, have generally some special cause for attacking particular individuals. About this time Captain Reed of the 99th, who then commanded at Boulcotts farm, had a skirmish with them. Hearing that there was a party of natives in his neighbourhood, he went out one afternoon with forty men along the rough cart road towards the Taita; in a small clearing they encountered a party of about sixty natives. There was thick wood on all sides, and after some skirmishing Captain Reed found that the natives began to surround him, so he fell back, and met a reinforcement from Fort Richmond under Lieutenant Page, of the 58th. The natives did not follow them up; and in fact disappeared again. A party of militia from the *Taita*, under Mr. White, a settler, turned out on this occasion, and a party of the native allies, the *Ngatiawas*, coming up at the time from the opposite direction, were mistaken by the militia for the enemy.

An officer and some men were wounded this day.

SECTION III. THE HOROKIRI OPERATIONS.

These successes gave them further encouragement; they returned in greater numbers to the Hutt. *Rangihaeta* prepared his pah for a siege; and to crown the climax, a settler brought in word from the north-west coast, that a reinforcement from *Wanganui* was coming to join *Mamaku;* and that *Rauperaha*, who had hitherto been nominally neutral, had consented to let them pass through his territory. At this crisis Governor Grey re-appeared, having been brought back by the news of the fresh outbreaks; and he being roused by these affairs, determined to re-commence hostilities, though it was mid winter. He proposed to intercept the reinforcement on their way down the coast, and then to seize *Rauperaha* secretly, and finally he had some idea of attacking *Rangihaeta* in *Patanui*. These measures were perfectly practicable, and quite in accordance with his line of policy, for they might have been effected without taking the men into the bush.

On the 20th July, the Governor, with Major Last and 200 men, went up the north-west coast as far as *Kaputi* Island, (see general map, Part I.) and landed at *Waikanae*, *Otaki*, and *Ohau*, and communicated with the chiefs of the *Ngatiawas* and *Ngatiraukauas;* these chiefs, who had always remained neutral, now promised to support the Government, by preventing the passage of the *Wanganui* reinforcement through their territory. This plan of opposing passive resistance to the passage of a force, is a favorite resort of a neutral tribe desirous of keeping on good terms with one party without coming to a fight with the other. It was proposed to establish a force at *Ohau*, the reinforcement being then seven miles from that place, but the Governor contented himself with forming a police-station at *Waikanae*, and then returned to *Porirua*, leaving it to the friendly natives to oppose the reinforcement, which they did so effectually (without coming to blows) that it was obliged to return to *Wanganui*.

On his return to *Porirua*, he carried out the scheme of seizing *Rauperaha*, and very successfully. At daylight on the 23rd July, a strong force of troops, seamen, and police, landed from the Driver at the *Ngatitoa* pah of *Taupo*, near the mouth of *Porirua* harbour, where *Rauperaha* was living, and seized him in his hut, together with two other great chiefs of the *Ngatitoas*, *Kanae* and *Joseph*, and took them on board the Driver.

This seizure of an allied chief without warning, has at first sight the appearance of treachery, and there is no doubt it produced a bad effect on the natives generally, and is not forgotten to this day. But perhaps it was the only way of meeting their systematic treachery; and that *Rauperaha* was treacherous was proved beyond all doubt. Not only the *Ngatiawas*, but his own relatives the *Ngatiraukauas*, warned the Governor of it. He had secretly given his consent to the *Wanganui* reinforcement; he had connived at a *tapu* of the path up the coast by *Rangihaeta*, which stopped that line for a long time. It is true, that in doing all this he did little more than the *Maori* customs permitted between relatives on different sides; but it is impossible to counteract such customs with the strict rules of civilised warfare; and this chief was one whose cunning had become a proverb throughout the land, and his capture fully produced the expected effect upon the enemy. Moreover, the subsequent treatment of him proved to the natives that no personal injury was intended. These men were kept in H.M.S. Calliope for about a year, with an interpreter to look after them, and were released at the very strong entreaty of their tribe. But the shame, and perhaps the life on board ship, brought the old chief to his death shortly afterwards; and thus died a very dangerous enemy to the advance of the settlers; for the craft of this Ulysses of savages was more to be feared than the reckless boldness of that Maori Ajax, *Rangihaeta*.

Rangihaeta might now have been attacked in his pah, now that the locality was tolerably well known. The same officers who had been up before, made another reconnoissance, and found a hill accessible for artillery and close to the water, and commanding the pah within a few hundred yards. There were two 12-pounder guns and a 6-pounder at *Porirua*, and the boats and guns of two frigates; thus it could have been attacked without having to march 100 yards from the water; but *Rangihaeta*, alarmed by the seizure of *Rauperaha*, and disappointed in the reinforcement from *Wanganui*, and also being short of provisions, and probably tired of a campaign that had lasted a long time for *Maories*, left his new pah, and retreated towards the coast up the *Horokiri* valley, where he had taken the usual *Maori* precaution of preparing a fortified position to cover his retreat. He had then with him about 200 men all well armed, including the *Wanganui* subsidy under *Mamaku*. *Puaha* the *Ngatitoa* chief of *Porirua* now roused himself to help the British, and followed up *Rangihaeta* and tried to persuade him to give up the murderers of the Hutt settlers, who were looked upon by them as the first aggressors in this campaign. Mr. Servantes, the interpreter who accompanied them, reported the desertion of *Pataunui*, and then the Governor ordered an advance upon it. On the 30th July, a party of about fifty police and militia, accompanied by 150 of the *Ngatiawa* allies, advanced from the Hutt by the now open *Pareraho* path. The native allies not being very hot in the pursuit, insisted on sleeping one night on the road, although they had only to march about twelve miles altogether. On the following morning they entered the deserted pah, and on the day after a detachment of troops came from *Paremata* and occupied the pah. It was in a well chosen position, being on a small hill, close to the water's edge and nearly surrounded by a creek, but with the thick forest within 100 yards of it; the pah was about 80 yards by 85, broken into flanks, and having a double row of palisades about 2 feet apart, the inner one being formed of trees 1 foot diameter, with a ditch inside of all about 4 feet wide and deep, and crossed by numerous traverses; in fact, similar to those in the north, only not quite so strong. It was occupied as a military post from that time until the road to the north-west coast was completed in 1850, which road passes close underneath *Patanui*.

Two chiefs were taken here, one of whom, called Martin Luther, was afterwards tried by court-martial and hanged as a rebel.

It was now discussed whether or not *Rangihaeta* should be followed up to his retreat in the *Horokiri*. This was a large ravine rather than a valley, with steep hills, several hundred feet high, on each side, and all covered with thick forest, and the retreat was seven miles up it. The Governor was opposed as before to taking troops further into the forest, but if the enemy were left alone they would get supplies, and return with fresh courage: the native allies were therefore persuaded to continue the pursuit. If now there had been a military post at *Waikanae*, it might have encouraged the friendly natives there to attack him on that side; as it was, there was naturally some difficulty in persuading the natives to advance alone, especially as the *Ngatitoa* allies and the *Ngatiawa* allies were distrustful of each other.

On the 3rd of August, a force of troops having been stationed at the mouth of the *Horokiri*, to support the native allies in case they required it, they commenced their advance with the two tribes, together about 250 men, and after advancing three miles came to a deserted camp of the enemy, on which they halted for the night, firing their guns in triumph.

On hearing this firing Governor Grey came on himself with 100 men, and on the following morning ordered up the militia to support the natives, and finally persuaded Major Last, the officer commanding the troops, to advance a strong force to the assistance of the natives. These, encouraged by the appearance of the militia, had proceeded on the 4th to the foot of the enemy's position.

August 6th, Major Last, with a detachment of the 58th, 65th, (recently arrived from England), and 99th, and some seamen and marines from H.M.S.'s Castor and Calliope, and the militia and police, in all about 500 men, advanced up to the foot of the enemy's position. The time and toil of this one day's march were perhaps as great as those of any in the previous campaigns. The intricate track led through continuous forest, so thick that even after it had been well used a year afterwards it was almost impossible to get a horse through, and it was now covered by the swollen stream. The troops arrived late and bivouacked in small huts; but detachments were employed throughout the night, during heavy rain, in bringing up provisions and ammunition, extending all along the muddy forest in straggling lines.

On the 7th August, Major Last, who had been prevented from attacking the evening before from ignorance of the locality, advanced with 250 men up to within 200 yards of the position; but he found it was so difficult of approach and so covered with wood, that it would have been only waste of life to storm a position from which the natives could and would have retreated with ease, therefore he would not attack it. There was however a good deal of skirmishing, in which unfortunately the life of a good officer was lost, Ensign Blackburn, of the 99th.

The troops were now in a dangerous position; they had been brought up for the purpose of supporting the natives in an attack on the enemy's position; they could not do that; they could not wait where they were, for the valley was becoming more flooded, and the carriage of provisions was almost impossible; and it was dangerous and impolitic to retreat, as it would perhaps have been the signal for the allies to join the enemy. The Governor (who was present) was however now as anxious to retire as he had been to advance, so with some difficulty he persuaded the native allies to continue the blockade of the enemy, while the troops fell back to *Patanui*. Accordingly, on the 10th of August the troops retired, leaving only three Englishmen with the allies, Mr. Servantes, the interpreter, and Mr. Scott and Mr. Swainson (the two latter were settlers attached to the militia). Before they retired, the 4⅗-inch mortars were tried; two of them having been brought with some difficulty from Porirua, by Captain Henderson, R.A. They fired 80 shells into the position, which must have produced some effect, as the enemy ceased firing. Several such mortars might have driven them out, but the labour of bringing up the ammunition was too great, and the height of the trees made their fire very uncertain.

There were three men and one officer killed in this valley. Not one of the enemy was killed.

It is perfectly true that it was impossible to do anything with regular troops in such a position. The soldiers were at the foot of a steep narrow spur in the middle of a forest, with a deep ravine on each side, ignorant of what was in their front, except that it was a boundless extent of mountain forest, into which the enemy was certain to retreat, and could retreat for 100 miles, and they had on either flank the very doubtful support of the allied natives. To what good purpose could they have followed up the enemy?

The *Wanganui* natives carried away from this campaign such an impression of the powerlessness of the troops, that in the subsequent campaign in their own country, a great number of natives came down from the interior merely from the desire of having a brush with the Queen's forces.

It would evidently have been of greater advantage than ever, to have now sent troops up the coast to *Waikanae*, but instead of a strong force, thirty policemen only were sent (under Major Durie), and thirty militia (under Mr. Macdonough). About August 16th, a party of eight stragglers, from the enemy who had come down to *Pari-Pari*, on the coast, in search of food, were seized by the inhabitants of that place and afterwards put on board H.M.S. Calliope. Capt. Stanley took the Calliope to Porirua to ask for some troops for Waikanae; but none were sent, and about the 22nd he landed 40 sailors there, as a support to the *Ngatiawas* of that place; the Calliope lying at *Kaputi* island during the time.

In the mean time *Rangihaeta* had retreated from his position in the *Horokiri*, followed by the native allies, and after some skirmishing in which several natives were killed, he retired up the coast altogether, and the peace of the neighbourhood of Wellington has never since been seriously disturbed; the whole of this long-pending land question having been amicably settled in 1847-8, by the payment to the natives (including *Rangihaeta* and the *Wanganui* nations), of about three times as much money as had been offered and almost accepted by them in 1844.

REMARKS.

In considering over these first operations in the South of New Zealand, there is one great fact which I think cannot be denied, viz., that on the whole they succeeded. In the beginning of 1846, the hostile natives were on the outskirts of Wellington, committing all kinds of injuries against the settlers, and threatening the whole settlement with annihilation; at the end of 1846, they had disappeared to 50 miles' distance, and there was not only no appearance of any renewal of the war, but the settlers were more active in commerce and agriculture than they had been since the first commencement of the Colony. And, further, it must be allowed that this was effected with comparatively small distress to the settlers, and with little bloodshed to the troops engaged, and even that this was caused by breaking through the line of policy determined on; and I think also most military men who were present will allow on reflection, that if better use might have been made of the materials at hand, it would only have produced the same result, with a more lasting impression on the natives.

But it is another question, whether a better result altogether could not have been obtained by employing a different force and a different system; for it must also be allowed that in its details this campaign was like those in the North, most unsatisfactory to the troops employed, reaping but a small advantage over the natives.

The Missionaries (more especially those of the Church of England) came in for their share of blame in the origin of these Southern wars; and it must be allowed that they took a more active part between the settlers and the natives, than was suited to their position; although they themselves state that this mediation was forced upon them by the government. The chief fault, that in my opinion can be charged to them, is, that they were too ready to confide in the word of the savage, and were therefore deceived by the plausibility of the *Maori;* thus in the disputes between the New Zealand Company and the natives, the Missionaries generally backed up the complaints of the natives, which had doubtless some foundation, but not to the extent reported by the Missionaries. And thus they came to be looked upon by natives and English as the friends of the former, and as rather opposed to the latter. I will, however, take this opportunity of bearing testimony as far as my experience goes, to the great and beneficial effects of the labours of the Missionaries; without their preparation, I believe the colonization of New Zealand would not have been effected without a very much greater expenditure of British money and British blood, if indeed it could have been effected at all at this time. And now, I believe, the Missionaries generally take a clearer view of the savage character, and find that they can combine their duty to the *Maori* with the advancement of civilisation. Among those who have distinguished themselves in the latter character, there is none who will be longer remembered with respect, both by settler and native, for his talents and high feelings, and for the great assistance he rendered in this campaign, than the Rev. O. Hadfield, of the Church of England Mission.

SECTION IV. THE MILITARY ROADS.

Among the various civil undertakings that Governor Grey commenced, immediately upon receiving the grant of money from the British Parliament, none were of greater importance than the roads at Auckland and Wellington. Those at Auckland were the least extensive and characteristic of the country, therefore those at Wellington will be described. They consisted of the two described in the third number of the Corps paper (1850), namely, one to *Porirua* and the North West coast, and one to the *Wairarapa* valley; being each about fifty miles long. Previous to 1846, there had been only two or three short roads, constructed by the New Zealand Company, extending four or five miles out of Wellington, and these from the disturbances had fallen into a very bad state; beyond them all was unknown, except to a few settlers and surveyors.

The Governor ordered the roads to be commenced, even during the war in 1846; it was rather expected that they would have been of service during that campaign, but carriage roads are not so easily made in a young Colony, and these were not completed until 1850.

The troops were employed upon that to *Porirua*, and Captain Russell of the 58th superintended the construction of this road from its commencement to its completion, and the greatest credit was most justly given to this officer (who had been educated at Sandhurst) for the manner in which he carried out the Governor's intentions, in the details both of the road, and of the employment of the troops and natives. There were four or five detachments of troops of about fifty men, with a subaltern over each, stationed at intervals along the line, two or three miles apart. They built stockades for themselves in the forest, and worked all day with their arms beside them, keeping guard at night. It was perhaps owing to this precaution that they were never molested. They received from one shilling to two shillings a day working pay, and were allowed to dress in blue shirts; and some of them became artificers enough to construct wooden bridges of 100 feet span. This sort of duty was very excellent service for the soldiers, it taught them more of the business of encamping, intrenching, and hutting, than they would have learnt all their lives at most stations, and by giving them a habit of acting for themselves, it prepared them all the more for their regular duties in that Colony; and many of them who had saved money on the roads, afterwards got their discharges and became good settlers, and were much more fitted for active service in the Colony than the Pensioners sent from England. When they came back from the roads to their regular service, their discipline was found to be rather relaxed, but this was not so much from the nature of the employment, as from the want of a sufficient number of officers to superintend them on the roads; it was rather a fault in the plan, that the whole of the officers were not taken with each company employed.

There were also from 100 to 200 natives employed on this line. They received two shillings a day, and were superintended by Englishmen who understood their language. They lived in huts, near the site of their work, and were supplied with food by their own people, some of them coming from *Otaki* and the *Wairarapa*. They were very amenable to the working rules; looking upon stoppage of pay as a heavy punishment; and they became apt at the ordinary work, for it was a kind of work that suited their peculiar taste for labour, their social habits, and their eagerness for money; on the average, they did about half a day's fair work for their two shillings. The employment of these natives on the road tended more than anything else to confirm the peace after this last campaign, for it not only occupied them, but caused a great trade in such European articles as they desired, giving them at the same time a taste for new articles of civilization.

The road was about twelve feet wide, winding along the sides of the ravines, and was well laid out and well executed; the soil, a loose schistose rock and clay, being very favourable for it: though after all, it can only be considered as the foundation of a road, for the metalling and the drainage were not calculated to stand for any length of time. It cost from £700 to £1000 per mile; the greatest expense being in the cutting and clearing away the gigantic trees. These were first cut down with a cross-cut saw and American felling axe, and then cut up or burnt, and the roots were afterwards grubbed up or blown up, one root sometimes requiring a week's labour to get rid of; crowbars and wedges were chiefly used for this.

The *Wairarapa* road was under the superintendence of Mr. T. Fitzgerald, the Colonial Surveyor of Wellington. Large parties of natives were employed on it, but no troops; it cost more than the other road and took a longer time to complete, because the greater part of it lay in the flat Hutt valley, where it was about 20 feet broad, and had to be raised and well metalled. The details were much the same as for the other road, and as far as it was finished in 1850, it was even superior to it.

The effect of the opening of these roads has been of course very great. All along both lines the settlers have extended, for twenty miles from Wellington; and there is now a fair cart-road to the commencement of the coast flats to the North West, and to the beginning of the *Wairarapa* plain, towards the other direction; thus breaking through the Mountain basin of Port Nicholson, and connecting Wellington with the two grazing districts in those directions, and also carrying the outposts of the settlers so much farther among the natives.

SECTION V. THE WANGANUI OPERATIONS.

We have now only one more campaign to describe, that at *Wanganui* in 1847. From the similarity of these campaigns to those in the North, it may seem to be unnecessary labour to go through the detail of them, but it is precisely this constant recurrence of the same result with different men in different places, that proves the fault to be in the system, and not in the men.

Wanganui (or Petre) was an off-shoot from the chief settlement at Wellington. The New Zealand Company's agent visited it in 1840-1, and concluded what he considered a clear purchase of about 60,000 acres at the mouth of the river. The surveyors proceeded to map it, and lay off a town site and rural sections, and in 1842 the settlers arrived to take possession. Then it was found that this purchase, like the others, had been too hastily concluded; some of the most influential Chiefs on the river opposed the sale, and prevented the settlers occupying their lands. The case was brought before the Crown Land Commissioner, and he decided that an additional £1000 should be paid to the natives; but it was then too late. The evident inability of the Government to enforce law (particularly evident here), and the general excitement among the natives after the *Wairau* affair, had so excited them, that they altogether refused to receive the £1000. The settlers were thus reduced to remain in the town site, the purchase of which was allowed by the natives, and there they remained from 1843 to 1846, living on their capital, except a few adventurous men, who cultivated their own proper sections under sufferance of one or other of the chiefs. Every now and then some slight excuse brought down a "raid" of *Maories* upon the little town, and the few settlers being without any sort of protection whatever, were too glad to purchase the departure of their bullies with tobacco and other presents. This method of escape from the immediate danger served, of course, to increase the confidence and cupidity of the natives; these "raids" or *taua*s as the natives call them, became more and more frequent, and in 1846 the result of the Hutt campaign, and the loss of some *Wanganui* natives in it, roused them to such a pitch of violence, that the settlers sent an earnest petition for military protection. There were then about 600 British in the place. It was now a question whether it would not have been better to have withdrawn the settlers altogether from so unpromising a settlement, the establishment of which in such an isolated spot at that period of the colonization was evidently a mistake. The fear of losing prestige by appearing to give way before the natives, and also the hope of settling the land question, prevented this; and Governor Grey finding himself strong in troops after the termination of the *Horokiri* campaign, determined to try the effect of establishing a Military post at *Wanganui* towards keeping the nations in awe; and accordingly in pursuance of his instructions, on December 10th, 1846, the following force was sent from Wellington, in H. M. S. Calliope, and the Colonial brig Victoria, Lieut.-Col. M'Cleverty, (Dept.-Qr.-Mr.-General in Australia) having arrived at Wellington, and taken command of the troops in the South.

	Offrs.	Men.
58th Regiment, Captain Laye, Commanding the force	5	180
Royal Artillery, with Two 12-Pr. guns of 21 cwt. on garrison carriages .	0	4
Royal Engineers, with Engineer Stores and Intrenching tools for 100 Men, Lieut. Collinson, R.E.	1	0
Commissariat — D. A. C. G. Power with £500 in Money and Salt Provisions for Two Months..............................	1	0

A Gun-boat under the command of Lieut. Holmes, R.N., of H.M.S. Calliope with a crew of seamen, was afterwards attached to the *Wanganui* post. Dr. Alleyne (a civilian) was the acting surgeon.

As the settlement was to be preserved it was evidently necessary to garrison it, and at that time this could only be done with regulars, and the presence of these regulars, although it brought on a fight, eventually saved the settlement; and the settlement will always be an important station for police, if not for troops, as it is on the chief high road to the interior from Cook's straits. But the misfortune in the formation of this Military post was, that sufficient preparation had not been made beforehand, by acquiring information concerning the settlement, and pre-arranging for the defence and for the communication with head-quarters; for the force was landed at this barely accessible outpost, knowing hardly anything of the place, except that the natives might be expected to attack the troops on landing. The twelve-pounders were also much too heavy for the service, and indeed, were really useless, it would have been better to have sent the two three-pounders which were then at Porirua, or two six-pounders from Wellington. These field guns were apparently kept by the commanding officer at Wellington, in case of further disturbance from *Rangihaeta*: Capt. Henderson, R.A. was not at Wellington at the time. But considering the shortness of the notice, this was perhaps the best equipped expedition that ever started in New Zealand. The engineer equipment was arranged mainly from those given in the Royal Engineer Professional Papers, and was purchased on the spot, at an expense of about £200. On the recommendation of Capt. Russell, 58th, (the Superintendent of the Roads), there were added, 100 American felling axes, some wedges and beetle mallets, and pit saws, and cross-cut saws There was not time enough to have them properly packed, but afterwards they were put into boxes and bags, so arranged that any one might be carried by a man: almost all the tools proved of great service.

The country about *Wanganui* has been partly described in Part I. The river is 300 yards broad at three miles from the mouth, and 100 yards at ten miles up: it is navigable for coasters to the site of the town, four miles from the mouth. It has a shifting bar with only seven feet at low water (1850), the tide rising six feet. The land being low at the mouth it is difficult to make. Both north-west and south-east winds beat with great violence on this coast, and there is no kind of shelter for a large vessel nearer than Port Hardy or *Kaputi* island; and the voyage from Wellington varies from twenty-four hours to several days. The ordinary communication to Wellington along the coast was at this time stopped by *Rangihaeta* at *Manewatu* river. Thus the communication by land was doubtful, and the communication by sea so precarious, as to demand the greatest attention in preserving it.

The village is situated on the right bank of the river, four miles from the mouth, on the low plateau mentioned in Part I., as forming the lower part of the *Wanganui* valley. The higher plateau commences about the parallel of the town; directly back from it at one and a half miles distant, is the steep point of the first line of the upper plateau, rising out of the plain to about 150 feet, and on the steep sides of this point is St. John's Wood. From here straight to the village extends a low narrow sand hill, fern covered, and with swamp on each side, ending on the upper side of the village in a sandy mound seventy feet high; at the back of the centre and lower side of the village were similar mounds, but lower, and the few houses then constituting Petre lay on a flat between these three hills and the river. On the opposite bank to the village, the higher plateaux came close to the river, terminating in cliffs of 150 feet, the one highest up being called Shakespere's cliff. Below the village on the opposite bank, in a small flat valley, was the native pah of *Putiki-Waranui*. This pah of

Putiki was inhabited by the *Ngateraukawa* branch of the *Wanganui* tribes under *Hori King*, and these had been generally favourable to the settlers, and had more than once taken their part in the "raids;" in fact, they benefited by the intercourse with the English more than the others, this being the only pah near the Settlement. For the chief part of the population of the *Wanganui* live far up the river among the high wooded hills, and besides *Putiki*, there is only one small pah three miles above it, and then none for ten miles; but the natives inland all claimed a right to come to the mouth of the river in the summer to fish, and occupied and cultivated certain spots for these visits; and it was upon these rights that they disputed the land sales. The principal divisions disputing the sales were the *Patutokotoko*, whose chief, *Turoa*, is of high rank, and *Mamaku* who fought in the Hutt, and *Maketu* the chief who attempted to join him, and they all lived from twenty to seventy miles up the river: on the other hand, the *Putiki* people had also friends and relations up the river.

Such was the condition of *Wanganui* at the end of 1846.

On the 13th December the force was landed from the Calliope, at the mouth of the *Wanganui*, with the assistance of a coaster of thirty tons. The *Maori taua* disappeared up the river at the sight of the man of war, and it was fortunate they did so, for the force put ashore at the mouth of an unknown valley, and four miles from the settlement, was ill prepared to meet opposition of any kind; and the difficulties of the communication were well exemplified next morning by the disappearance of the Calliope, driven off by stress of weather. The troops were put into such houses as the village afforded (for which a good rent was paid) until a stockade could be built; the whole force turning out every morning an hour before daybreak, to guard against surprise.

The Governor in his instructions for the establishment of this post, directed that there should be a defensible blockhouse for 100 men, a very necessary thing in any outpost that was likely to be occupied, as this was, for several years. With the concurrence of Captain Laye, the Sand Hill at the upper end of the village, terminating the said ridge extending from St. John's Wood, was selected to be occupied by the blockhouse and a stockade for our whole force. We determined on concentrating the force on this site, notwithstanding the difficulty of constructing anything on such sandy soil, and the impossibility of getting water there, and notwithstanding that it left part of the village undefended.

1. Because it commanded every other site about the village.

2. Because Captain Laye considered very properly that his first duty was to provide for the full security of his men and stores, upon whom the very existence of the settlement depended, just as the first duty of a naval commander would be to provide for the safety of his ship.

3. Because there was no prospect of our being able to erect, within a reasonable time, a stockade strong enough to be defensible by less than 200 men.

4. We knew nothing concerning the natives; being quite uncertain whether to consider the whole 5000 inhabiting the valley as all friends or all enemies.

Upon further consideration, and a better acquaintance with the natives, I am of opinion, that in general in New Zealand it is a safe and desirable plan to enclose the village or part of it by a few small posts or block houses, placed at from 200 to 400 yards apart, so as completely to command the intervening ground; and each garrisoned by from 20 to 100 men, according to the situation and strength of the post. These block houses might be constructed with a projecting upper story, and each would constitute a barrack and keep to a small stockade, serving as a barrack yard, and in which might be placed field artillery; twenty-four or twelve-pounder Howitzers would be a most important addition to such posts, and might fire through the port holes in the stockade; for even if the natives succeeded in getting into the stockade, they could not use the guns. Such a system would enclose a place of security for numerous outsettlers, and a small body of troops or even Militia could thus defend by passive resistance a large space of ground. In the war at Tahiti, in 1845, the French defended their chief town and head quarters by a series of such small block houses, but they unfortunately placed them half a mile apart, and the country being covered with underwood, the natives entered between the posts and destroyed part of the town. But to have carried out this plan at *Wanganui* would have required that the place should have been examined beforehand, and the small block-houses provided all ready to have been transported with the troops.

As it was, there was considerable difficulty in constructing even the stockade. The only timber available was on the opposite side of the river, and a mile distant from the site; and the commander would not allow his men to go so far from the post, and the settlers, from fear of the natives, would not go even for liberal pay. Finally, the natives themselves came to our assistance, and were so roused by the unusual sight of ready money, that even some of our more doubtful friends up the river brought down rafts of timber from ten miles distance, to build a stockade for their invaders. And even after the logs arrived there was some difficulty in squaring them, and carrying them up to a height of seventy feet, and fixing them in the sand. The carriage was effected by means of a tram-road, worked by a fatigue party of soldiers, with blocks and tackle. A party of a dozen artificers out of the detachment, and two or three carpenters in the village, assisted by working parties of soldiers, and most materially by the officers and crew of the gunboat, were employed on this work. The commanding officer showed the greatest desire to give me every possible assistance, and the service was very much benefited and expedited by the great zeal and attention of Lieut. Balneavis, of the 58th Regiment, who acted as assistant engineer, and superintended the whole of the works executed at this post for the first fifteen months after its formation. Nevertheless, the difficulties were so great that it was not completed till the 1st of April; and as these difficulties were chiefly in the want of artificers and transport, I may here say, that perhaps there was no period during the whole military operations in New Zealand, at which a company or half a company of Sappers, provided with a proper Field Equipment, would have proved of greater service; and considering that the civil carpenters were paid seven shillings, and labourers four shillings a day, I think it may be stated, that the presence of a party of Sappers, instructed in wood cutting, sawing, rough framing and brick-making, would have saved a thousand pounds in the cost of the establishment of this post.

The stockade was about sixty yards by thirty, and consisted of rough squared timbers, about nine inches thick, placed upright three to four feet in the ground and eight feet out of it, and braced together on the inner side by two horizontal pieces nine inches wide. The loop holes were four feet from the ground inside, and (owing to the fall) six feet outside. The sandy nature of the soil prevented our adopting the native plan of loop-holes on a level with the ground. As the stockade was to be only a kind of barrack-yard to the block-houses, it was but little broken into flanks; when defended by block-houses, a stockade cannot be too simple in its form. A twelve-pounder gun was placed at each end of it, a space of twenty feet square being boarded over, from which they fired on their garrison carriages, through port holes in the stockade. The ammunition was kept in a small field powder magazine lined with timber, but it required frequent airing to keep it dry, owing to the dampness of the sand. Water was to have been supplied by a tank to be filled by hand from the river, but when the disturbances interfered with the works, the men were obliged for some time to get water from wells sunk in the flat below. The fuel was wood, supplied at the stockade by a contract under the commissariat department; there was a cookhouse built of clay inside the stockade, but the men generally cooked in the air outside. As it was probable that the blockhouse would take some time to complete, temporary huts were built inside the stockade for the men; they consisted of rough poles, thatched with the grass and reeds, used by the natives for this purpose, and were indeed made by the natives. This stockade with its appurtenances cost nearly £500; but it saved the settlement of *Wanganui*.

The stockade being completed and occupied, it was hoped that the good feeling which prevailed between the natives and the soldiers and settlers, encouraged by a trade that was beginning to spring up, even with the natives up the river, would in a short time have brought about an amicable settlement of the land question; but a little accident threw the whole place back again from comparative peace into a worse state of disturbance than ever, and demonstrated that notwithstanding the apparent civilisation and friendship, there was a deep feeling of unsatisfied resentment, which any chance quarrel might blow into a war.

The Midshipman of the gunboat accidentally wounded a petty chief of *Putiki* with a pistol. That it was perfectly unintentional, the Chief himself and all his friends allowed, but actuated by a jealous fear of the soldiers, and by the inoperative *Maori* custom of *utu* or satisfaction, the whole body of the *Putiki* natives were roused to come over and demand that the Midshipman should be given up to them to live or die, according as the wounded man lived or died. This was, of course, refused, it would however be desirable, that in such cases, the law should provide a punishment of some kind on the offender, such as a fine to the injured party; because the subsequent events proved that in thus demanding *utu*, the natives were simply acting up to a law of their own, so imperative that it is sure to be fulfilled sooner or later. As it was, every body considered the question to be satisfactorily settled by explanation, especially as the wounded man was recovering under the care of our surgeon. But his relatives up the river, jealous of the *Putiki* natives (though their own relations), and still excited about the land question, determined to have their *utu*. Six of them, all young men, united, and after discussing the different settlers on whom they might take revenge, selected a Mr. Gilfillan, because he lived in a lonely spot, five miles from the village and unarmed. They went to his house, and in the most deliberate manner tried to tomahawk him, but he escaped, and trusting to the hitherto invariable custom of *Maories* to spare women and children, he came into the settlement for help. A party of settlers went out to his house next morning, and found that these six young savages had murdered his wife and two of his children, and had destroyed the house.

Five of the murderers were captured by the *Putiki* natives, and delivered over to the troops. They were tried before a court martial composed of all the officers on the station, and in pursuance of its sentence, the commanding officer hanged four of them, and sent the fifth (a boy) to Wellington to be transported for life. They were executed a week after the murder was committed.

Immediately after the murder, Captain Laye had dispatched one of the coasters down to Wellington for a reinforcement, but owing to the precarious nature of the sea communication, the reinforcement (consisting of 100 men of the 58th) did not arrive till May 3rd. They were placed in a house at the lower end of the village, which was roughly stockaded with what timbers were at hand, and a similar rough stockade was made close to the river below the main position, in order to protect the gunboat. Thus there were three posts; the main one, which was called the Rutland stockade (from the 58th Regiment) and occupied by 150 men; the lower or gunboat stockade, occupied by thirty men; and the town stockade, occupied by 100 men. A fourth post was afterwards made on the sand ridge behind the centre of the town, and called the York stockade, after the 65th Regiment. One or two of the houses in the village were also stockaded as places of refuge for the settlers, who had now crowded into the place from their different out stations; and a sort of militia company was formed by Captain Laye, out of forty of the settlers, who were not however generally willing to serve without pay, and did not prove of much service.

But these preparations for the defence of the village, although they protected it from danger during the day, were not sufficient to give security to the settlers in the night time. The natives might have crept in between the military posts, as the village was 800 yards in length, and the stockaded houses of the settlers were too small even to hold them all, much less to cover the intervening space. The cause of the insufficiency was chiefly the want of materials; there was hardly a piece of timber to be got in the place, even by paying very high prices, and no man would now go to the nearest wood to cut it. Secondly, there was a want of labour, especially of artificer's, the soldiers were too hard worked in providing for their own posts, and the settlers would do no work except for high wages. So the commander had to be content with preserving his own positions, and his prudence saved the settlement from following the fate of *Kororarika*.

In the mean time the relatives of the hanged were employed up the river in rousing their friends to seek for satisfaction for their death. But it is not so easy a matter to excite the *Maori* up to the war point. A British commander in New Zealand need seldom fear a sudden rising among the natives, it requires a long continued course of complaint, or some very serious injury to rouse them to open hostilities, and at least a month of *korero* will elapse before they raise any considerable force. By the middle of May they had assembled about 400 men at a point fifteen miles up the river, under *Turoa* the leading chief of the *Wanganui* and *Mamaku* (of the Hutt campaign). From subsequent information, it appears that they had formed a sort of plan of operation from the beginning. They were to make their head-quarters at *Papaiete*, on the river, seven miles above the town, where their women and provisions were to remain, there being an easy retreat from thence up the river; and they were to advance along the flat valley on the right bank, turn up the hill by Mr. Harrison's house, and come down upon the village by St. John's Wood. Their design was to secure always a safe retreat, and to assist this, they formed intrenchments at various points along their whole line, especially in rear of various small creeks that crossed the flat near the river bank, and even cut a broad path through the fern to their camp, where also they had made a well-planned line of intrenchments. They evidently intended to defend this line of operations step by step; and from the mere fact of it being necessary even for natives to cut a path through the fern, it will be evident that to have attempted to follow them along this line with regular troops in open day, would have been a useless waste of life.

On the 19th of May they made an attack upon the village. Early in the forenoon about 400 of them came down from St John's Wood, along the narrow sand ridge, and stationed themselves on the hills about the village, under cover as much as possible, and kept up a fire of musketry upon the stockades and the houses, during the whole day. They got into one or two houses on the outskirts of the village, but they did not venture into the main part, as it was too closely commanded by the three military posts. The troops remained in these posts, returning the fire of the natives with musketry and great guns, and the gunboat under Lieutenant Holmes, R.N. very materially assisted the defence, by bringing a flanking fire to bear on the enemy from different parts of the river. In the afternoon, one of the native chiefs, *Maketu*, was shot, which discouraged them so much, that, finding their attempt to destroy the place ineffectual, they retired altogether. It may seem at first to have been a fault that the commander did not sally out and attack the enemy, but in fact the ground was not so open as it appeared; although clear of timber it was covered with high fern, and broken into hollows with swampy bottoms. The natives were scattered all over these, and an attack upon them would certainly have broken all order among the troops, and ended in a desultory skirmish with a retreating enemy: and those who know the helpless state of the British soldier in his ill contrived dress and accoutrements, if once the ranks are broken in difficult ground, will appreciate the hesitation of a commanding officer to leave his posts, to gain a doubtful advantage: especially when he had three posts to protect, and was uncertain how many more natives there might not be in reserve ready to take advantage of a weakness in any one of them: we afterwards heard that in this attack on the place, it was a pre-concerted plan to try and draw the troops out from their posts, along the line of operation they had laid out.

I know that it was with difficulty he could restrain himself, his officers, and men from sallying out, and that when he did allow an attack to be made early on the following morning on a house that was thought to be still occupied by the enemy, the whole force volunteered; but it was doubtless owing to the firmness and prudence of Captain Laye that the natives were this day taught, that to attack a regularly established military post was to run their heads against a wall, and were taught this lesson without the loss of a single man among the troops.

Capt. Laye received the special thanks of the Governor (and afterwards of her Majesty) for his conduct in command of this post.

On the 24th of May, Governor Grey arrived at *Wanganui* from Auckland, in H.M. Steamer, Inflexible, Captain Hoseason, (which had relieved the Driver). He had started directly on hearing the first news of the murders, and brought with him 100 men of the 65th Regiment, with whom he landed at *Wanganui*. Ninety seamen and marines and most of the Inflexible's officers landed at the same time; and a few days afterwards Captain Henderson R.A. arrived from Wellington in H.M.S. Calliope, with some more Artillerymen, a 24 pr. howitzer, a 3 pr. gun, and some 3 pr. rockets. On the 27th May, under the Governor's directions, a large force of troops and boats went up the river for about two miles, but as the enemy were at their camp at *Papaiete*, this demonstration of force produced no effect: but no demonstration ever would produce an effect upon an acute savage like the *Maori*. The Governor then went on to Wellington for further reinforcements, and returned on the 3rd of June, with Lieut.-Col. M'Cleverty, commanding the troops in the southern division, and 120 men of the 65th; also some men from the Calliope, and some native allies of the *Ngatiawa* and *Ngatitoa* tribes (Lt. Servantes accompanied them); and a small party of the armed police under Mr. Strode. The great chiefs *Tomati Waka* from the North, and *Te wero wero* from *Waikato*, accompanied the Governor. By the great assistance of the paddle box boats of the Inflexible, and thanks to the smoothness of the water at the *Wanganui* bar, the whole force was landed in 24 hours from Wellington against a strong head wind, the distance being 100 miles. These two remarkable trips of the Inflexible from Auckland and Wellington show the enormous advantages of having an efficient steamer of her class, on such like coasting expeditions. The force now at *Wanganui* consisted of:—

	Offrs.	Men.
Military.—Lieut.-Col. M'Cleverty, Commanding.		
„ 58th Regt.—Capt. Laye	8	300
„ 65th „ —Capt. O'Connell	6	220
„ Rl. Art.—Capt. Henderson	2	20
Naval Brigade.—H.M.S. Calliope,—Capt. Stanley, R.N.		
„ H.M. Steamer Inflexible—Commander Hoseason, R.N	8	180
„ The Gun boat of the station,—Lieut. Holmes, R.N.		
Total	24	720
Ngatiawa allies		50

On the 5th June at about 8 a.m. a part of this force, consisting of 400 men of the 58th 65th and Royal Artillery, marched up the right bank of the river; seven men-of-war boats containing 160 seamen and marines, and carrying five carronades and two rocket tubes, proceeded simultaneously up the river. The troops extended in one long file along the narrow path through the fern, on the flat river bank, and at each of the small creeks they had to cross there was considerable delay, which was much increased by the landing of a three pounder field gun from the boats (by the express desire of the Governor, who was present and controlled the movements). The enemy retired along their line of operations as the troops advanced, for nothing was seen of them, until about four miles up, near *Aramoa*, when they appeared on the hills about a mile off; the troops halted here, but the boats pushed on for a mile further, and came to an encampment of the enemy which they evacuated, and which was burnt by the seamen; a good many guns and rockets were fired at the distant enemy without any effect; and about 1 o'clock the whole force returned to camp, having been perfectly unmolested by the enemy during the whole day. This day's expedition is a sample and type of the whole proceedings of this campaign, and is especially instructive as to the difficulty of manœuvring regular troops in such operations even under most favourable circumstances. It is true that the ground was level and untimbered, but it was covered with such a thick high fern that the advanced guard had great difficulty in forcing their way on, and could only move very slowly, and the only way in which the troops could follow at a reasonable rate was by one narrow path; thus the attacking party were compelled to advance very slowly, while during the whole march, they might have been observed by the enemy from the hills enclosing the valley, which being separated from the river bank by swampy ground, formed a secure commanding position along which they could follow the movements of the troops; and even if there had been troops enough to detach a body of men along these hills, their march would have been still slower than that on the flat below. Moreover, the enemy might have been on the flat close to the troops and unperceived, for, knowing the ground, they could have retreated close in front of the soldiers, keeping up a skirmishing fire, and be hardly visible, and yet retreat faster than the troops could advance. Thus it must be evident that to have followed them up with regular troops in open daylight, along their line of operations from gully to gully, until they finally retreated into the hills altogether, would have been to lose men to no purpose; it was thought by some that the boats would have been successful if they had gone up the river to *Papaiete*, but they would have been fired upon from both banks the whole way up, and would have found *Papaiete* deserted and the enemy firing at them from the hills beyond it. The governor ordered me to examine the whole of this country after the campaign was over, and the result of that examination was (as expressed in the Report dated January, 1848), that it was nowhere sufficiently practicable for regular troops to give a reasonable chance of success in open daylight; but as stated in the report, I consider it would have been practicable to have surprised the enemy in his camp at *Papaiete*, by sending two divisions of boats up the river before daylight, one to attack the camp and the other to support it from the opposite bank, while a body of troops advanced along the right bank as a reserve; one of the small war steamers in Her Majesty's service, drawing five feet of water, would have been able to get up the river as far as *Papaiete*, and could thus have surprised the enemy with the loss of hardly a man.

The naval brigade with their boats now returned to their respective ships, which during the time they were at *Wanganui* had lain at *Kapiti* island.

During June and July the troops and the few settlers who were left remained almost blockaded in the village. On the morning of the 19th, a few hostile natives came down the river bank, so close to the stockades, in their eagerness to catch some stray cattle, that a party of soldiers went out to cut them off: the natives made across the swamp for the end of St. John's Wood, and a reinforcement of them collected on the brow of that hill, and Colonel M'Cleverty ordered out more men to secure the retreat of the first party, but as they were unfortunately not positively ordered to retreat, the firing went on between the two parties, until there was such a force of natives collected on the brow of the St. John's Wood hill, that Colonel M'Cleverty found himself obliged to order a force of about 300 men out, who were extended all the way from the stockade along the narrow sand ridge to within 300 yards of St. John's Wood. Of this force the advanced guard only were engaged, between them and the natives on the hill above (then about 200 strong), a sharp fire was kept up for nearly three hours: a detachment of artillery with two field pieces were with the advanced guard, and kept up a steady fire the whole time—they lost one man, but owing to the enemy being scattered under cover along the brow, neither round shot, spherical nor common case produced much effect. In the meantime a company was sent across the swamp to the left to endeavour to turn the flank of that spur, as it was at first thought practicable to storm the brow in front of the advance, but finding that the swamp was up to the men's waist, and also considering that there would probably be a large body of natives on the hill, in reserve, as we were then aware of their design to draw the troops along their line of retreat, Colonel M'Cleverty ordered the force to fall back to the stockades; as soon as the advance (now rear guard) began to retire a body of about fifty natives rushed down the hill with a shout, the guard immediately fixed bayonets and charged, two or three natives were bayoneted and two soldiers killed; after this the natives kept at musket range, and after keeping up a desultory fire with our native allies, they retired altogether up the river. While this was going on, another party of the enemy came down the bank of the river intending to surprise the stockades if the troops had left them undefended, but as the line of troops extended the whole way from the river bank to St. John's Wood, and was flanked by the gun boat on the river, this attack produced no effect beyond a continuous fire between the two parties, and the natives retired with the others.

There were killed on this occasion:—

Military . . . . 4 men.

The enemy lost five men and a good many wounded.

The enemy were sufficiently emboldened by the affair of the 19th, to make one more attempt to draw the troops from the stockades. On the 23rd they appeared again at St. John's Wood in the forenoon, in strong force; but as before, we had received intimation of their intention to attack the town, and Colonel M'Cleverty prepared for them, by occupying the York Hill (behind the centre of the town) with 100 men and a field piece. A party of about fifty of the enemy rushed down from St. John's Wood half way to the town, and then retreated again; then finding that there was no prospect of drawing any troops out of the stockades, a few of them advanced with a white flag, and some of our allied chiefs having gone out to meet them, after a long *korero* they effected a sort of reconciliation; giving our allies to understand that their honor was satisfied by the number of soldiers that had fallen. The real truth of the case being, that their energies were exhausted with a four months campaign in the winter months, and their food also; and that the season for planting potatoes had arrived. There was a good deal of war dancing and firing off of guns on both sides, and then the enemy retreated to their camp at *Papaiete*: after this we saw very little of them, and we heard from time to time that they were gradually dispersing to their proper homes far up the river. The settlers began to go out again and return to their old farms, and to enter into communication with our late enemies concerning their lost cattle, and to trade with them; and in the course of two months there was such perfect peace re-established by general agreement, that several of the officers went up the river into the very heart of the country of our enemies.

Thus ended the last serious disturbance that has occurred in New Zealand up to the present date; and as the peace was confirmed and strengthened in 1848, by the payment of the £1,000 for the land, and the complete concession by the whole of the natives concerned of the block claimed by the New Zealand Company; it may be considered that the peace and prosperity of this populous and troublesome district is as permanently established as that of any settlement in the Colony.

REMARKS.

From this account of the *Wanganui* campaign, it will be perceived that the circumstances throughout were much the same as in all the former campaigns. The outbreak was caused chiefly by the natural opposition of the savage to civilisation, excited into a flame by a small local quarrel. There was a difficulty in rousing the natives to active hostility, and they were much divided amongst themselves; nevertheless, it required a large force of troops to be in the field for several months merely to hold their own, and allow the excitement of the natives to expend itself against their posts, and die away of itself, leaving peace indeed, but peace at the expense of the credit of the British power.

SECTION VI.—REMARKS ON THE ENGINEER DEPARTMENT.

As this subject more particularly concerns the readers of this paper, it is only right that attention should be drawn to the incomplete state of this department, as regards soldiers and equipment, during the whole of the campaigns in New Zealand. The engineer department in New Zealand had to establish several defensible posts, to provide cover, either temporary or permanent, for two regiments in various places, and to assist in the field operations, and to carry on all this work in a new colony, where every material had to be sought for, where all labour, especially artificer's labour was expensive and inferior, and all tools of an inferior description, and want of transport was a complete bar to their rapid execution: and there was during most of the time only one officer and a clerk of works, without tools or equipment of any kind, without a single sapper, and without authority to incur any expenditure beyond the pay of the department. And yet it is evidently one of the most necessary requirements in establishing a new colony among savages, to provide a very well equipped engineer department, in order to place every settlement in a complete state of defence: and if the Colony is to be really securely planted, a very great expenditure must be incurred under this head at the very commencement. It was however never decided by the Home Government whether the Imperial or Colonial treasury should pay for such expenses, and the troops would have been left without the most ordinary cover, if Governor Grey had not taken upon himself the responsibility of ordering the most necessary works. Thus, when I took charge of the engineer department in Cook's straits, I was the only person belonging to the engineer department in the district, and in constructing the stockade and block houses at *Wanganui*, I had to employ such artificers as I could pick up out of the regiments or civilians in the place, and although the officers commanding gave me every assistance, men so employed can never get into a proper system of work without such superintendence as the corps of sappers alone can provide. This was very much felt in executing the various small artificers' work required in a stockade, in making rafts, wharfs, &c., but it was much more felt when we came to complete the block houses after the campaign.

This block house was at first intended to form one building for 100 men, having been planned in Auckland before the site was selected; but it was afterwards divided into two, in order more completely to command the site, one at each end of the stockade, a large part for eighty men and a small part for twenty men. The large one consisted of two blocks, one sixty feet by twenty, and one at right angles twenty feet by twenty. The small one was a rectangular building forty feet by twenty. The plan was chiefly taken from Laisné's Aide Memoire; it consisted of two stories, the upper one projecting three feet over the lower. The walls of the lower story consisted of main uprights twelve inches square, six feet apart, filled in with horizontal pieces six inches square, fastened in with fillets, and lined inside with one inch boards, a row of similar uprights extending down the centre. The uprights were let into twelve inch plates at top and bottom, and the upper story rested on twelve inch girders laid across over the uprights, and consequently six feet apart. The walls of the upper story were of uprights and horizontal filling-in pieces of smaller scantling. The lower story was ten feet high, the upper story eight feet. The boards of the lower floor were one and a half inch, those of the upper floor two and a half inches. The roof was of ordinary construction covered with shingles, as it was not required to be bomb proof. The entrance was intended to be by ladder to the upper story, and from that to the lower by trap door and ladder, but in addition to these, a door was made from the lower story into the stockade. The projecting floor of the upper story could be raised between each girder, on hinges, so as to fire through. There was a horizontal loophole between each upright on both stories, four feet long and six inches wide; those on the lower story seven feet, those on the upper four feet above the floors. These were filled in with glass, and had horizontal shutters outside. There were two brick fireplaces in each block house. The interior space was left quite open. In consequence of an earthquake that happened during the construction, it was thought necessary to strengthen the block houses with cast iron angle pieces at each upright; and in consequence of the sandy nature of the soil, the foundation was carried eight feet deep, the uprights being eight feet longer. This basement story was used as a commissariat storehouse. The construction of such buildings would properly have required a good body of artificers, with close superintendence, but as it was absolutely necessary that it should be erected for the preservation of the post with the small garrison available, it was completed with the means at hand. The timber was partly procured on the spot, and partly brought in small vessels from neighbouring places, the bricks were made on the spot, the iron work, glass, and other fitments were procured from Wellington. It must be evident, that the moving about of such large pieces of timber, the carriage up hill, the framing, and fixing and finishing of such a work, with the small means at hand to perform any kind of work, required very great labour, time and expense, and it will not therefore be a matter of so much surprise to engineer officers, that they occupied twelve months in construction, and cost about £3,000. And I will here again state, that it was only owing to the constant zeal of the Assistant Engineer Lieutenant Balneavis, 58th Regiment, that they were completed at all; for I was obliged to be absent at Wellington during the greater part of the time.

The detail of these block houses is given as a work that was actually executed. I must however state, that I think it would have improved the defence of the position, and have been cheaper and more expeditious, if the block houses had been divided into several small parts for about twenty men each, as mentioned at the commencement of Section V. They would have defended a larger space, and have been more convenient to erect, and might have been constructed at other places and transported by sea; this however would have required a corps of intelligent artificers and careful superintendence, such as was not to be procured in New Zealand.

SECTION VII.—CONCLUDING HISTORY.

The remaining history of New Zealand since 1847 has been that of the usual advancement of a young colony emerging from its first difficulties. During the year 1847, the Colony had been divided into two provinces, and Mr. Eyre arrived as Lieutenant Governor of the southern provinces; and Major General Pitt arrived and took the command of the troops in New Zealand (under the general officer at Sydney), and the first company of pensioners arrived at Auckland. During 1848, the different land questions in the south were amicably settled between the government, the New Zealand company, and the natives, and the company and their settlers got possession of their lands, excepting at New Plymouth, where the natives had always refused to complete the land purchases of the company. In this year also, Governor Grey was made a Knight Commander of the Bath by Her Majesty, for his services in New Zealand, an honour which everybody must allow was fully earned, for during his two years' rule the Colony had passed from a bankrupt and retrograding state to one of wealth and advancement; during these years the council had made the laws establishing magistrates, for adjudicating questions concerning natives in a summary manner, and re-establishing a revenue from the customs duties, thus providing funds for education and for hospitals, both for English and for natives, and for establishing a police; and Sir George Grey had expended the large grant allowed to the Colony by the British parliament (nearly £30,000 a year), in settling land questions and making roads. The prosperity of the Colony was brought about, it is true, by the enormous expenditure of the imperial government in the above manner and upon the troops, but it could probably have been brought about in no other way. The Colony has since gone on slowly increasing; the settlements of Otago and Canterbury have been formed, and as the associations by which they were formed and also the New Zealand company have ceased to exist, the whole of the Colony is now under a uniform system of government. The government have made several further purchases of land from the natives, and the settlers have thereby been enabled to extend their stock farming operations. The force of troops in the Colony has been gradually reduced (by allowing the men to purchase their discharge in the Colony) to a strength of about 1000 men who are distributed at Auckland and Wellington, and the two out stations of the bay of islands, and *Wanganui;* and these four stations will probably require to be kept up to their present strength for several years to come, in order to preserve that peace which was established throughout the Colony at so great an expense. Auckland continues to be the head quarters of the troops, and as they are required solely in the northern island, it is no doubt the proper place for the head quarters.

In October, 1848, shocks of earthquake were felt in Cook's Straits, lasting altogether for nearly two months, which injured most of the brick buildings in Wellington, and caused the inhabitants after that to build their houses with a frame work of wood. The colonial barrack at *Porirua*, a stone building, was destroyed by this earthquake.

In 1852, the new constitution was passed by the imperial parliament, and in 1853 it was introduced into the Colony.

There is no prospect of any very rapid increase in the British population or productions of New Zealand, for the resources and geographical position of the Colony are such as will cause a slow though certain growth of prosperity. The superior attractions of Australia, both for its gold and its sheep farming, will prove a bar to the rapid progress of New Zealand in one direction, while at the same time it will give a small but sure impetus to it in another, by providing a large market for agricultural produce, for which the Colony is likely to be always celebrated.

MEMORANDUM ON THE EMPLOYMENT OF ARTILLERY IN NEW ZEALAND,

Drawn up entirely from the notes and opinions of an Officer of Artillery, who served in the Colony during the two last military operations.

In a thickly wooded, mountainous, and swampy country such as New Zealand, without roads, horse tracks, or (with one or two exceptions) navigable rivers, moving any body of troops far from the sea coast is attended with great difficulties: taking guns with such a force adds much to those difficulties, but as it is advisable, if possible, to have some Artillery to accompany troops even in such a country, the description of gun recommended for such a service is here mentioned.

The natives of New Zealand, and it is supposed all other savages, when they fight with small arms, are scattered in small parties in skirmishing order, therefore Shrapnel shells are the best weapon to be employed against them, next to the rifle or musket. Shrapnel shells must be fired with considerable velocity to be effective. The $4\frac{2}{5}$-inch mountain howitzer, with a charge of only eight ounces of powder, can give but a very low velocity to a twelve pounder Shrapnel shell weighing eleven pounds. This howitzer is not provided with a field carriage on wheels, but it is fired from a wooden bed similar to a mortar bed, with cheeks. If a common field carriage were used, it would have to be made disproportionately strong and heavy to stand the recoil; two carriages were made for the $4\frac{2}{5}$ howitzers, in New Zealand, but they broke when Shrapnel shells were fired. The wood used was *Pohutukaua* (Metrosideros); this wood is generally used for ribs and knees of ships, and is highly thought of by carpenters as a strong tough wood.

The $4\frac{2}{5}$ howitzer is equipped to be carried on horses or mules; one horse carries a howitzer, another two beds, the ammunition is carried on horseback likewise, in boxes; this equipment may do very well for a mountainous country, such as Spain, where there are regular mountain roads, and where the traffic of the country is carried on by pack horses, where the animals are accustomed to carry pack loads, or where a large force is employed to act in regular warfare, but with small parties such as are likely to be employed in a country like New Zealand, where there are no roads or horse tracks, or even horses, or even if you had horses, where no animal but a *Maori* would possibly carry a pack load any distance from the beach, it is advisable to have a gun that can be easily dragged by a few men, and that can at the same time project Shrapnel shells with a sufficient velocity. The impossibility of feeding any body of men at a considerable distance from the coast, in such a country as New Zealand, totally without resources as it is, would render sending an equipment of horses for the purpose of transporting artillery a useless expense, putting aside the almost impossibility of feeding them if you had them; what is wanted for such a service is a light handy howitzer. The twelve pounder howitzer, even with the naval field carriage, is too heavy. There appears no reason why a nine pounder howitzer should not be made for this kind of service, it need not weigh more than 4 cwt., nor with proper carriage, limber, and ammunition (sixteen rounds), more than 14 cwt., which is not much more than the weight of a light three pounder.

Such a howitzer, with a charge of fourteen ounces of powder, would, it is considered, project Shrapnel with nearly as great a velocity as the twelve pounder howitzer, it would require to have nine pounder common shells made for it, and a lighter description of case shot, and this is an objection, but then this gun is only intended for particular service.

A garrison carriage or slide should also be provided, besides its field carriage, so that it might be mounted on a traversing platform, or fitted in a boat. No expedition should be sent to islands like New Zealand, without a boat fit to carry a gun, for although there are few navigable rivers, yet the creeks and estuaries run up the country in many places for a considerable distance, and, as in all the islands of the Pacific, the natives depend very much on fish for their food, and consequently live chiefly on the coasts of bays, &c., and are all provided with canoes, the possession of a gunboat adds much to the security of a post. The officers of the navy very naturally do not like having their boats away from the ships for any length of time, and although nothing could surpass the readiness of the officers and men of the naval force employed in New Zealand, to do everything in their power to assist and co-operate with the troops, yet it is always as well to have each branch of the service as independent as possible.

Of course, it is not supposed that this howitzer could breach pahs, probably nothing but mining or blowing them in with gunpowder will ever do that. The breach at the *Ruapekapeka* would not have been practicable, although made by thirty-two pounders, had it been defended.* The $4\frac{2}{5}$ mortar will be found useful, it is usually carried slung on a pole by two men, and can be fired without a bed; however it is better to have the bed if possible, but it is heavy for two men to carry.

In mountain warfare against large bodies of troops, the rocket would be a most useful weapon, especially when it has not been kept too long; and in New Zealand it would be always advisable to have some six and three pounder rockets, there should be leathern wallets provided to carry them on men's backs: a man should carry four six pounder, and six three pounder rockets, with their sticks. In the bush rockets could not be used.

All ammunition should be packed in the smallest possible cases: a few tarpaulins seven feet square are very useful, as they can be easily carried, and when large tarpaulins are cut up they soon wear out.

ON ARTILLERY IN MILITARY POSTS.

In a country where there is plenty of wood, the best description of defensible temporary post is probably a stockade with weather-boarded barracks inside. The twelve pounder medium gun or iron twenty-two cwt. gun does very well for the defence of such a post. The guns should be mounted on traversing platforms, unless there should be cover for an enemy very close to the stockade, when perhaps it would be better to have a loophole with a mantlet. Such a post might be held by very few men against natives.

* See Vol. 3. p. 69.

The guns should be furnished with field carriages besides the garrison carriage, and half of their ammunition should be Shrapnel shells. A post should have a dry brick or stone magazine covered with slates, capable of containing 100 rounds per gun, and 180 rounds for each musket. If the ammunition is packed in metal lined barrels or cases, as it ought to be, there can be no danger of accident if the commonest care is taken.

A couple of $4\frac{2}{5}$ mortars will be found useful, if there is cover for an enemy within 300 or 400 yards of the post.

When troops are sent to take up a new post, and are likely to be there for any length of time, the frame work of a field magazine, and two or three large tarpaulins should be sent with them. The magazine should be put up as soon as possible in the driest spot that can be found. The intrenching tools should be liberally supplied, those issued to the line are generally very inferior, the thick American axe is the best, two spare handles should be sent with each axe, as they are difficult to make, and they should be of the best ash. Hand carts are very useful. An officer of artillery should at once ascertain the distances of the prominent points within 1,500 yards of the post, and take care that the non-commissioned officers and men know them. Distances in a new unenclosed country are very deceptive.

It is as well to have a few Shrapnel and common shells filled ready. The fuze holes should be tightly corked with a good sound cork, having a lanyard attached to it, so that the cork can be easily drawn, and a wooden expence magazine box is useful for each gun.

END OF PART III.

PAPER III.

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REMARKS ON BREACHING STOCKADES WITH BAGS OF GUNPOWDER.

ACCOMPANIED BY THE RECORDS OF EXPERIMENTS MADE AT THE ROYAL ENGINEER ESTABLISHMENT AT CHATHAM, IN 1846—47.

The following extract from the record books of the Royal Engineer Establishment at Chatham is published with the consent of the Director, as it is considered that the public record of all the experiments on such a subject cannot fail to be of great use to officers of Engineers.

These experiments were made at the time when the military operations in New Zealand were going on, and it was thought desirable to show the pensioners, and other troops who were going out to that Colony, the method by which the native pahs or stockades could be breached without the aid of artillery. The experiments, as far as they went, were very successful, and clearly proved the practicability of breaching any stockade of ordinary strength, by means of bags of powder laid on the ground close to the timbers, and covered with about its own weight of earth in sand bags. The general result may be taken to be this, that with timbers about one foot square, where there is only one row of them, 100 lbs. of powder in two bags is sufficient to form a large breach; and where there are two rows of timber, three or four feet apart, 200 lbs. of powder in four bags, placed at the foot of the outer row, are sufficient to form a five-feet breach in the inner row. It is however very desirable that further experiments should be made on breaching various kinds of stockades in this manner. These experiments were only tried on one or two descriptions of New Zealand stockades, but there are various other plans for constructing pahs in the same country, some with triple rows of timbers, stronger and more difficult to breach than those experimented on.

It so happened that no New Zealand pahs were attacked after the account of these experiments was received; but there is no doubt, that if any had been attacked, the experience thus gained at Chatham would have been found very useful. If such a plan had been tried at some of the attacks on pahs in the north of New Zealand, in 1845 and 1846, there is little doubt that effective breaches would have been made in them, at a small cost in time, labour and men, compared with that which was required to transport heavy guns and waggons through the forests; and the certainty of the result depends only upon the quantity used, which is of trifling consideration as far as transport is concerned. The real difficulty in an operation of this description is the placing of the charge—this is no doubt a hazardous duty, but considering that it would be generally required in countries where forests afford shelter close up to the point of attack, and against savages unaccustomed to constant watchfulness, it would not be so dangerous as ordinary siege operations close to a fortress.

The knowledge of these experiments would also be found useful in other countries, in civilised as well as savage warfare. It might probably be used against the Burmese stockades, either for breaching them, or for destroying them when taken, an operation that sometimes gives considerable trouble; and also against such stockades as the Malay pirates use among the Bornese islands, and in civilised warfare, against the stockades in the gorges of outworks, which are probably rarely of greater strength than those experimented on. As however there were stockades in New Zealand of a still stronger description, and with an arrangement of timber that would make it difficult to breach in this manner, and as it is desirable to have further experiments on the best arrangements of palisades for resisting charges of powder, and also for resisting guns, and on the best mode of breaching such palisades as those in Burmah and China with artillery alone, it would evidently be very advantageous to continue experiments like these from time to time, recording the results in this public manner for the benefit of officers requiring to carry on such operations.

T. B. C.

EXTRACTS FROM RECORD-BOOKS.

ROYAL ENGINEER ESTABLISHMENT AT CHATHAM.

On the 20th January, 1846, the following experiments were made in breaching stockades by gunpowder.

The stockade was thirty feet in length, and was composed of logs of timber, placed upright, one foot square, and twelve feet long; three feet of which were fixed in the ground, the earth being firmly rammed round them.

They were in close contact, and united together by two ribands, nine inches by four inches, secured to the logs by 10 inch spikes.

The first attempt to breach was by firing a charge of thirty pounds of powder, confined in a bag, and suspended to the stockade opposite to the upper riband. The effect was merely to dislodge a few of the timbers from their upright position.

A second charge of thirty pounds, also confined in a bag, was laid on the ground near the middle of the stockade. Two bushel-bags of earth were laid upon the bag of powder, and two were placed in front of and in contact with it.

On being fired it formed a narrow breach in the stockade, by drawing two of the piles out of the ground, and breaking another asunder.

A third experiment was made with one charge of seventy pounds of powder, and another of fifty pounds, placed with an interval of five feet, and both touching the stockade; four sand bags filled with earth were applied, as in the preceding experiment, upon and against each charge.

In this instance a spacious breach was made, and some of the piles were thrown upwards of fifty feet from the stockade.

The object of these experiments was to ascertain the minimum charge for forming a breach, and although they did not altogether settle this point, it may be concluded that sixty pounds of powder, properly loaded in the manner above stated, will be a sufficient charge for effecting a practicable breach. The extent of breach required will, of course, regulate the number of charges to be used, but the necessity for further experiments was obvious.

It being considered necessary to try further experiments in breaching a double stockade, another portion of a stronghold, similar to Heki's pah, was constructed near St. Mary's battery, on the left of the lines.

A charge of 120 lbs. of powder, in two tarred sand bags, was lodged against the outer stockade.

On this charge were placed two bushel-bags of earth; two similar bags were placed in front of the charge, and one at each end. The charge was fired by means of a piece of Bickford's fuze, five feet in length.

The result was the destruction of about ten feet of the principal external stockade, pieces of which were thrown upwards of 200 feet from the line in which they had been placed. The timbers of the inner enclosure or keep were merely disturbed from their upright position, but were not breached.

8th June, 1847.

The Royal Sappers and Miners, the Sappers and Miners, Artillery, and Infantry of the East India Company's Service, and the company of the corps of Embodied Pensioners (under Captain Smith) about to proceed to New Zealand, were this day marched to the field works, to witness the breaching of a double stockade by gunpowder.

The stockade was composed of oak timbers, thirteen feet long, and averaging one foot one inch in thickness and breadth, placed in trenches four feet deep, so that nine feet were above ground.

There was an interval of four feet four inches between the two lines.

The timbers of each line were united by two ribands, one foot wide and four inches thick, of pitch-pine plank.

The upper riband was placed at the distance of seven feet from the ground, and the lower with its upper edge flush with the surface. The ribands were connected with the upright timbers by means of ten-inch spikes, one occurring at each timber. The two lines of stockade were joined together at their extremities by two cross ribands of the same width and thickness as the longitudinal one, the lower being placed below the surface of the ground, and the upper about seven feet above it.

A practicable breach was formed by lodging 200 lbs. of gunpowder in four bags at the bottom of the outer line of stockade, the lower bag resting on the ground.

Two sand bags filled with earth were placed on the top of the upper bag, two in front of the charge, and one at each end, in order to confine the action of the gunpowder as much as possible to the stockade.

A piece of Bickford's fuze, six feet in length, was attached to one of the central bags, six inches of it being inserted within that bag.

The fuze was ignited by a slow match, and the explosion of the whole charge was simultaneous.

The width of the breach in the outer line of stockade measured nine feet six inches on the surface of the ground, and a practicable opening measuring about five feet six inches was also made in the inner line.

PAPER IV.

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ACCOUNT OF THE DEMOLITION OF HOUSES FOR THE PURPOSE OF ARRESTING THE PROGRESS OF THE GREAT FIRE AT MONTREAL, IN JULY, 1852. BY CAPTAIN GALLWEY, R.E.

Though rules for the demolition of houses by gunpowder, in case of fires in towns, cannot be established with any degree of precision, a record of the experience of individual Engineer officers employed on such duties cannot fail to be most useful to the Corps, by leading to a general system of operation: and, since promptness of action is required on such occasions, it is evident that to be forearmed is an object of great importance.

Having been present, as District Commanding Royal Engineer, during the great fire at Montreal, on the 9th July, 1852, the duty of conducting the demolition of houses devolved upon me, and I shall give below a short statement of the means employed and results obtained.

The houses demolished were all of stone or brick, their main walls were one foot six inches to two feet, and party walls one foot thick; they were two stories high in all cases save one (a three story building), and their roofs were covered with tin or shingles.

The gunpowder used was in barrels of forty-five pounds each, plugged with pieces of portfire from six to eight inches long, which had been held in readiness in the Ordnance stores since a previous fire.

An Officer of Royal Artillery, an Officer of Royal Engineers, two Non-commissioned Officers and one Bugler, R.A., were employed in the operation. When it was considered necessary to blow up a house, we examined the premises to decide on the best position for the charge; the Bugler then sounded an alarm, adopted for the occasion, to warn the people to keep at a distance, which was pretty well understood after a short time.

The required charge, covered with a wet blanket, was then placed in position under my direction, and the portfire was lighted.

The charge used was, in all cases save one, one barrel (45 lbs.) In choosing the best position, local circumstances guided me; the charge was generally placed where two or more walls met, at other times in a cupboard, and once under a stone staircase. The demolition in all the above cases was complete and quiet, and as far as I could judge, no materials were projected ten yards.

The best result was obtained when the charge was placed under a stone staircase.

A failure occurred in attempting to demolish a three-story strongly built house; at the time of placing the charge (two barrels of forty-five pounds each), the roof and two upper stories had been consumed, thereby taking away the resistance above, and the result was the splitting of the angle (where the charge was placed) from top to bottom, about two feet wide, and in a few minutes the walls for about ten or twelve feet only along each face fell in.

The general result, although very good as far as the demolition was concerned, was unsatisfactory as far as regards arresting the progress of the flames, chiefly owing to the want of organization on the part of the civil authorities, and the great deficiency of water, a plentiful supply of which should always be available, to play on the fire as it approaches the isolated part.

I am glad to say that there was a happy exception in the case of the barracks, which were saved by the great exertions of the military, after a successful explosion had been effected, everything inflammable being at once pulled away from the ruins.

In Canada, the Mayor and Chief Engineer (a civil functionary in charge of every thing pertaining to the safety of the town, in case of fire), are the only individuals who can *order* the demolition of houses by gunpowder, but this must be *executed* under the superintendence of an officer of Royal Engineers. This, it will be seen, greatly hampers the efforts of our officers, and on this occasion I often refused to conduct an explosion that had no probability of success attendant on it, and I perceived many opportunities for advantageous explosions which it was out of my power to carry into effect.

I beg to offer a few remarks as to the best mode of proceeding. In the case of such a tremendous fire as the one which I witnessed at Montreal, when the front of the flames was nearly a quarter of a mile long, and they were perfectly tempestuous in their progress, it is futile to endeavour to meet it *in front*. The attack should be made *on each flank*, so as gradually to reduce it. This can only be done by a combined action under one head, and I would submit that, in future cases of such a calamitous nature, the entire conduct of the operations should be given over to the Commanding Royal Engineer, who, I conceive, should appoint two or more directing Engineers, as the case may require; each accompanied by every requisite for such service that both the military and civil authorities can afford.

The forty-five pound barrels of gunpowder are the most convenient for use, and can be carried by one man.

Bickford's fuze is preferable to portfire, the "spitting" of the latter, and its burning at a very uneven rate, rendering it dangerous. Great benefit would be derived from dividing a charge in a large building, but then the difficulty of securing simultaneous explosion presents itself, when demolitions are hurriedly conducted.

T. L. GALLWEY,
Captain Royal Engineers.

Montreal, 29th September, 1852.

Remarks upon Conflagrations of Towns or Houses. By an Officer of Royal Engineers.

In the fires that take place in towns, it is frequently of great importance to obtain with rapidity the demolition of houses or ruins.

The ordinary process would be generally too slow, and in the case of ruins, frequently attended with great danger, indeed it has actually been the occasion of many accidents. Gunpowder therefore is resorted to, but requires to be used with much caution, and by professional men of experience; the application of powder must be under such varied circumstances that no precise rule can be laid down for it, and the ablest Officers of Engineers engaged in such operations can only adopt measures from analogy.

It becomes a matter of much interest therefore, to collect as many circumstantial descriptive details as possible of the application of gunpowder on such occasions, with the results attending each.

To bring a house down the powder is usually applied in the interior of the building, a mode which is necessarily attended with inconvenience and difficulties. Frightful premature explosions have taken place, and the calculations for the effect must be too complicated and arduous to be made on a sudden emergency. It has, therefore, long ago occurred to me that a system might be adopted that would be more efficient and safe, viz., by suspending bags of powder to a ladder or single pole, reared or run up by small wheels, against a house on the outside, and exploding them on the wall between the windows, either high up, midway, or near the ground, as the case might be; the effect of the explosion would be to drive the fragments *within* the building, and it would be less liable to do other injury than that intended. There would be no necessity for making the arrangement within, and the superincumbent part would simply fall, in a manner that could be anticipated. It would be particularly advantageous, it is considered, to throw down in this manner the upper parts of ruins left in a dangerous condition.

Some experiments would be required for effectively acting upon this system:

1. As to the amount of charge of powder to apply under different circumstances.

2. To ascertain the manner in which a pole could be reared to given heights with a pully and rope attached at the top, by means of which the bag of powder would be subsequently laid against the wall at any desired height. The pole would require no great strength, indeed little, if any, more than to be self-supporting.

3. The mode by which a train or communication would be conveyed for ignition of the charge from the piece of fuze below.

Note on the Demolition of Buildings at Hamburg in 1842.

Whilst attached to the Prussian Royal Engineers I obtained the following authentic information relative to the use of gunpowder in the demolition of houses at the great fire at Hamburg in 1842, and I think it may be useful to insert it here.

Strong brick houses, four to six windows wide, were reduced to heaps of rubbish by firing charges of from 200 lbs. to 300 lbs. of gunpowder placed in the centre of the cellar of each; but the delay which this caused to the firemen, and the burning timber not being removed,* prevented this mode of stopping the progress of the fire being successful in some cases.

A strong house, five windows wide, was also battered down by eight 12-pounder shot fired at it from a distance of 120 paces.

After the fire, the wall of St. Peter's Church, which was left in a dangerous state, was blown down thus—this wall was 30 feet high and 5 feet thick; and a portion of it 22 feet long, with buttresses at each end, was destroyed by four charges of powder, (averaging 28 lbs. each), lodged in the centre of the wall at the level of the ground; struts being fixed between it and the houses on the opposite side of the street, to prevent it falling against them, and a mound of sand 4 feet thick being formed inside to act as tamping. All the charges were fired simultaneously.—Ed.

* In case of a fire breaking out in the villages of the Russian military colonies, a screen of sail-cloth is sometimes hung up and kept well wetted, to secure the next house from the effects both of the heat and of the flying embers.—Ed.

NOTE.

The object generally aimed at in the destruction of houses by gunpowder or other means is to cut short the progress of a fire by depriving it of its *pabulum*. This is done by interposing a space freed from inflammable substances by the destruction of the houses which stood upon it. The uncertainty of the result however of this ordinary process is justly noticed by Captain Gallwey, and will be readily understood by a brief reference to the mode in which it may be expected to operate under varying circumstances.

First then, let it be supposed that the fire is progressing *against* the wind, which it will readily do under favourable circumstances, such as the presence of wooden houses, inflammable stores, &c. In this case it is evident that the sudden interposition of a non-inflammable space, produced by the demolition of houses, will arrest the progress of the flames.

Secondly, let it be supposed that the fire is progressing *with* the wind: in this case the mere destruction of a line of houses must generally prove insufficient to check the flames; and will sometimes, by facilitating the passage of the burning flakes driven along by the wind, augment the rapidity of their progress. It may therefore be stated as a general principle that the object should be to establish an atmosphere incompatible with combustion, and thus to interpose in the way of the flames an aeriform screen: instead then of seeking to destroy the houses by throwing down the walls, it would be better to confine the work of destruction to the roofs and floors, to block up the windows on the windward side, and to keep up a combustion within the space thus gained of substances capable of producing large quantities of either carbonic acid, or sulphurous acid, or other gaseous bodies unfavourable to combustion. It is in this manner that the fires of mines are extinguished, and the same principle is equally applicable here.

In carrying out any such system care must be taken not to use materials which evolve a large quantity of unconsumed carbon or smoke, as the smoke itself would then become food for the flame, but on the contrary, those which, being fully decomposed, produce, as the result of combustion, gases which are neither supporters of combustion nor in themselves combustible. The repeated explosion of small quantities of gunpowder would act very favourably in this respect, and doubtless the apparent effect of the destruction of a house has often been due to the quantity of gaseous matter developed by the ignition of the gunpowder. Powder with an excess of sulphur would act still more effectually: and it may be added that a similar system should be adopted in rear of the flames in order to produce over the burning mass an atmosphere unfit for the support of combustion, every chimney in a fitting position being made to pour out its supply of non-combustible gas.

These remarks are only intended to be suggestive, and are not given as detailed explanations of either the means or mode of applying chemical agents to arrest the progress of conflagrations.

J. E. PORTLOCK.

NOTE.—An apparatus like "Phillips's Fire Annihilator," for evolving non-inflammable gas may prove useful, but it is difficult to apply it with effect on account of the great draught caused by the heat.—ED.

PAPER V.

NARRATIVE OF THE MEANS ADOPTED FOR PULLING DOWN SOME VERY DANGEROUS RUINS AFTER THE GREAT FIRES AT EDINBURGH,

In the month of November, 1824.

By F. B. HEAD,*

LIEUTENANT IN THE CORPS OF ROYAL ENGINEERS.

Taken from Papers lithographed at the Royal Engineer Establishment for Field Instruction at Chatham, in 1825.

INTRODUCTION.

As the demolition of masonry by mining, although of frequent occurrence in actual warfare is one of those duties of Engineers in the field that cannot be practised at this Establishment on account of the expense, all authentic records of such demolitions may be considered peculiarly useful and interesting to the corps. I therefore requested Lieutenant Head to favor me with a narrative of his proceedings after the great fires at Edinburgh, in which he used mining with success for the purpose of removing part of the enormous ruins that threatened to overwhelm the neighbouring houses. The manner in which other ruins were pulled down by a chain cable, by the able and zealous co-operation of Captain Hope, of His Majesty's ship Brisk, and a body of officers and seamen of the Royal Navy, may be considered no less interesting.

To this narrative, which Lieutenant Head has permitted me to lithograph for the use of the Establishment, I thought it proper to annex an Appendix containing copies of the official letters written on the occasion. It must be highly gratifying to the officers in His Majesty's service, as well as to the men under their command, when they find that those important services which they occasionally have it in their power to render to the civil part of the community, in the event of fires or other sudden calamities, are duly appreciated, as has been the case at Edinburgh. And it is to be hoped that Officers will always be disposed to exert themselves on such occasions, when the assistance of an organised and disciplined body of men may be of incalculable value to their countrymen in civil life.

* Now Sir Francis Bond Head, Bart.

Three of the plates have been taken from a series of eight interesting engravings of the ruins occasioned by the great fires in Edinburgh on the 15th, 16th, and 17th of November, 1824, which were published for the benefit of the sufferers, but which were on much too large a scale to accompany this narrative.

The letters given in the Appendix refer to Lieutenant Head only, but the Lord Provost of Edinburgh and the other officers of state for Scotland also reported the services of Captain Hope and of the officers and seamen employed under him to the First Lord of the Admiralty, in a manner equally handsome; besides which they voted their thanks to a number of officers and soldiers of different corps who assisted at the period of the fires.

Signed, C. W. PASLEY,
Lieutenant Colonel Royal Engineers.

Chatham, 25th March, 1825.

NARRATIVE.

Edinburgh, *13th December*, 1824.

On the 17th ultimo, having been previously desired by Major General Sir Thomas Bradford to render every assistance in my power to the civil authorities, I was requested to inspect the ruinous walls in the Parliament Square, and to report to the proprietors of that neighbourhood and to the civil authorities, who were to assemble for that purpose, whether I would undertake to take down these ruins, and if so, by what means.

These ruins consisted of a gable AB (see Plates 1 and 2) twelve stories, or 130 feet high, situated at the south of the Parliament Square, and of another wall EF situated on the east of the same square. This latter ruin EF, about 80 feet high, was firmly connected to, and supported by a wall at right angles, of the same height, three feet thick and ten feet in length, which formed a buttress, (marked DEGH in Plate 2,) supporting it on the only side on which it was desirable that it should be made to fall, the ruin on its other sides being surrounded by houses on a lower level, only six feet distant from its base.

It was evident, however, upon inspection, that though this buttress would effectually resist every effort that could be made by ropes, to haul it into the Parliament Square, yet that, if its base GH were to be blown away and its support thereby destroyed, the weight of the upper part DEGH would in its fall inevitably drag down the whole of the ruin in the direction required.

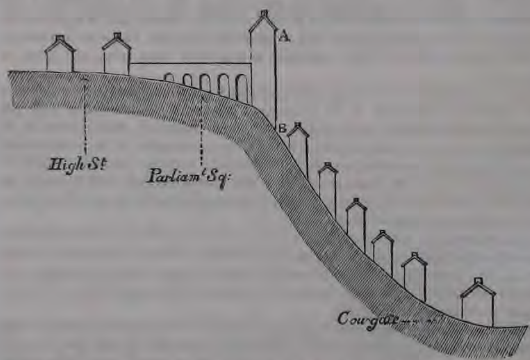
I proposed, therefore, by a miner's jumper, to bore five holes in a line parallel with the base of the buttress, and at a height ($2\frac{1}{2}$ feet) convenient for the men to work them: that the jumper should be driven slanting into the wall, and that it should penetrate about an inch further than the centre of the wall, (which was three feet thick) in order that the powder should blow out both sides of the wall; also that the powder should in every instance be imbedded in a stone, and not in the mortar.

One precaution was evidently necessary: that when the holes were loaded the firing paper should be so cut as to ensure the outer holes exploding first, and in regular succession towards the wall, for if the buttress were first deprived of its foundation near the wall at H, its superincumbent weight would of course have acted the wrong way. By attending to these precautions I was fully persuaded that the result would be successful, and I was permitted to carry the plan into execution.

The first party of miners refused to approach the work, though I offered them a high reward; some people had already been crushed near the spot K, and I could not prevail on them to undertake the job. I got therefore two other parties from opposition quarries, and bringing them at once together, with the work before them, they did not hesitate to commence, and in two hours the five holes were bored; however as the ruin AB on the south of the Parliament Square would have done incalculable injury by falling the wrong way, I thought it prudent to attempt to bring it down first by means of a cable, as the fall of the east ruin, by concussion, might possibly overturn it.

This object was successfully accomplished by the able advice and assistance of Captain Hope of His Majesty's Ship Brisk, and by the strenuous exertions of a body of officers and seamen under his command, who displayed on this occasion all the characteristic zeal and energy of the British navy.

In order to explain the singular fabrication of this south ruin, I must mention that the Parliament Square itself is supported on arches, in order to obtain a level; that the houses on the south side of the square are six stories high on the front which looks into the square; and from nine to twelve stories high on the side or rather gable which overhangs the Cowgate. The house which had been burnt was the highest of them all, and when a person entered it from the Parliament Square he might either mount six stories or descend six stories, as represented in the annexed figure.



From the fire, the roof of this house had fallen in, the front N (Plate 2), which looked into the Square had fallen to one-fourth of its height, and the two side walls (L and M) to one-third of their height.

The great south gable AB, cracked and rent from top to bottom, stood in its whole height literally moving by the wind, and threatening to fall back upon the Cowgate, (*see woodcut*): had it done so it would not only have crushed the houses immediately beneath it, but, as these houses were all built on the declivity of a very steep hill, it was impossible to calculate where the devastation would cease.

As the side walls L and M were leaning very much inwards, no man could be induced to venture between them, and indeed as the great gable AB was the same height on both sides, there was but little to be done within but gaze upon it with despair.

The side walls, though leaning inwards, seemed to prevent the gable from falling towards the Parliament Square, and yet we did not dare to attempt pulling them down, for fear the shock of their fall and their sudden removal should overturn the south gable.

We resolved therefore to endeavour to get a chain cable round this gable, in a direction which will afterwards be explained, and to haul it sufficiently tight to become a support and a brace to the gable: then to pull inwards the side walls L and M, and as soon as they should be seen to fall, to haul on the chain cable with as much force as we could venture to apply without fear of breaking it; as in that case, the gable would probably (in reaction) have rolled backwards.

We felt confident that the cable would be sufficient to bring down the ruin, but even if it were not, by securing both ends firmly in the Parliament Square, it would evidently tend at least to support the gable from falling on the Cowgate, and give time and security to take other measures.

After the description given of the tottering state of these walls, it may perhaps excite an idea that a chain cable was a greater force than was necessary to apply.

It must however, in the present instance, be remembered, that we could not venture to haul and give, but that the force applied must necessarily be steady and constant in the direction required.

I had calculated that the south gable weighed about 1280 tons, and from the experience acquired the day before, in attempting to pull down some very slight walls with ropes, there seemed every reason to believe that the chain cable would be absolutely necessary to ensure any certain influence upon such an enormous mass, especially as it would neither stretch nor be liable to be cut by the rugged walls over which it had to pass.

Having decided upon this plan of operation, the following is the manner in which it was executed.

From the top of a distant chimney C, after repeated efforts, a ball of whipcord wound round a leaden bullet was thrown over the east summit of the great gable at A (see the dotted line in Plate 2), and, when it reached the bottom, the sailors from the Cowgate cut off the bullet, and made fast a very small rope. A stronger rope was then fixed to this, and then a stronger which we continued to haul from the chimney C, and we thus succeeded in getting up the end of a 3½-inch hawser. As the chimney on which we stood was much shaken by the fall of the house which had been between it and the great gable, we could not venture from it to raise the whole weight of the hawser, and we were accordingly obliged to haul upon it from the Parliament Square.

As soon as we got the end of it secured there, we fixed one end of the chain cable to a stanchion S, which had been prepared in the Square in an advantageous situation, and to bring the slack of the chain cable round the east side wall of the ruin down into the Cowgate, we made the other end fast to the hawser, and coiled the cable on the spot where the bullet had fallen.

We then, by a purchase which we fixed to the hawser, making the sailors walk away with it steadily, and avoiding anything like a jerk, succeeded in raising the chain cable until the end of it came to the top of the wall at A; and during this operation we had guy-ropes in every practicable direction to relieve the wall as much as possible from the weight of the iron cable.

To prevent the hawser from being rubbed at the point where it was connected with the cable, we had covered it with canvas, which we had greased; still, when this came to the top of the wall at A, it would not pass over; however we continued hauling steadily, and at last two or three stones were forced away, and then, without difficulty, we at last got hold of the end of the cable, and from the stanchion S applied a considerable purchase upon it.

We made this fast to the stanchion, and I then ordered the mines to be loaded and primed. As soon as they were ready the sailors were applied to the purchase, (which consisted of a couple of double blocks, sufficient to break the cable). They hauled and hauled, every body cheering them on, for upwards of a minute, when the gable was seen to commence its fall. As soon as the dust cleared away a most singular, unexpected, and apparently unfortunate circumstance presented itself. On the east end of the gable, there was (as I mentioned) a rent or crack from top to bottom. The whole of the gable had now fallen inwards, except a small slender column, (BO, Pl. 2) which remained tottering, 130 feet high, and which appeared more dangerous than the whole gable had been. The chain cable however was round it, and evidently there was no alternative but to haul upon it immediately, in the hope that it would come towards us. This being done, the cable in a most singular manner, cut it in two at O, and the column BO fell vertically on its end O, and then crumbled into pieces.

As soon as it fell, the populace was ordered to fall back, and with two miners I instantly lighted the five matches at GH. In about fifteen seconds the charge No. 1 exploded, and immediately afterwards No. 2. For several seconds no effect took place. At last the bulwark was seen very slowly to begin its fall, bringing the whole mass with it; the firing paper of the other three holes was extinguished and smothered by the explosion of Nos. 1 and 2.

In the five mines there were $4\frac{1}{2}$ lbs. of powder, so that the success was obtained by two-fifths of that quantity.

As soon as the dust cleared off, the houses behind the ruins, which were only six feet from them, were brought to view; they were uninjured, and even the windows were not broken.

The south gable also fell without injury to any house, but the iron cable on the last haul broke.

Signed, F. B. HEAD,
Lieutenant, Royal Engineers.

MEMORANDUM.

In order to pull down old walls with ropes, the simplest method appears (from the experience which has been lately gained at Edinburgh) to haul and give; by which means the walls are easily made to vibrate, until the adhesion of the mortar to the stones is destroyed. The wall then falls on that side to which it had inclined before the operation of hauling commenced, and this at Edinburgh almost invariably took place, and many accidents happened from the masons fancying at first, that the tottering wall would fall on the side towards which they hauled it.

The theory of this is, that the force applied, though able to loosen the adhesion of the materials, is not sufficient to overpower the natural tendency that the wall has to fall according to the laws of gravity.

It may be observed that the walls which fell at Edinburgh as soon as they were overbalanced, broke to pieces in the air, and fell upon a base equal only to about one-tenth of the height of the wall. This of course was caused by the non-adhesion of the mortar, and was much the effect of the fire.

Various methods were in contemplation for getting a rope over the south gable, in case our first attempt had failed. A chimney sweeper offered to ascend for that purpose, by ladders fixed together to the height of 100 feet, which it was proposed to raise and support with guys, near to the top of the wall, but without touching it. The idea of shooting a small line over by an arrow was also suggested, as it appeared too hazardous to use Captain Manby's method of effecting this object by a mortar.

F. B. H.

APPENDIX.

(No. 1.)

Edinburgh, 27th November, 1824.

MY LORD DUKE,

In consequence of the late very extensive and calamitous fires in this city, it having become an object of the most urgent importance that part of the ruins which overhung the houses in the vicinity of the Parliament Square, and exposed the persons and property of the inhabitants to the most imminent peril, should be taken down with as much care and expedition as possible, the Lord Provost and Magistrates with the concurrence of the public functionaries committed the execution of this duty, in the absence of Lieutenant Colonel Thackeray, to the sole direction of Lieutenant Head of the Royal Engineers. On the 20th instant that gentleman, with the able co-operation of Captain Hope, the officers and seamen of His Majesty's ship Brisk and of the Stork and Royal Charlotte revenue cutters, partly by mining, and partly by the application of chain cables, accomplished his undertaking with the most complete success and without the smallest accident. And when it is kept in view that one of the ruinous walls of stone and lime, one hundred and twenty feet in height, threatened every moment to overwhelm a number of houses situated on a lower level, and deterred all approach from ordinary workmen, the difficulty and danger of the operations in question may in some degree be appreciated. Having witnessed the whole of Mr. Head's proceedings, we would be wanting in justice to him were we not to express it as our humble opinion that nothing could exceed the skill, decision, and promptitude evinced by him on the occasion.

Feeling therefore, as we do in common with the rest of our fellow citizens, a deep sense of the importance of Mr. Head's services to the public of Edinburgh, we venture in the most earnest manner to recommend him to the favorable notice and attention of your Grace.

We have the honor to be,

&c. &c. &c.

Signed, ALEXANDER HENDERSON, Lord Provost.
C. HOPE, Lord President.
WM. RAE, Lord Advocate.
WM. BOYLE, Lord Justice Clerk.
S. SHEPHERD, } Barons of Exchequer.
T. CLERK RATTRAY, }
JOHN HOPE, Solicitor General.
HENRY JARDINE, King's Remembrancer Exchеqr.

His Grace the Duke of Wellington,
&c. &c. &c.

(No. 2.)

London, December 2nd, 1824.

My Lord,

I have had the honor of receiving a letter from your Lordship, the Lord President of the Court of Session, and other distinguished Gentlemen residing in Edinburgh, expressing their approbation of the services of Lieutenant Head of the Royal Engineers, in the direction of the measures considered necessary for the safety of the town upon the late occurrence of the fires in that city. I beg leave to return my thanks to your Lordship for this communication, and to assure your Lordship that nothing can be more satisfactory to me than to learn that the services of Lieutenant Head, upon this occasion, have merited the approbation of your Lordship, of the Magistrates, and other distinguished persons, who have signed the letter above referred to.

I will not fail to communicate to Lieutenant Head this testimony of approbation, which I doubt not he will receive with the gratitude which it deserves.

I have the honor to be,
My Lord, &c. &c. &c.
Signed, WELLINGTON.

The Lord Provost of Edinburgh.

(No. 3.)

Office of Ordnance, 8*th December,* 1824.

Sir,

I am directed by the Master General, to transmit to you the enclosed copy of a letter addressed to his Grace by the Lord Provost and other distinguished Gentlemen of Edinburgh, respecting the conduct of Lieutenant Head of the Royal Engineers, in the direction of the measures considered necessary, for the safety of the town, upon the late occasion of the fires in that city.

The Master General desires that you will communicate this letter (together with His Grace's answer, of which I also enclose a copy) to Lieutenant Head, and inform him how gratifying it is to the Duke to receive these testimonies of his good conduct.

I have the honor to be,
Sir, &c. &c. &c.
Signed, FITZROY SOMERSET.

General Mann,
&c. &c. &c.

(No. 4.)

84, *Pall Mall,* 8*th December,* 1824.

Sir,

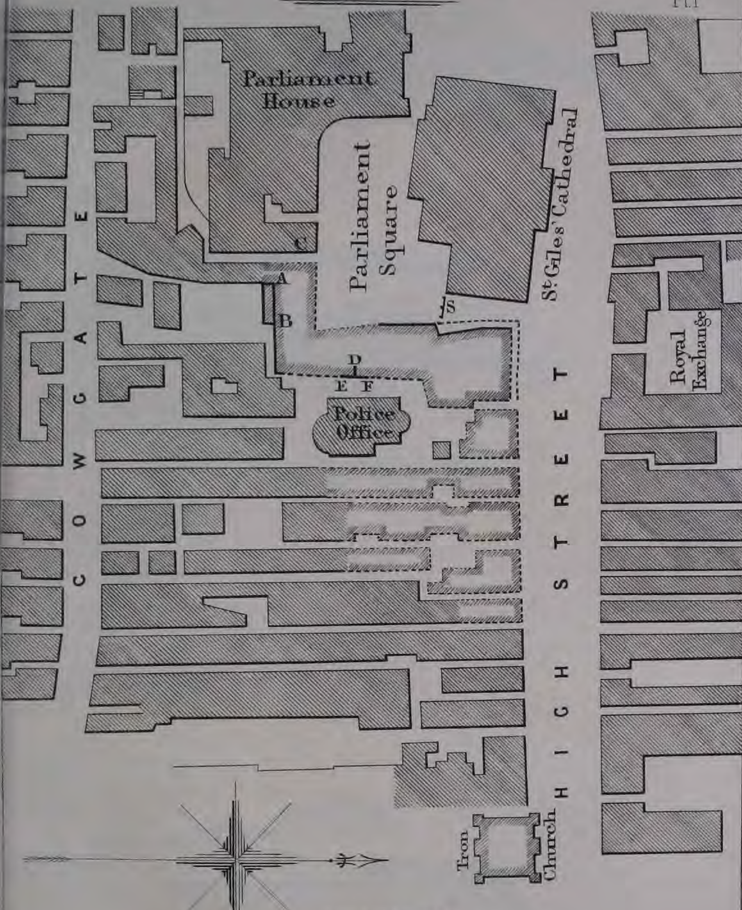
I have great satisfaction in communicating to you copies of sundry papers relative to your conduct upon the occasion of the late fires at Edinburgh, which has called forth such high approbation.

I am,
Sir, &c. &c. &c.
Signed, GOTHER MANN.

Lieut. Head, Royal Engineers.

DEMOLITION OF HOUSES AFTER THE GREAT FIRE IN EDINBURGH, Novr. 1824.

Pl. I



REFERENCES.

The houses partially shaded are those which were burnt.

AB. *The great gable pulled down by the chain cable*

EF. *The high ruin required to be pulled down towards Parliament Square.*

D. *The cross wall supporting* EF, *and which was blown down with gunpowder.*

C. *The chimney from which the rope was thrown over the gable.*

S. *The stanchion to which the chain cable was made fast.*

Scale of Feet.
100 50 0 100 200 300 400

Pl.III.

PAPER VI.

ON MODES OF RAISING BUILDING MATERIALS.

BY MR. R. MENNIE,

SURVEYOR IN THE OFFICE OF THE INSPECTOR GENERAL OF FORTIFICATIONS.

Description of an Inclined Plane for the Transport of Building Materials to Upper Fort Neuf, Corfu, Ionian Islands.

From the difficulty of access to the Upper Fort Neuf, it was found necessary to provide means for the transport of building materials for the construction of a defensible building, and for extensive alterations and repairs to the batteries (amounting to many thousand tons), and it was decided that an inclined plane should be constructed, leading directly from the sea to the level of the work at the Upper Fort Neuf, as the most convenient and economical plan.

A sketch of it, (see Plate 1) with a return showing what was accomplished daily, is submitted, as it may be useful in cases of emergency* in countries where the necessary conveniences cannot be obtained, such as engines, trams, rails, &c.

The inclined plane was constructed with uphers for uprights and outside stays, many of them were from the scaffoldings of buildings previously erected, and nearly all the braces were of old materials from demolished buildings. The planking was new 2-inch white deal, with strong hoop-iron nailed on for ways for the trucks. The fillets for retaining the trucks in their places were made from 3″ × 3″ white deal scantling, cut arriswise.

There was a double run with two drums at the top, consequently twice the quantity shown in the return was taken up daily.

R. O. MENNIE.

10th April, 1854.

* An inclined plane was also used to raise materials to a height of about 350 feet in constructing the citadel at Quebec.—Ed.

Memorandum of Work performed by Men and Horses in moving Materials by an Inclined Plane up to Upper Fort Neuf, Corfu, Ionian Islands.

Height of Plane above sea level.	Length of Plane.	Number of loads taken up daily.	Angle of inclination.	Each load consisting of the following.			Building Stone taken up daily.	Lime,* Sand, or Shingle, taken up daily.	Bricks taken up daily.	Employed daily.					Hours per day.	Remarks.
				Building Stone.	Lime, Sand, or Shingle.	Bricks.				Horses.	Non-Commissioned Officer.	Sappers.	Carters.	Laborers.		
				Cubic feet.	Cubic feet.	No.	Cubic feet.	Cubic feet.	No.							
152′ 0″	396′ 9″	110	23°	11¼	8	190	1237½	880	20,900	3	1	2	2	9	10	*When the lime admits of being loaded and unloaded with the hand, a quantity equal to that of Building Stone is taken up.

Description of the Mode of Employing a Stretched Rope for the Transport of Materials to any place difficult of access, as used at Corfu.

A strong iron picket is driven into the ground, to which the standing rope (about 5-inch) is attached; a cross of wood, as shewn in the sketch (Plate 2), is placed on the top of the work, over which the rope passes, (at *a*). In fixing the cross it should be first placed in an inclined position (as shewn by the dotted lines), so as to admit of its being perpendicular when the rope is hauled tight, which is done by a block and tackle at the upper end of the rope. The running rope is passed over a roller in the upper part of the cross (at *b*), and is put in motion by a horse attached to a drum, or by a snatch block fixed at the lower end of the standing rope.

Where there is room on the top of the work the drum or block may be fixed there, which will lessen the length of the running rope.

A traveller, shewn at A and B (Plate 2), having two wheels, runs along the standing rope, to which strong boxes are attached.

Lime, sand, shingle, mortar, or any small articles can be taken up in these boxes. Stone, brick, or any larger materials can be placed on flat trays similar to the scale of a weighing machine. Water can be taken up in buckets or in small barrels slung.

The boxes are emptied by a man stationed at the upper landing, having a staff with a hook at the end of it, to press down the pin *n* (see Plate 2), by which he lifts the latch at the side of the box, when the box turns over and empties itself. The boxes then pass down the rope by their own weight (rather rapidly but without injury), the horse being previously removed from the drum to admit of its revolving as the boxes descend to receive another load.

The standing rope on which the trucks travel is kept well greased, which is done by a boy sitting on the flat tray on which bricks or stone are raised. The rope lasts for many months.

At the upper citadel the rope was fixed with an inclination of nearly 45°, for want of room, yet it worked very well.

Some work being required to be done on the top of the defensible building at Fort Neuf, the materials for which were lying on the glacis on the opposite side of the ditch, they were conveyed across by means of the rope, and the work was done before the construction of a scaffolding and gangway could have been completed, which operation would also have been more troublesome and expensive.

The whole of the concrete for the roof of the bomb-proof barrack, which is 425 feet long by 48 feet wide inside, was taken up by this means; and wheelbarrows being placed under the boxes, when the latter were capsized their contents fell into the barrows, thus avoiding the trouble of reloading.

The height of the trestle or cross will depend upon the space at the landing place required to give sufficient room for the boxes to clear the edge of the building, and to allow of their being at the proper height for emptying them.

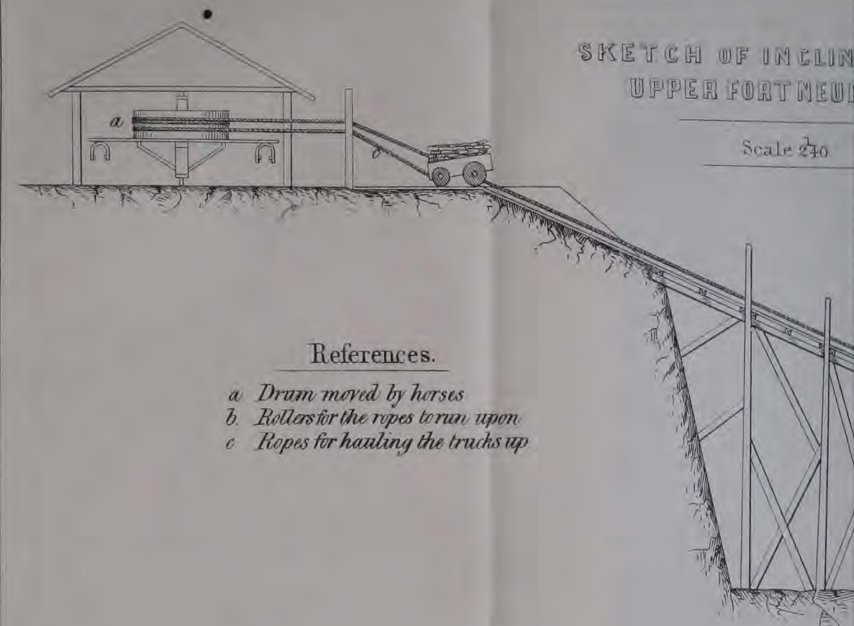
R. O. MENNIE.

Memorandum of Work performed in conveying Building Materials by means of a Stretched Rope, as shewn in the accompanying Sketch.

Number of loads taken up daily.	Each load consisting of the following:			Building Stones taken up daily.	Lime, Sand, or Shingle taken up daily.	Bricks taken up daily.	Employed daily.				Hours per day.	Length of rope.	Angle of inclination.	REMARKS.
	Building Stone.	Lime, Sand, or Shingle.	Bricks.				Horses.	Labourers to load.	Ditto to unload.	Labourers to wheel away.				
	Cubic feet.	Cubic feet.	No.	Cubic feet.	Cubic feet.	No.						Feet.		
120	5	6	100	600	720	1,200	1	2	1	Depends on distance.	10	235	20°	The rope may be fixed at almost any angle.

SKETCH OF INCLIN
UPPER FORT NEU

Scale $\frac{1}{240}$

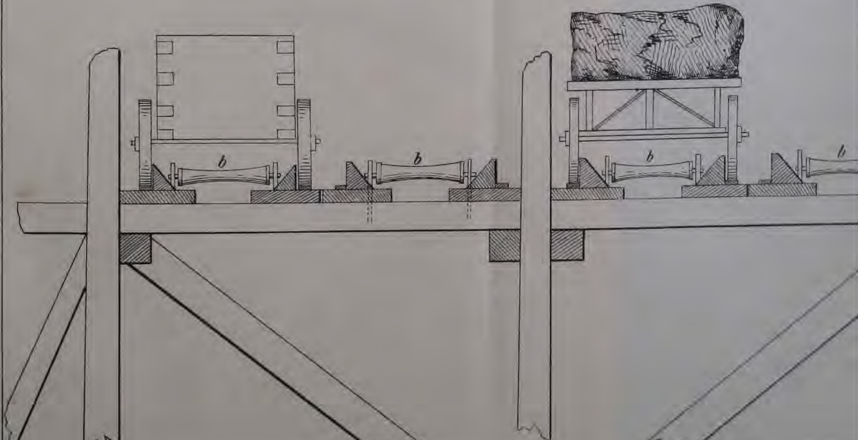


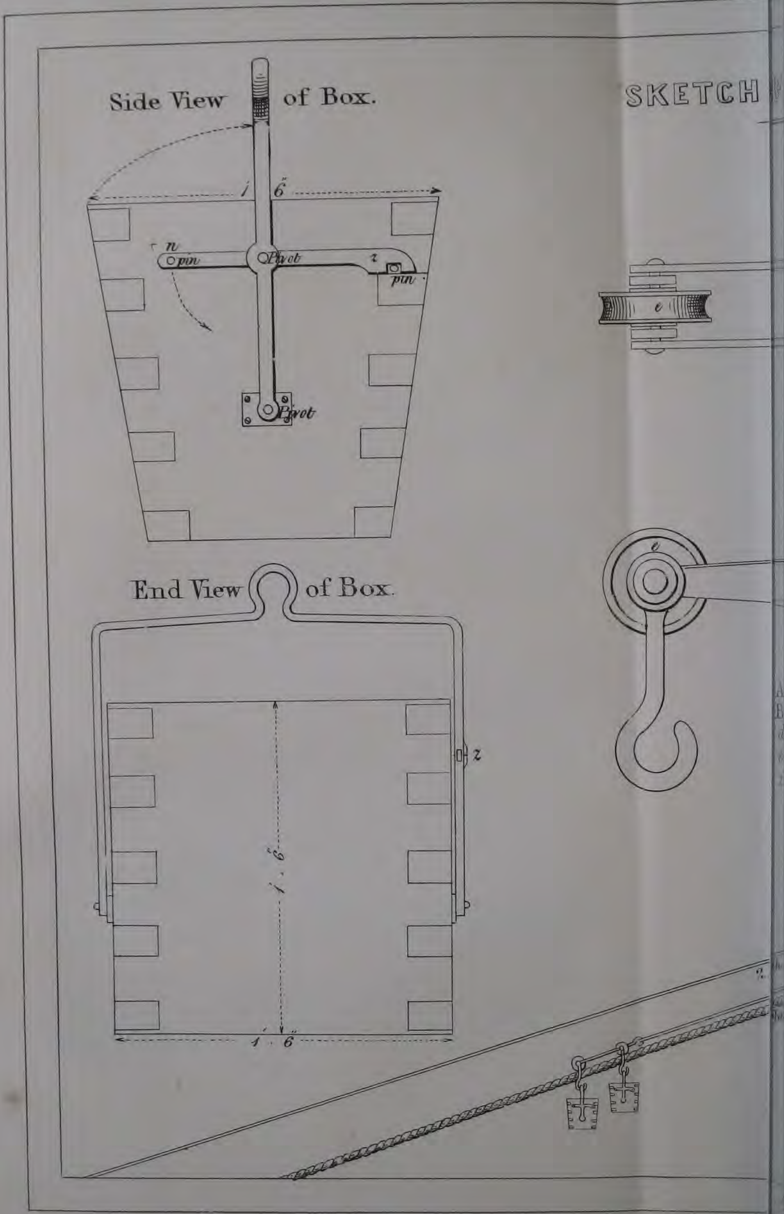
References.

a Drum moved by horses
b. Rollers for the ropes to run upon
c Ropes for hauling the trucks up

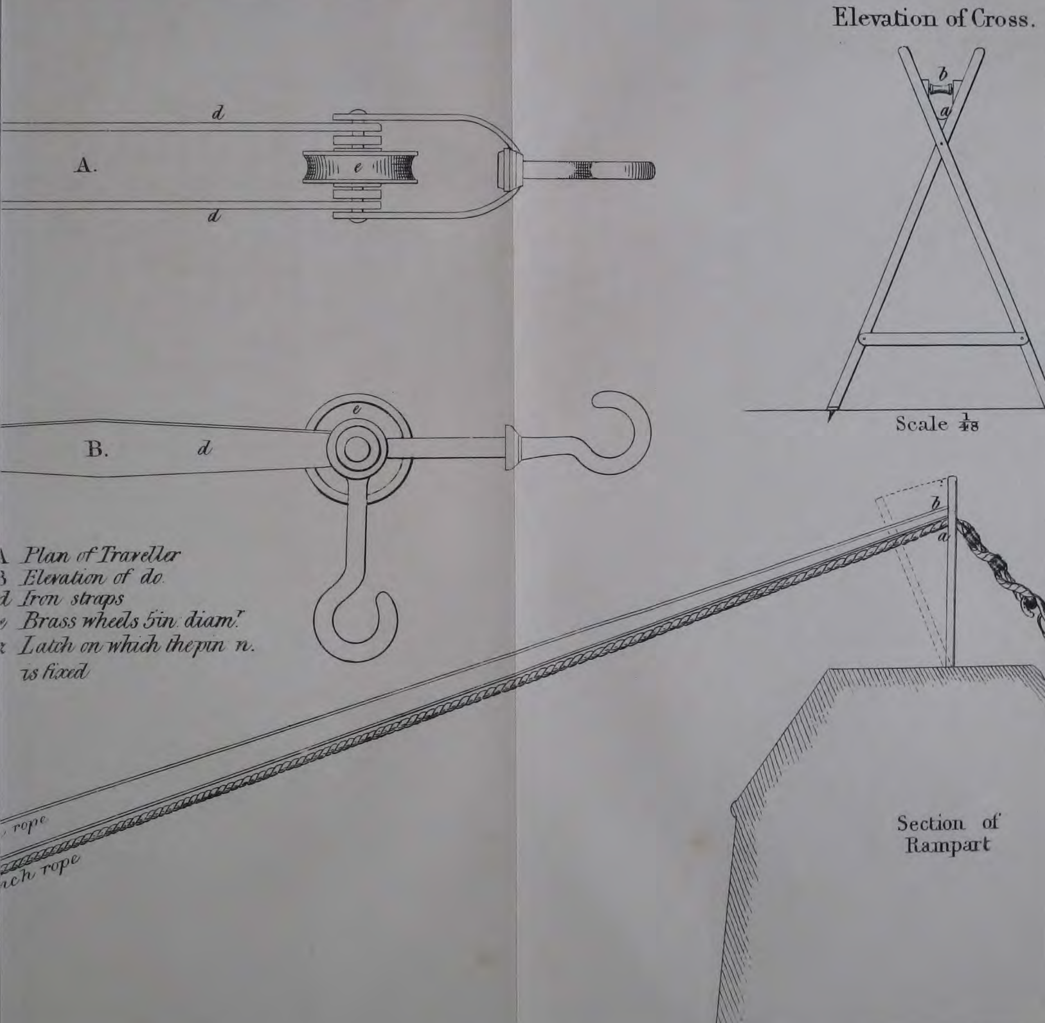
SECTION OF INCLINED PLANE.

Scale $\frac{1}{24}$




Side View of Box.
1 6
n
pin
Pivot
z
pin
Pivot
End View of Box.
z
1 6
1 6
SKETCH
e
e
2

F STRETCHED ROPE USED AT CORFU.



PAPER VII.

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NOTES UPON THE NATIONAL DEFENCE.

CONTAINING SUGGESTIONS FOR THE ESTABLISHMENT OF AUXILIARY DEFENCES IN AID OF A MOVEABLE FIELD FORCE.

By CAPTAIN WESTMACOTT, R.E.

The confidence formerly entertained that the insular position and naval superiority of England secured its shores from invasion having been considerably shaken, and the necessity for placing the country in a position to defend itself from insult and punish aggression having been considered and advocated by the highest authorities, it is not proposed, in introducing the following remarks, to enlarge upon the subject further than is necessary to arrive at the immediate object of this paper.

It is assumed that an invasion, partaking more or less of the nature of a surprise, is possible; that the ultimate object of an enemy, beyond mere insult or local injury, would point to the Metropolis; and that, from the comparatively small force probably available on the emergency, the first object of the defence would be to check the enemy's advance, and gain time for the collection of sufficient troops for his final discomfiture or annihilation.

To occupy every point on the coast where a descent is probable would be neither possible nor desirable. Martello Towers and Coast Batteries, in well selected positions, would be in the highest degree valuable in increasing the difficulties of a landing, but the great outlay requisite would preclude the works generally from being of such importance as to demand the delay of a regular siege, while minor works of any pretension, situated *on* the coast and incapable of properly resisting an attack in force, would, on being reduced, afford the enemy a convenient "point d'appui" and be a serious injury to the defence. Not so, however, if the first line of defensive works were established some distance *inland;* the circle of defence would here be narrowed, enabling a smaller force to act with advantage, and when ultimately carried, the positions would to the enemy be comparatively useless, while to the defence, every hour's delay being of importance, their object would, in a greater or less degree, be fulfilled.

To these Auxiliary Defences in aid of the available Field Force the following remarks refer, as distinct from works of greater importance that would be required for the protection of Harbours and for other local purposes, or, assuming extremities, ultimately to arrest the enemy, and compel him to fight a battle on ground of the defender's own selection.

In the event of a landing having been effected, in the face of such opposition as the defences and the troops immediately available on the coast could offer, the latter, it is presumed, would fall back, disputing the enemy's progress with considerable advantage, the enclosed nature of the country generally favouring their purpose. If, therefore, positions to retire upon were previously prepared, support would be afforded to their operations, and time gained for concentrating the regular forces upon the front menaced, and for collecting, at certain pre-arranged points, the Militia, Local Corps, and Volunteers. These rallying points should, for their ultimate purposes, contain sufficient powers of *offence* to bar an enemy's progress until reduced, and be secured from being carried by a "coup de main" or assault without previous attack by artillery, thus rendering negative the enemy's probable measure of pushing rapidly forward with his light troops only, and obtaining possession in advance of his main army of points of importance on his proposed route. For immediate or ordinary use, the works might afford barrack accommodation for regular troops, or serve as depôts for the Militia, with the contingent of arms, stores, and ammunition that might be required on an emergency by that particular section of country and no more, in order that an enemy might not benefit by their possession.

In the event of an attack, these positions might be held by volunteers or local levies, aided by a proportion of regular or veteran troops, leaving the main strength of the Army available for the active duties of the field, while placing the others in a position to do important service, of which they would not be capable, if opposed, in open collision, to a disciplined and experienced enemy.

The distances from the coast at which the first circle of these Auxiliary Defences should be established would necessarily depend on local circumstances, as would also the number and nature of the positions to embrace a given section of country. It might not appear requisite that every approach should be secured, as the enclosed nature of the country would compel the enemy to advance in three or more separate columns, and an impediment opposed to one would cause the combination or at least the detention of the rest; yet, in a country with the lines of approach so numerous and good, precautions must be multiplied, and as will be presently explained, means exist at no great cost for establishing lines of defence, on which points may be prepared convertible at any time into tactical positions; and the consideration of expense is not of sufficient importance to prohibit the provision being made. The final or interior line of defence, on some part of which the ultimate struggle may be expected, would require either some superior works or entrenched camps, to which the minor auxiliaries would serve as a connection—this line should be sufficiently in advance, probably eight or ten miles, to prevent the Metropolis being immediately affected by the active calamities of an attack.

The question of defence must, of necessity, be considered in connection with that of the expenditure involved. It not unfrequently happens that positions good in themselves, are rendered ineffective or possibly injurious by being occupied with feeble works, of which the data are founded upon the cost rather than the requirements of the case; or that where defences designed upon a liberal scale are undertaken, their completion is dependent on the amount of funds gradually appropriated for the purpose, thus involving the serious possibility of the works being found unfinished and open to attack upon the occasion arising. Peculiar circumstances might render this consideration worthy of attention.

It is with the view, therefore, of meeting the necessities for defence, under the difficulties assumed, that the following system is suggested, premising in the first place that the positions in question, though not requiring for their ultimate completion the expenditure, or pretending to the importance, of fortresses, yet possess considerably greater powers of resistance than mere field works thrown up on the emergency would afford; and it will be endeavoured to show how, by a particular arrangement, it appears practicable to effect this without any vast aggregate outlay being either immediately or ultimately required.

The substance of the system which is proposed for adoption is simply that the works for any intended position should be designed and carried out on a *principle of progression*, commencing as it were from a nucleus, complete in itself, and capable of being added to, either during the progress of any one part or subsequently, without interfering with its immediate object or arrangements, each stage of the construction preserving the same conditions, being so far complete, independent, and susceptible, without involving the alteration of work already executed, of being improved, added to and strengthened.

The accompanying sketches will illustrate the principle upon which it is proposed to establish and develop the works, commencing with the simplest and most economical form of a defensible building or blockhouse, useful for immediate purposes, and capable of being subsequently improved, by additions, equally simple in themselves, into a trace of considerable capacity and strength.

A site having in the first instance been selected suitable for its present and prospective requirements, and of sufficient area to permit the after arrangements being carried out, the progressive steps may be thus described.

1st. A single block building, or keep, to be erected, containing accommodation for a few men as guard, with stores, magazine, and local armory; the whole to be loopholed, the windows secured and provided with musket proof shutters, and the roof, as a precaution against fire or being easily torn up if attacked, to be of corrugated iron. If intended to be left as an isolated building, an upper floor might be added, or projections built, as shewn in sketch, to flank the exterior.

2nd. The next step, or supposing more extensive accommodation to be required, would be the addition of four or more similar blocks, in the form of a cross, enclosing the central block or keep, and affording a mutual flanking fire. The central portion to be lighted from the roof, or arranged to project between the exterior blocks, to allow space for windows being introduced. The whole to be loopholed, the doors and windows properly secured, and the building sufficiently prepared for defence against a desultory attack, without interfering with its occupation for general purposes. A small ditch should be formed, giving height and security to the loopholes and windows.

The cost of a building, such as described in sketch A, should not exceed £300, if one story high, or £500 if an upper floor be added. That in sketch B would amount to £1200, or £2000 if in two stories; in the one case affording barrack accommodation for about 100 men, with two officers' quarters, stores and magazines, in the latter for 200 or considerably more for short periods.

3rd. If intended for a position of importance, precaution against surprise and cover from artillery fire would be required. A ditch, with a rampart of earth, is therefore next provided, sufficiently high to protect the buildings from direct fire, part prepared with banquettes for musketry, and part for heavy artillery or guns of position to command the approaches.

Thus an enclosed redoubt would be arrived at, such perhaps as shown in sketch C, being the simplest form of the proposed works before being further developed.

Assuming such a redoubt to be assaulted and carried by superior numbers, the defenders, having resisted to the last moment, retiring within the defensible building or keep, would, with a close musketry fire, themselves unseen, sweep the interior of the work, allowing the enemy no time for spiking guns or improving the advantages gained; thus it is conceived, rendering it necessary that the interior building should, in the first instance, be destroyed by a fire of artillery, or otherwise rendered untenable, not only in part but altogether, as a breach in one section would not prevent the active defence of the remainder, while the fire from the adjoining section or the central block would prevent its occupation by the enemy.

To effect its destruction by a fire of artillery, at low angles, over the rampart by which the building would be covered, though possible, is difficult and uncertain in practice, and would occupy time, while to shell the redoubt, or open approaches against it, would be assigning to these simple works an importance, which to say the least, would be very desirable for the defenders.

Up to this point it has been supposed that the slopes of the ditch and the covering rampart have been left at any angle that the nature of the soil permitted. In some parts of the South of England especially, which is also otherwise well adapted for this description of defence, the chalk formations would at once afford means for giving a good scarp to the works. Where these facilities did not exist, the impediment offered by the simple earth slope might be improved by palisading or any other expedient usually resorted to. As timber, however, is perishable, and liable to many methods of destruction in a resolute attack, obstacles at a moderate cost, of a more permanent description, and less easily surmounted, are suggested in sketches D. Nos. 1 and 2 describe a masonry wall on the summit of the earth scarp—this could not be escaladed without ladders, and to carry these up the slope and rear them, in an unavoidably constrained position of body, would at no time be easy, and is certainly liable to considerable difficulty and repeated failure under an active fire from the defenders, while the great length of ladder, (nearly forty feet), necessary to reach the wall from the bottom of the ditch, and its consequent weight, would almost preclude that method of getting over the difficulty, whether the ladders be in one or several lengths. The summit wall, sketch No. 1, with the parapet at the back, would only apply where the ground was of a very solid or tenacious nature, probably allowing of being itself scarped to a sufficiently steep slope. The detached summit wall, No. 2, being freed from the pressure of earth immediately behind, could, if the weight were properly distributed, be in many instances employed. No. 2 is also preferred, as giving an additional fire from its loopholes, and greater facilities for retrenchment if breached, as well as affording no footing on the top, thus presenting greater difficulties in descending to the interior, if escaladed. If the ground be too weak to permit any weight on the top of the slope, a wall such as shown in sketch 3 might be employed at the bottom of the ditch—this would not be expensive and is of general application. The proportional cost of a revetment wall, such as would be employed in permanent fortification, requiring a similar length of ladder as in sketches 1 and 2 to escalade it, would be as thirteen to one nearly.

No fixed data can be laid down, either for the buildings, or for the trace and particular nature of the defences themselves, these will necessarily depend upon the site and the features of the neighbouring ground, but it is presumed that an enclosure redoubt such as shewn in sketch C, would apply very generally, and be a good centre to work from, and this alone, without further development, would, with a profile such as shewn in sketches D and properly flanked, afford a powerful means of resistance, with a garrison of 300 to 500 men.

The cost of a work of the above nature, with the defensive enclosure and flanking caponnieres, exclusive of the building within, might average from £2000 to £3000.

If this be still deemed insufficient for its ultimate objects, the subsequent development is shewn in sketch E; detached works being disposed in front formed upon the bastion trace, with flanks broken as there described to fire upon the slopes of the redoubt, and the rear as well as the faces of the bastions. A second and a third series of such bastioned fronts, traced upon the data shewn in detail, might be progressively added, the modern improvements in the range of the small arms permitting the extended lines of defence. The figures upon the sketches shew the progressive steps in the construction.

In the case of an extensive establishment, for whatever purpose, being in the first instance determined upon, the requisite buildings, in place of being disposed in form of a cross as in sketches B or E, might be arranged to enclose a square space, as in sketch F, with connecting walls at the angles. This arrangement of the buildings at once suggests their capability for forming the curtains of a bastioned work with ditch and outworks, similar in principle to sketch E—the counterguard in front serving as a rampart to cover the masonry of the curtains, and upon which to mount guns for the active defence. The outworks themselves might contain defensible keeps, convertible as barracks or cavalry stables, the inner or rear walls being slight, in order that no cover might be afforded to an enemy in occupying them, and thus these works being seen into, and in turn commanded, by those behind them, would, if useless, be not detrimental, supposing the garrison in the first instance too weak efficiently to occupy and defend the whole. The surplus earth excavated from the ditches might be formed into a glacis, with advanced covered ways of large capacity and slopes of easy access for cavalry or artillery, to facilitate sorties or afford temporary cover to the field force when pressed; light epaulements for guns could be thrown up at convenient spots for occasional use, or as cover for the artillery from rifles or long-range muskets.

The system of outworks here proposed, detached but mutually supporting, with the security finally given by the redoubt and defensible building within, are conceived to be particularly calculated for the force that would probably, for the greater part, be employed as the garrison. The fall of one work leaves the others intact, while a continued enceinte, if forced in one part, is difficult to recover, and this would possibly cause a panic among defenders unused to the union of discipline.

The above outline may, it is hoped, sufficiently explain the intention and nature of the defences suggested, the fortresses existing or required upon the coast or inland being, as before observed, a separate consideration. In regard to the works in question, the first outlay is small, each portion as constructed is useful and complete in itself, while the additions may be made from time to time as circumstances demand or allow. The defensive buildings with the covering rampart would form a serious impediment to an enemy at an inconsiderable expense, and when ultimately elaborated as proposed, would assume a formidable importance. A few good positions around London or on its approaches occupied with works such as described, which as a distinction from fortifications may be called permanent field works, could in a short time be converted into the strong points of an entrenched camp to cover the metropolis on any side open to menace.

Before quitting this subject it may be suggested that works of the above nature, either in their early state of progress as redoubts, or as subsequently developed, would appear capable of being adapted to colonial defence, where expense and the numbers and nature of the troops available require a careful attention.

The first part of this paper has been occupied in considering generally the employment of defensive works in aid of a force to be opposed to the sudden irruption of an enemy, superior, not only in numbers but probably also in discipline, to the greater part of that which, in the first instance, could be brought against it.

That such would be the position of England, if ever attacked, there is sufficient reason to suppose, and it appears therefore necessary that measures should be taken to enable the inferior force to check and successfully resist the superior, and to place inexperienced troops or raw levies in a position to use their own weapons to the best advantage, and be at the same time secured from the effects of their adversaries,—such is the spirit and intention of fortification—an art to which, with the small standing army maintained by Great Britain, it would be prudent to give more attention. The name of fortification produces with some persons the idea of a vast and an unproductive outlay—the same may be said of police and of many other measures requisite to a State, but which, being more immediate and present, are admitted and acted upon. It may be desirable to examine how a portion of these unproductive expenses can be brought to answer a double purpose, by systematizing the outlay or annual expenditure required for them, and employing it in advancing the defensive arrangements referred to in the previous remarks.

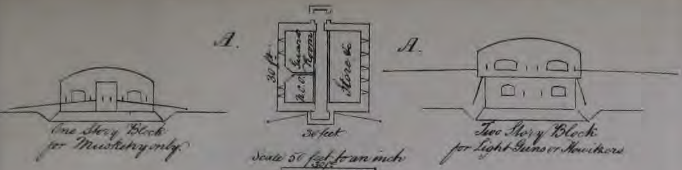
Numerous instances might be advanced of large works, such as barrack or other military buildings, gaols, penitentiaries and poor houses, or of small posts, such as Coast Guard stations, and, especially in Ireland, the police barracks, which might be advantageously adapted to military purposes without injury to their particular objects, if, in the first instance a proper site were selected, and a few simple defensive elements introduced into the general arrangement of the structure. If this be admitted, large sums would thus become available for forming a network of minor defences throughout the kingdom.

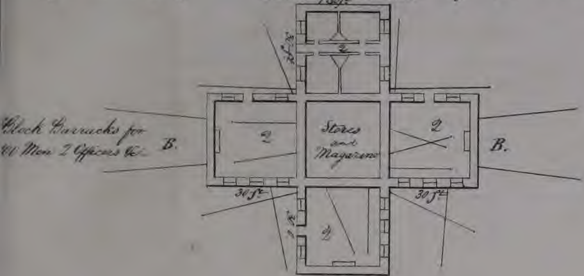
An opportunity also presents itself by taking advantage of the militia depôts, in forming the nucleus of internal defences that would be in the highest degree valuable, either for local or general purposes, as auxiliaries to our small force of disciplined troops.

The militia depôts, containing their stores, arms, and ammunition require to be in some measure defensible for their own security: the making them sufficiently so for ulterior purposes would not necessarily involve any greater initial expense, the principal point for attention being, that in selecting a site, attention should be given not only to its immediate fitness for the depôt, but to its relative usefulness as a protection to the place, or as commanding any particular approach; this might be desirable for local political objects as well as for general defence. In respect to the Militia Artillery, especial provision appears desirable for their prompt collection upon any point exposed to attack—their depôts might be placed in important coast works or detached in batteries and defensive seaboard positions.

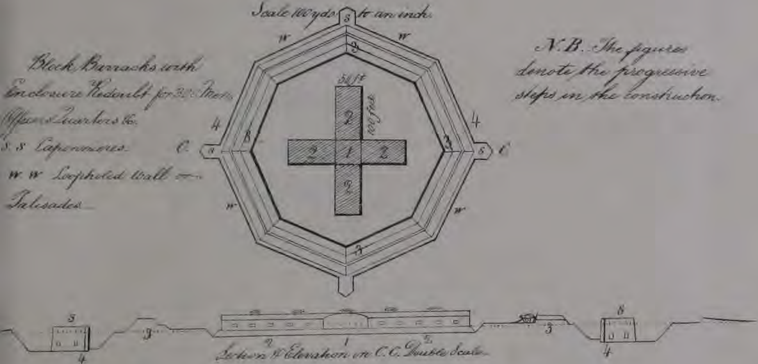
In the accompanying suggestions and sketches, all details except such as appear requisite to explain principles have been avoided, and the simplest form, both in the buildings and their subsequent development into defensive works, has been preserved—the subject is capable of such extended handling that some difficulty has been experienced in condensing without involving it in obscurity, but to enlarge further upon it would occupy too much space, and exceed the limits of a paper, which proposes to treat, only generally, upon the points under consideration.

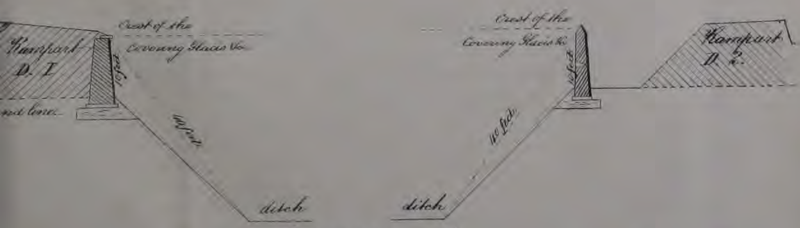
S. WESTMACOTT, Captain R.E.

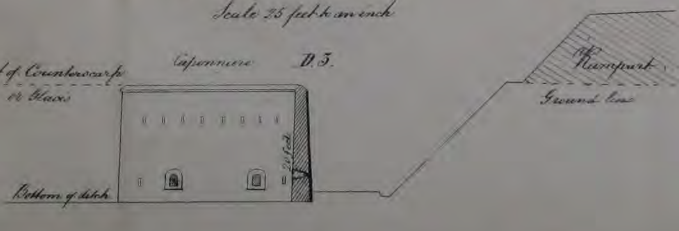

A.
A.
30 ft.
Guard Room
N.C.O.
Stores &c.
Stores &c.
30 feet
One Story Block for Musketry only
Two Story Block for Light Guns or Howitzers
Scale 50 feet to an inch


30 ft.
Block Barracks for 40 Men 2 Officers &c.
B.
B.
Stores and Magazine
2
2
2
2
30 ft.
30 ft.

Redoubt
C.


Scale 100 yds to an inch
N.B. The figures denote the progressive steps in the construction.
Block Barracks with Enclosure Redoubt for 300 Men Officers Quarters &c.
S. S. Caponnieres
W. W. Loopholed Wall or Palisades
W
W
W
W
4
4
C
C
2
2
1
2
2
3
3
3
Section & Elevation on C.C. Double Scale


Crest of the Covering Glacis &c.
Rampart
D. 1
Ground line
40 feet
ditch
ditch
40 feet
Crest of the Covering Glacis &c.
Rampart
D. 2
Scale 25 feet to an inch

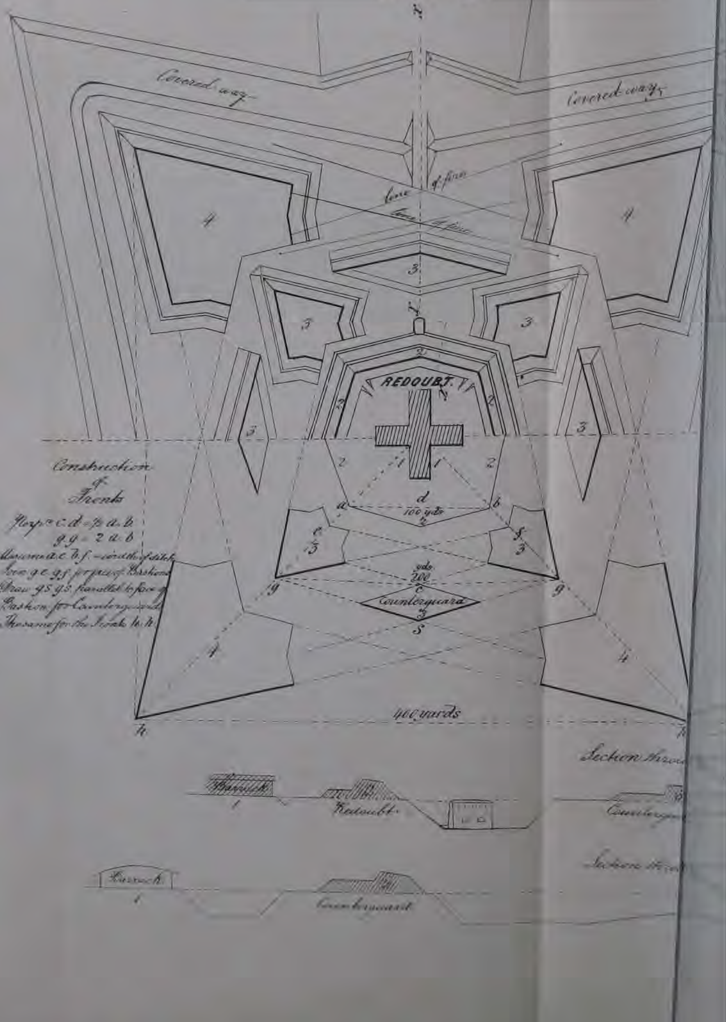

Caponniere
D. 3.
Crest of Counterscarp or Glacis
Rampart
Ground line
20 feet
Bottom of ditch

Trace showing a method for the Progressive Development
Redoubt with detached Bastio

N.B. The slopes to be palisaded or revetted &c as required

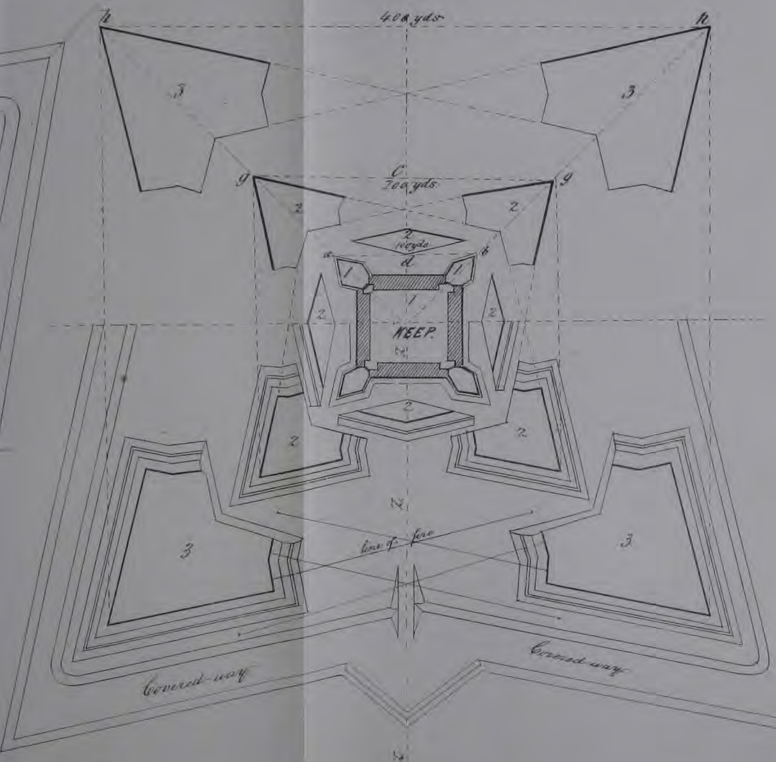
Scale 100 yards

Sketch V.



Works upon a Block Building or Keep and Central
r other advanced works.
figures denote the successive stages in the construction.
r inch.

Sketch F.



lan E on X.X.X.

an F on Z.Z.Z.

PAPER VIII.

ON METEOROLOGICAL OBSERVATIONS.

By MAJOR JAMES, R.E., F.R.S., M.R.I.A., F.G.S., &c.

The intention formerly expressed of publishing in the Professional Papers the abstracts of the meteorological observations taken at our principal stations has been abandoned, not only because it has been found that the size of the pages will not admit of the tables being printed in a proper manner, but because it is thought that it would not be judicious to load the volumes with so large a mass of tables on one subject, (and that, possibly, one in which many of the officers take little interest). An application has therefore been made to the Lords of the Treasury for authority to publish the abstracts in a separate quarto form, and we shall thus be able to supply every officer with a copy of them.

Since the establishment of the meteorological observatories at our stations, a very important event has occurred which will have great influence on the science of navigation, and will enable us to form more just conceptions of the physical laws which govern the circulation of the atmospheric and oceanic currents, and meteorological phenomena in general.

I allude to the results of the proceedings of the maritime conference, held at Brussels in August and September, 1853, for the purpose of establishing a uniform system of meteorological observations at sea, and to concur in a general plan of observation on the winds and currents of the ocean.

The meeting at Brussels, to use the words of the Report, "was convened at the instigation of the American government consequent upon a proposition which it had made to the British government, in reply to a desire which had been conveyed to the United States, that it would join in a uniform system of meteorological observations on land, after a plan which had been prepared by Captain James of the Royal Engineers, and submitted to the government by Sir John Burgoyne, Inspector General of Fortifications." This meeting was attended by representatives from Belgium, Denmark, France, Great Britain, the Netherlands, Norway and Sweden, Portugal, Russia, and the United States; and the governments of Russia and Spain have since expressed their regret that through some misapprehension as to the time of meeting they had not sent representatives also.

The representatives on the part of Great Britain were Captain Beechey, R.N. and Captain James, R.E. M. Quetelet, the Astronomer Royal at Brussels, presided at the sittings.

By carefully collating the observations on the direction of the wind and of the currents of the ocean, from the log books of upwards 10,000 voyages, Lieutenant

Maury of the United States Navy*, has been able to construct a series of wind and current charts which have already proved of the greatest value to navigators.

In constructing these charts the ocean is divided into spaces of 5° of latitude and 5° of longitude, and the direction of the wind which is observed at any given time in any one part of these districts is assumed to be that in which it is blowing in every other part—this is the only assumption made. A special chart is appropriated to each month of the year, the course of the vessels during each month is pricked off on the charts, and the direction of the wind and currents in traversing the different spaces is noted on them; and in this way a knowledge of the prevalent direction of the wind and currents in all parts of the ocean, and at all periods of the year, is arrived at. A "pilot-chart" is then constructed, on which the results obtained from the separate monthly charts are represented, in spaces between the rays of what is called a "Rose," so that the general result is presented at one view to the navigator.

From this brief sketch of the principles upon which the wind and current charts have been constructed, it will readily be understood how Thermal charts of the ocean are constructed, and the course of warm or cold currents, like that of the Gulf stream and that from Davis's Straits, traced out, and how in like manner the course of the Isothermal and Isobarometrical lines can be traced across the ocean.

This system of investigation has been already most fertile in results, which are thus alluded to by the Secretary of the Royal Society. "The routes to many of the most frequented ports in different parts of the globe have been materially shortened, (that to San Francisco in California by nearly one third); a system of southwardly monsoons in the equatorial regions of the Atlantic and on the west coast of America has been discovered; a vibratory motion of the trade-wind zones, with their belts of calms and their limits for every month in the year, has been determined; the course, bifurcations, limits, and other phenomena of the great Gulf stream have been more accurately defined: and the existence of almost equally remarkable systems of currents in the Indian Ocean, on the coast of China, and on the north-western coast of America and elsewhere has been ascertained. There are, in fact, very few departments of the science of meteorology and hydrography which have not received very valuable additions; whilst the most accurate determination of the parts of the Pacific Ocean (which are very limited in extent) where the sperm whale is found, as well as the limits of the range of those of other species, has contributed very materially to the success of the American whale fishery, one of the most extensive and productive of all the fields of enterprise and industry."

But when it is considered that even for spaces so large as 5° of latitude and 5° of longitude the least number of observations which are required for the three great oceans amounts to the enormous number of 1,669,200, the minimum number for each square being 100; and when it is borne in mind that certain parts of the ocean are more frequently traversed by the vessels of one nation than by those of another, and that some parts are very rarely traversed by any, it will be evident that this admirable system of investigation, so ably begun by Lieutenant Maury, can only be carried out effectually by the co-operation of all the principal commercial nations; and for this purpose the conference at Brussels was assembled.

A form of log to embrace all the observations required was agreed upon at the conference, as well as the hours at which the observations should be made and the mode of making them. The form of log contains the columns for the latitude and longitude of the vessel by observation and by dead reckoning, for the direction and rate of the current, for the observed magnetic variation, for the direction and rate

* The United States Astronomer at Washington.

of the wind, for the height of the barometer, the temperature of the air and of evaporation, for the forms and direction of the clouds, the number of hours of fog, rain, snow, or hail, the state of the sea, and the temperature and specific gravity of the water at the surface and at certain depths, with occasional observations with thermometers having white, black, and sea-green bulbs.

The great importance of using no instruments but such as have been previously compared with standard instruments is strongly insisted on,* and a mutual interchange of sets of the instruments to be used by each nation recommended.

"The conference having brought to a close its labours with respect to the facts to be collected and the means to be employed for that purpose, has now only to express a hope that whatever observations may be made will be turned to useful account when received, and not be suffered to lie dormant for the want of a department to discuss them."—See report of the conference.

This recommendation has been wisely and most liberally responded to by our government, and Captain Fitzroy of the Royal Navy, so well known for his scientific ability and labours, has been appointed to take charge of a department expressly formed for the purpose under the Board of Trade.† The governments of the Netherlands, Norway and Sweden, Belgium and Portugal have also appointed officers to carry out the recommendations of the conference, and thus we may hope to see "at length, every part of the ocean brought within the domain of philosophic research, and a system of investigation spread as a net over its surface, till it becomes rich in its benefits to commerce, navigation, and science, and productive of good to mankind." See Report.

The establishment of this system of co-operative investigation amongst nations marks a great epoch in the history of science, but to reap its full benefits, co-operation amongst the meteorologists on land is also absolutely necessary, and the most eminent amongst them in Europe and America (both North and South) have already expressed a strong desire for a second conference to arrange the details of such a system: and there is every ground for hope that before long we shall see it held, and arrangements made for mutual interchange of the results obtained from the observations taken in all parts of the world. We shall then establish a system, to use the words of Sir Thomas Brisbane, by which the science of meteorolgy will be more advanced in a few years, than it has hitherto been in centuries—for as Lieutenant Maury very justly observes, "the importance of concert among meteorologists all over the world, and of co-operation between the observer on shore and the navigator at sea, so that any meteorological phenomenon may be traced throughout its cycle, both by sea and land, is too obvious for illustration, too palpable to be made plainer by argument, and therefore the proposition for a general conference to arrange the details of such a comprehensive system of observation addresses itself to every friend of science and lover of the useful in all countries." See Lieutenant Maury's Sailing Directions, 5th edition, p. 30.

W. JAMES, Captain R.E.

15th May, 1854.

* The American government has already ordered 1000 Thermometers to be made and compared under the direction of the Officers of the Kew observatory.

† The admirable, and from the nature of the subject in such a place, most remarkable speech of Lord Wrottesley, in the House of Lords, on the 26th April, 1853, contributed greatly to the success of this measure.

PAPER IX.

NOTES ON THE CONSTRUCTION OF A BATTERY WITH A FOUNDATION OF FASCINES.

BY CAPTAIN HEINLÉ,

OF THE PRUSSIAN ROYAL ENGINEERS.

Translated by Captain Bainbrigge, R.E. from the "Archiv für die Offiziere der Königlich Preussischen Artillerie and Ingenieur Corps," for 1852.

Orders having been sent for the construction of a battery for seven heavy guns without delay to enfilade the main channel of the River Oder below Stettin, it was commenced on the 2nd of April, 1848, under the direction of Captain Heinlé, of the Prussian Royal Engineers. It was arranged that it should consist of three faces, the centre one for three short 24 pounders and two 25 pounder howitzers, the right for two iron 12 pounders, and the left to contain only a magazine; the gorge was to be closed by a palisade, and there was to be a block-house inside, intended for a keep and barrack. The site chosen is a swamp at least 20 feet deep, the surface of which lies only one and a half to two feet above the ordinary level of the water, and it had been overflowed shortly before the work was commenced, so that it was necessary to form a solid foundation for the whole battery, because the soil was so soft that, without this, it would have been incapable of supporting either the parapet or the blockhouse.

For this purpose the whole surface to be occupied by it was covered by two layers of fascines crossed, along the exterior of which others forming a border were added above them; these fascines were merely bundles of brush-wood tied in two or three places, and were a foot in diameter and ten feet long.*

The earth for the parapets and terreplein was then wheeled in, and two other layers of fascines, crossed as before, were formed in the parapet itself, to prevent the soft material of which it was composed from slipping.

The mud taken from the ditch was so moist that it could not be rendered solid by ramming, and it was necessary to cut small drains at the foot of every slope to carry off the water which ran from it.

After the rampart was formed, it had to be covered with a layer of regularly formed fascines, carefully picketed down, over which a layer of sand six inches thick was placed, in which the sleepers of the gun platforms were laid. The surface of the ramp was formed in the same manner, except that it had no sand, but planks were laid over it when the guns were brought up.

* The importance of making the fascines *compactly* is however pointed out by Major General Lewis, C.B. in his Notes on their use in foundations in Vol. VI. Professional Papers, p. 217.—ED.

The interior area was also covered with sand six inches thick, as otherwise it would have been impassable after rain.

The materials for the blockhouse and magazine were* fitted together in Stettin; the erection of the former occupied two days, and that of the latter six hours, but the covering of it was much delayed by the difficulty in getting dry earth for it, which had to be brought by water from a distance.

The beams which formed the roof of the magazine were covered with fascines, over which a layer of straw three inches thick was placed, and the walls were surrounded by straw and brushwood, outside of which sand was filled in one foot thick to carry off the water from the damp earth surrounding the whole; it had also a double floor, and its walls and roof were well caulked with oakum.

The erection of the palisades at the gorge was difficult, as the ditch in which they were fixed required to be excavated below the level of the water, and the palisades sank irregularly in the soft soil; therefore portions of the ditch were cut off by dams and the water pumped out, after which a layer of brushwood one foot thick was formed at the bottom, and two inch planks were laid over it, upon which the palisades rested, and the latter were secured by two ribands inside, and by fascines picketed down along the bottom on the outside.

A wharf for landing the guns was also constructed, which was supported by a strong trestle and two pontoons. As the work was ordered to be carried on day and night the sappers were divided into three parties of eleven men each, and were relieved every six hours, and 300 labourers were employed; thus on the sixth day the mounting of the guns was commenced, and on the twelfth day the whole battery was complete.

The result of the night-work was unsatisfactory, and was not equal to more than one-third of that produced by the day-work during an equal time; this was partly caused by the difficulty of *lighting* the surface sufficiently. Lanterns were found insufficient, as they lighted up only a small space and dazzled the workmen, so that they could not see the path for their wheelbarrows, and often slipped into the ditch; therefore bundles of pine branches were stuck up and ignited, and five of these were found to light up the whole battery sufficiently.

The rampart and palisading of this work have stood well, but the parapet required to be heightened nearly twelve inches, in consequence of sinking as it became dry. The block-house sank a few inches, but its walls remain vertical. The powder magazine sank irregularly, and was found to be so damp that it was rebuilt, care being taken to construct ventilators; and it was evident that fascines placed under the earth covering such buildings would not last, as in this case they were found to have rotted within four months after the work was completed.

* Although not distinctly stated, the expression here used (abgebunden) *implies* that both these buildings were formed of *timber*.—Ed.

PAPER X.

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EXTRACTS FROM RECORDS OF EXPERIMENTS

MADE AT THE ROYAL ENGINEER ESTABLISHMENT AT CHATHAM WITH

LOADED SHELLS, PIERRIERS, AND A FOUGASS.

COMMUNICATED BY COLONEL H. JONES, R.E. DIRECTOR.

REPORT OF EXPERIMENTS ON THE EXPLOSION OF LOADED SHELLS, IN AN EARTHEN PARAPET, MADE AT THE ROYAL ENGINEER ESTABLISHMENT AT CHATHAM.

4th August, 1853.

1. A 13-inch shell loaded with 11½ lbs. of L.G. powder was buried in the end merlon of an elevated battery, the line of least resistance being 4′ 6″, as shown in Plate 1. The charge was ignited by means of Bickford's fuze, and by its explosion destroyed the cheek of the embrasure, completely filling up the embrasure with the debris, the crater left being 4′ 6″ deep, and of an irregular elliptical area 19′ 0″ by 13′ 0″.

2. A 10-inch shell with 4 lbs. of powder under similar circumstances did not destroy the embrasure, but only made a crater in the merlon 2′ 6″ deep, with a circular area of 9′ 0″ diameter. (See Plate 1.)

3 and 4. Two tin cases six inches in diameter by six inches long, each filled with five pounds of powder, were buried in the front part of the merlon, (see Plate 1.) The line of least resistance of No. 3 being 4′ 6″, and of No. 4 5′ 0″, and the interval 9′ 0″; by the explosion of these charges the whole of the front portion of the merlon was destroyed, the craters being 2′ 2″ and 4′ 0″ deep respectively, No. 4 forming a deeper crater than No. 3, (partly caused by the line of least resistance being greater, and partly owing to the charge of No. 3 exploding a second or two before that of No. 4.)

* The results of other experiments with 10-inch shells having a charge of 7 lbs., made at Chatham, 30th May, 1853, are shewn in Plate 2. The effect of shells thus buried is of course more than that produced when they *bury themselves* at the same depth; as in that case, the holes which they make in falling are only partially filled with earth, and the lateral effect of their explosion must be less.—ED.

ROYAL ENGINEER ESTABLISHMENT.

Register of Experiments with Pierriers, the Diameter of the Bore being 16 inches.

4th August, 1853.

Number of Experiment.	Powder in oz.	Stones, lbs.	Elevation, degrees.	Range in yards.	REMARKS.
1	40	95	75°	..	The stones were thrown very high, and were very much shattered by the explosion; the pierrier jumped on its bed and remained standing at an elevation of 82°, the lower quoin also was displaced and drawn back one inch towards the trunnion, shewing that this charge is too great. The range could not be ascertained. The stones averaged from 1½ lbs. to 5 lbs.
2	24	95	75°	70	The stones fell about 70 yards from the pierrier but were much shattered.
3	16	95	75°	50	The stones fell more together but close to the pierrier and they were not too much shattered by the explosion, as in Nos. 1 and 2. In these three experiments a quantity of chips of stone were left in the chamber, and the quantity increased as the charge of powder was diminished.
4	12	95	75°	30	Much closer together than in the previous experiments.
5	16	95	60°	70	Much the same as No. 2.
6	16	95	45°	80	Further than No. 5, but more scattered.
7	8	95	45°	30	Fell close to the mouth of the pierrier.
					The Director considered No. 3 was a good experiment.

10th August, 1853.

The experiments this day were carried on against the head of a double sap at a distance of about 70 yards.

Number of Experiment.	Powder, oz	Stones, lbs.	Elevation, degrees.	Range in yards.	REMARKS.
1	16	95	75°	50	The stones fell far short of the sap.
2	12	95	45°	60	,, ,, fell at about the proper distance.
3	12	95	45°	60	,, ,, ditto, ditto, many being found in the sap, so much so that the sap would have been much delayed.

CONTINUATION OF EXPERIMENTS WITH PIERRIERS.

13th August, 1853.

The experiments made this day were carried on against a redoubt the area of which was about 1370 square feet inside the crest, the pierriers being 60 yards from the centre of the redoubt.

Number of Experiment.	Powder, oz.	Stones, lbs.	Elevation, degrees.	Range in yards.	REMARKS.
1	16	95	45	90	Stones much scattered, main body fell about 90 yards from the pierriers.
2	16	95	45	80	Much scattered, but a proportion fell in the redoubt, the majority about 80 yards from the pierriers.
3	24	95	75	..	Thrown very high, and a strong wind blowing at the time carried some of the stones behind the pierriers and scattered them so much that this experiment was not of any value.
4	12	95	45	70	Fell all round the redoubt and many inside: this charge appears to answer for a range of from 60 to 70 yards.
5	12	95	45	70	Also very effective.
6	24	190	45	..	Ranged about 150 yards, but the stones were much scattered. A pierrier would be of no service at this distance except against a large body of men.
7	16	190	45	80	Ranged about 80 yards, and very effective at that range.
8	12	190	45	50	Ranged 50 yards, very effective at that range.
9	14	190	45	80	Ranged 80 yards, but much scattered. These stones were principally of a large size.
10	12	170	45	60	Ranged 60 yards, but much scattered. These stones averaged about 1½ lbs. each (small).
					All these charges were fired with wooden bottoms 11″ diameter and 1 inch thick, the arrises being rounded to allow them to fit closely into the bottom of the chamber: with the wooden bottoms the stones were thrown much closer than without.
					The stones were sized as much as possible; those of large size would have most effect, but a charge should always consist of stones as much as possible of one uniform size.

8th September, 1853.

The experiments commenced with a charge of 12 oz. and the charge was gradually increased up to 24 oz. The ranges are an average of four observations, viz., two of the shortest range of the main body of the stones, and two of the longest: the weight of each charge of stones was 170 lbs.

At an elevation of 45 degrees.

Charge in oz.	12	13	14	15	16	17	18	19	20	21	22	23	24
Range in yds.	50	60	70	80	90	95	95	100	100	120	135	145	155

At an elevation of 60 degrees.

Charge in oz.	12	13	14	15	16	17	18	19	20	21	22	23	24
Range in yds.	45	55	60	65	70	70	75	90	100	110	105	110	115

All these charges were fired with wooden bottoms; with the large charges (from 20 oz. upwards) the stones were very much shattered. The stones were sized roughly, the pierrier being filled to within 3 inches of the muzzle at every shot.

From the foregoing experiments it appears that the pierrier may be used with good effect with stones of about 2 lbs. weight at from 50 to 160 yards range, the elevation being 45°; the charge of powder at 50 yards being 12 oz., and increasing 1 oz. for every 10 yards increase in the range; beyond 160 yards the stones are very much scattered, and the explosion of the charge of powder necessary to throw them beyond that range breaks the stones into very small pieces, and renders them of little effect. A wooden bottom should always be used, and the pierrier should be filled to the muzzle with stones, which gives a charge of about 170 to 190 lbs.

For a range below 50 yards the elevation should be increased to 60°; this elevation will give an increase of about 5 yards for each ounce above 12 oz., commencing with that charge at 45 yards; and the decrease will be about 5 yards per oz. to 8 oz., below which the stones would not have much effect: for the short ranges the weight of the stones should be about 4 lbs.

Baskets to contain the stones would no doubt keep the charge closer together and allow an increased range to be obtained.

EXPERIMENT WITH HAND-GRENADES FIRED FROM PIERRIERS.

The result of four rounds of hand-grenades is given below, the hand-grenades being loaded with sand. The number of hand-grenades used was 21 in each round, their weight being 1¾-lb. gives a total charge of 36 lbs.; the elevation was 45°.

No. 1.—	6 oz. powder,	35 yards.	Scattered in a circle about	6	ft.	radius
No. 2.—	7 ,,	55 ,,	ditto	ditto	12	ditto
No. 3.—	9 ,,	91 ,,	ditto	ditto	25	ditto
No. 4.—	11 ,,	131 ,,	ditto	ditto	30	ditto

REPORT ON THE EXPLOSION OF A STONE FOUGASS UPON THE GLACIS IN FRONT OF ST. MARY'S CASEMATES AT CHATHAM ON THE 7TH OCTOBER, 1853.

The preparation of the fougass was commenced on the 5th instant by one non-commissioned officer and eight men; it was completed upon the following day, but was not loaded or prepared for explosion until the morning of the 7th instant.

The fougass was of the form shown in Plate 3. The charge of powder used was 80 lbs., which was lodged in a 14-inch box, over which was laid an oak shield 3′ 9″ square and 4 inches thick: this shield was formed by doubling 2 inch planks with the grain crossed. Over the shield, four tons of stones (flint) were placed in the first instance, but 1⅔ tons were afterwards added, so that the total load was 5⅔ tons of stones, each ton of these stones averaging by measurement about a cubic yard.

In order to explode the charge, a powder hose, properly cased, was carried up as shewn by the line DEAxy on the accompanying sketch (Plate 3), and at the end of this was fixed two feet of Bickford's fuze, which was ignited by a slow match.

The explosion was very successful, the stones being scattered to a distance of about 250 yards, and over a wide area, with such force as would have told with fearful effect upon the head of an advancing column or upon passing boats. The oak shield was broken into fragments.

Return of expenditure of stores and materials used in the stone fougass, exploded on the 7th of October, 1853.

Oak shield 3′ 9″ × 3′ 9″ × 4″	1	
Cubical box 14″ × 14″ × 14″	1	
Hose trough (interior dimensions)	17	feet lineal.
Powder hose	17	ditto
Bickford's fuze	2½	ditto
Powder	80	pounds.
Slow match	2	inches.
Pickets	20	ditto
Flint stones	5⅔	tons.

Tools used for construction,—

8 Picks	1 Field level
8 Shovels	1 Hand saw
1 Mallet	1 Hammer (claw)
1 Tracing line	1 Tape
1 Rammer	1 Measuring rod.

Also one hand-cart and wheelbarrows for collecting stone.

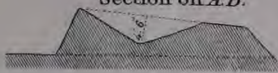
This "Pierrier-Fougass" is taken from the French plan with the exception that in the latter the charge and shield are placed in the position denoted by the dotted lines.

* The surface A E would require sheeting if the soil were loose.—ED.

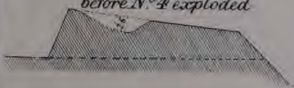
SKETCH SHEWING THE RESULTS OF EXPERIMENTS WITH SHELLS,

made at the R. E. Establishment Chatham, 4th May, 1853.

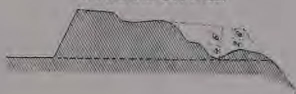
Section on *A.B.*



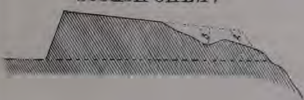
Section on *C.D.*
before N.º 4 exploded



Section on *G.H.*

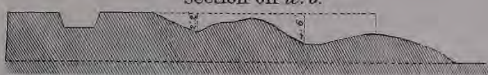


Section on *E.F.*

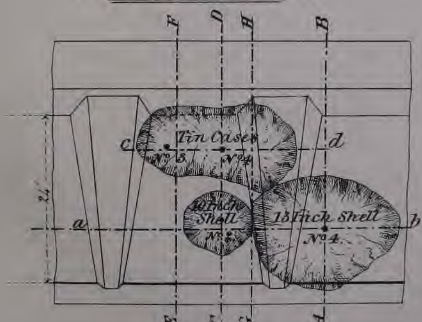


Section on *c.d.*

Section on *a.b.*



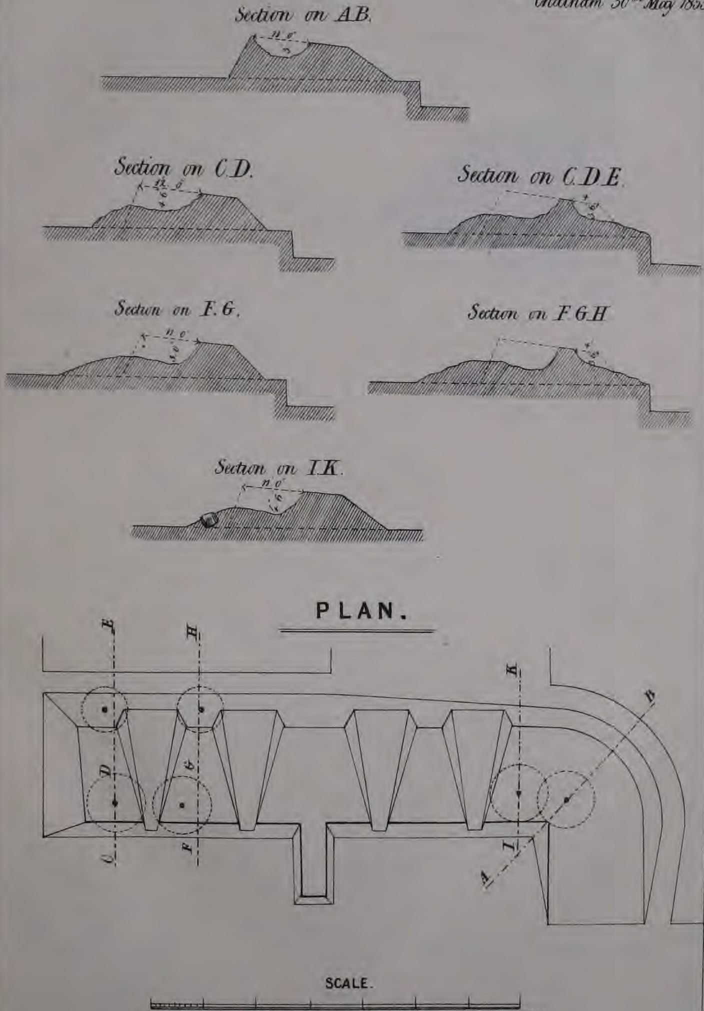
PLAN OF BATTERY.



Scale, 20 Feet to an Inch.

Plan and Sections of a Battery shewing the effect produced by the explosion of 10 inch Shells with a Charge of 7 lbs of Powder

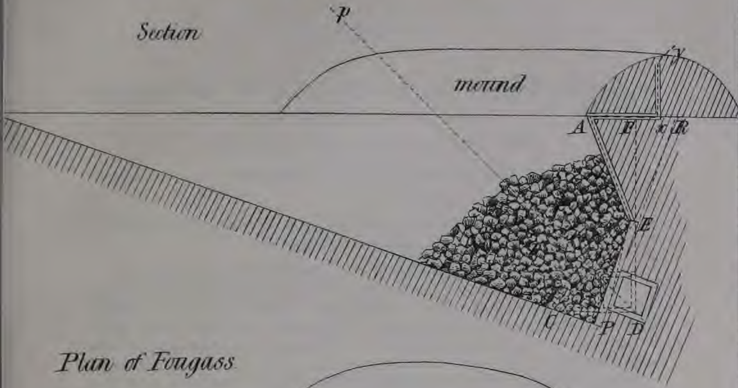
Royal Engineer Establishment
Chatham 30th May 1853



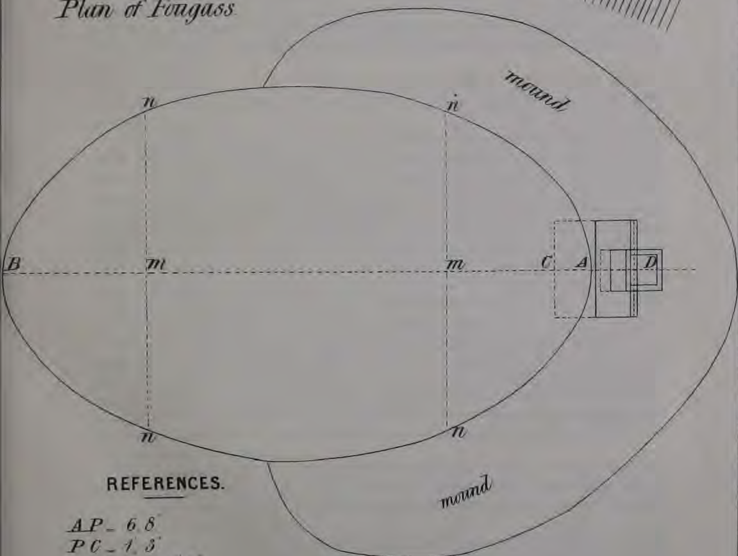
FOUGASS.

Fired at the R.E. Establishment, Chatham, 7th Octr 1853.

Section



Plan of Fougass.



REFERENCES.

A.P. = 6. 8.
P.C. = 1. 3.
C.D. = D.E. = 2. 7.
C.E. = 3. 8½
A.F. = R.F. = F.E./3 = 1. 4½
A.B. = 21. 3.
A.m. = B.m′ = 5. 3½
m.n. = m′.n′ = 5. 6½
Charge = 80 lbs
Box 1¼ cube
Z. 5⅓ Tons of Stones

Scale 5 feet to an inch.

PAPER XI.

REMARKS ON THE USE OF ASPHALTE IN COLD CLIMATES.

BY COLONEL H. SAVAGE,
Commanding Royal Engineer in Nova Scotia.
AND LIEUTENANT PARSONS, R.E.

Extract from a Report on the Seyssel Asphalte used at Fort George, Halifax, Nova Scotia.
BY LIEUTENANT PARSONS, R.E.

"The magazine yard was covered in 1849 with Seyssel Asphalte of the fine quality, laid one and a quarter inch thick on a bed of concrete, and having a fall from the magazine to a gutter turned in the asphalte; asphalte fillets were laid against the magazine and area walls. Each winter till the present year (1854), when occasional mild weather rendered it practicable to remove the frozen snow and examine the asphalte, many and extensive cracks were found in it, and the general levels of the surface appeared considerably elevated by the frost, the gutters so much so as to throw the water from them towards the magazine, and the fillets were found to be loosened from the surface.

The defects so discovered in the asphalte were thoroughly repaired each year before the commencement of the cold weather, but invariably with the same result each succeeding winter.

The asphalte covering of the superior slope of the parapet of the Cavalier Barrack, which was laid on a bed of concrete in the summer of 1850, has each winter failed in a similar manner to that on the area of the magazine, and apparently from the same cause, viz., from the expansion caused by the moisture absorbed and contained in the masonry, as also from being unprotected by a covering of earth from the severe frosts; which instances afford ample proof that where asphalte is exposed to the direct action of frost it will always prove a failure in a climate so severe as Nova Scotia. In 1851-52, and 53 four casemates for officer's and soldier's barracks were covered with three-quarter inch asphalte of fine quality, laid in two coats breaking joint, each coat being three-eights of an inch thick, and the earth forming the rampart was filled in over the asphalte from three and a half to six feet in depth.

Two of the casemates first asphalted and covered with earth were found to have leaks where the arches butted against the interior retaining wall; on examination the fillet in connection with the walls was found to have parted from it The use of fillets was then discontinued, asphalted brick being built upon the three-quarters of an inch covering of the arch until a joint in the ashlar masonry was reached, when the upper stones being removed, a coat of asphalte was laid over and carried well into the thickness of the wall.

This practice was continued throughout the remainder of the casemates, and these, from being uninhabitable on account of the water coming in streams through the arches, are, since the application of the asphalte, perfectly dry, and are now occupied by officers and soldiers.

Wherever it was found impracticable to do without fillets, deep grooves were cut in the brick work or masonry to receive them, and rubbed with a small quantity of mineral tar. The thickness of the asphalte over the casemates exceeds that stated in the Company's book of instructions as sufficient for covering arches, (viz., seven-sixteenths of an inch), on account of the practical difficulty of laying it so thin and evenly in two coats; and although the wooden guages used were less than three-eighths of an inch thick, it was found from the expenditure of asphalte that the two layers actually amounted to nearly three-quarters of an inch in thickness; in this extra quantity there appeared a decided advantage, as bubbles of air or gas arising in it were rarely found to extend quite through the three-eighths of an inch coat; their number and occasionally large size shewed the utility of the precaution of laying the asphalte in two coats. In the course of the work it was found desirable to effect adhesion between cast-iron and asphalte, so as to leave no opening for water to insinuate itself between the asphalte covering and the iron hopper heads of the vertical drain pipes: a small quantity of mineral tar rubbed over the surface of the iron caused the asphalte to adhere to it so strongly that a surface of four square inches lifted a weight of 60 tons. Asphalte was also found to adhere readily to granite and free-stone when their surfaces were in like manner rubbed with mineral tar.

Two tanks (each to contain 66,000 gallons of water), and their filtering chambers, together with a small reserve tank for 30,000 gallons more, having been built, the top of the arches being four feet below the surface of the parade in the Fort, the groined inverts at the bottom being floated over with asphalte of fine quality, three-quarters of an inch thick, with fillets over the joints.

These tanks have been found perfectly free from external soakage, and are perfectly water-tight, and the water in them has not been affected apparently in any way by the asphalte.

In executing the before-mentioned services 122,000 asphalted bricks were laid, and have in every way answered the purposes to which they were applied; forming a very compact and water-tight lining to walls.

The interior (vertical) slope of the parapet of the Cavalier, lined in 1850 with asphalted brickwork appears to have been affected by the frosts to which it has been exposed, it having cracked in several places, evidently from contraction of the materials.

There is no other asphalted brickwork in the fort exposed to the weather except the top of the parapet, but the evidence here afforded shows that, unless it is protected by a covering of earth, it will not stand the climate even for a season. The asphalte used was generally mixed with about 4 per cent. of mineral tar; great care was taken, in laying it, to have all surfaces perfectly dry and the joints free from dust; and all bubbles of air or gas that rose were pricked with pins, and the holes filled in with hot asphalte.

The asphalted bricks were prepared and the whole of the asphalte was laid by a portion of the 18th Company Royal Sappers and Miners, instructed by Corporal Penton who had been sent to learn the process at the Seyssel Asphalte Company's works in London.

(Signed) R. M. PARSONS, Lieutenant R.E.

13th February, 1854.

Extract from a Memorandum, by Colonel H. Savage, Commanding Royal Engineer in Nova Scotia.

"From the results of the above experiments and my own personal observation for over five years, I am decidedly of opinion that asphalte, unless covered with several feet of earth, or otherwise *protected from the action of the frost*, will never succeed in a climate so severe as that of this country; having found it invariably to fail where it has been exposed, as in the case of the pavement in the area round the south magazine, and in the lining and covering of the parapets of the cavalier of the citadel at Halifax. The expansion and contraction of the asphalte in winter was particularly noticeable, some of the cracks having opened nearly a quarter of an inch, and on the return of warm weather they became nearly closed."

PAPER XII.

RECORDS OF EXPERIMENTS ON THE PENETRATION OF BULLETS,

MADE AT THE ROYAL ENGINEER ESTABLISHMENT AT CHATHAM.

Communicated by CAPTAIN H. ORD, R.E., *by permission of the Director.*

Register of Experiments on the resistance afforded by various materials to Bullets fired from the Regulation Musket and Sappers' Carbine, and also to the projectile fired from the Minié Rifle.

Royal Engineer Establishment, Chatham, 21st May, 1852.

DIMENSIONS &c. OF ARMS, EXPERIMENTED WITH.

	Musket.	Carbine.	Rifle.
Weight of Arm	9 lb. 1 oz.	6 lb. 12 oz.	9 lb. 13 oz.
,, of Projectile	484 grains.	484 grains.	680 grains.
,, of Powder	$4\frac{1}{2}$ drams	$3\frac{1}{2}$ drams.	$2\frac{1}{2}$ drams.
Diameter of Bore	·735 inch.	·733 inch.	·702 inch.
,, of Projectile	·684 inch.	·684 inch.	·687 inch.*
Windage	·069 inch.	·049 inch.	·015 inch.
Length of Barrel	3·25 feet.	2·5 feet.	3·25 feet.

* The ball now approved is only ·568 inch in diameter, its length is ·960 inch, and at 30 yards it penetrates about 7 inches into wet elm boards, whilst the spherical musket ball penetrates only $5\frac{1}{2}$ inches.—Ed.

SAP ROLLERS.

1. No. 1 sap roller was of a heavy construction and well made, being stuffed with gadded bundles of wood, and the whole was strongly bound together; the wood was cut in January, 1852, and was not green, nor very dry. The dimensions &c. of this sap roller were—

	Ft.	in.	
Length	6	0	
Exterior diameter	4	7	
Interior diameter	2	0	
Thickness of ring	1	4	on one side.
Ditto ditto	1	3	on the other.
Weight	1534 lbs.		
Range	10 to 50 yards.		

2. No. 2 sap roller was of a lighter construction than No. 1, of the same kind of wood loosely put together; its dimensions &c. were—

	Ft. In.	
Length	6 6	
Exterior diameter	4 9	
Interior ditto	3 $2\frac{1}{2}$	
Thickness of ring	0 $8\frac{1}{2}$	on one side.
Ditto ditto	0 10	on the other.
Weight	1074 lbs.	
Range	45 to 200 yards.	

It would appear from these experiments, that both the heavy and light sap rollers are shot proof against the arms used, and that the Minié rifle has not shewn any decided superiority of penetration over the other small arms.

FASCINES.

24th May, 1852.

3. These experiments were carried on with a view not only to test these fascines, as fascines, but also to ascertain what thickness of fascine brushwood would be required to make a sap roller shot-proof. The first experiment was against single fascines 9 inches in diameter and 6 feet long, placed vertically one above the other, the target being 3 feet 9 inches high. The wood was not very dry, it was cut in January, 1852.

FASCINE BRUSHWOOD.

25th May, 1852.

4. As it was found that the projectiles generally passed through a *joint*, a target was made of fascine brushwood, two fascines thick, but the fascines were opened and the whole pressed down into a solid compact mass, so that all joints would be avoided. The target was 1 ft. 7 in. thick, 6 ft. long, and 4 ft. high, of the same description of wood as before. Range 50 yards and 100 yards.

27th May, 1852.

5. A target was made 2 ft. thick, of the same length and height as before, and of the same description of wood. Range 40 yards to 200 yards.

From these experiments it may be deduced that a thickness of two feet of fascine brushwood at short ranges of 30 to 50 yards is not a sure safeguard against bullets from the musket, carbine, or Minié rifle; consequently a common sap roller must have its ring of a greater thickness than one foot, although when stuffed with gadded bundles, or even with loose rods, a thickness of 8 inches is sufficient.

Two fascines laid in a double row, are not shot proof.

The Minié rifle shewed no superiority in point of penetration in these experiments, taking the two last experiments only.

GABIONS.

31st May, 1852.

6 and 7. Three gabions were filled with a soil of blackish earth and sand, and placed close to each other in a line; their diameters were 2 ft., 1 ft. 7 in., and 1 ft. 11 in. respectively. Sap faggots were placed at the openings 11 in. in diameter. The gabion wood was cut in January, 1852. Range 20 to 150 yards.

From these experiments it may be deduced, that gabions of 20 or 21 inches diameter, are shot-proof, and only shot-proof, and that when they have been under fire for some time, a ready passage for bullets is afforded through the old shot holes, especially to the Minié projectile.

Sap faggots are not shot proof.

SAND-BAGS.

2nd June. 1852.

8. During the last experiment upon gabions, sandbags were placed at the openings of the gabionade, and some were penetrated entirely by the Minié ball. Range 20 to 200 yards.

Some sandbags were filled with a light sandy soil, and placed on the ground presenting the sides to the firing party, (sandbags unfilled measured 2 ft. 5 in. × 1 ft. 4 in.) they were not shot-proof against the Minié rifle.

4th June, 1852.

9. As it was apparent that sandbags are not shot-proof against the Minié ball, it now became necessary to ascertain what thickness would be sufficient. The target was therefore made of sandbags placed *end-on* to the firing party, and the Minié rifle only was fired. A day's rain had consolidated the earth in the sandbags, and the target was 6 ft. by 1 ft. 7 in. thick. Range 100 to 250 yards.

It would appear that sandbags of the ordinary construction are not shot-proof against the Minié ball, and that a thickness of 1 ft. 5 in. would be about sufficient to make them shot-proof.

[Some of the balls that missed the target struck a brick revetment, the penetration was generally 2 inches, and on one occasion the Minié ball penetrated 2½ inches.]

SOD-WORK.

4th June, 1852.

10. The target was built of sod-work 6 ft., by 4 ft. high and 2 ft. thick. Range 20 to 300 yards.

It would appear from the experiments that a thickness of 2 ft. of sod-work is not proof against the Minié rifle bullet, although quite sufficient against the musket ball. Although this target was compactly built, and well rammed, yet it cannot be said to be a mass of equal density, which must account for the discrepancy of some of the penetrations at short ranges compared with those at long ones. The practice at 200 and 250 yards appears to have been most effective.

RESULTS OF THE FOREGOING EXPERIMENTS.

Materials experimented on.	Range.	Thickness found Shot Proof.
	Yards.	
Sap Roller	10	Two rings, each 8½ inches thick.
Fascines	20	Three 9-inch fascines.
Fascine Brushwood	30	2 feet.
Gabions	20	1 foot 8 inches.
Sand Bags	100	1 foot 5 inches.
Sod Work	200	2 feet.

FIR PLANKING.

2nd August, 1852.

11. A target was formed of 2-inch deal boards in five thicknesses, which were securely and firmly fastened together by means of screw-bolts.

The dimensions of the target were 5 ft. × 5 ft. 6 in. × 10 in.

4th August, 1852.

12. Experiments were continued with the same target.

7th October, 1852.

13. The same target was used as at the last experiments, but having been exposed to the weather for two months, during the latter part of which much rain had fallen, the boards had become to a certain extent soaked with water.

15th October, 1852.

14. Experiments were continued the same as preceding.

ABSTRACT OF PENETRATION AT VARIOUS RANGES INTO A DEAL TARGET AS ABOVE DESCRIBED.

Nature of Arms.	300 yds.	250 yds.	200 yds.	150 yds.	100 yds.	75 yds.	65yds.
	Inches	Inches	Inches	Inches	Inches	Inches	Inches
Musket	..	2·875	3·730	4·234	4·694	6·094	5·427
Sappers' Carbine	..	1·000	2·900	3·291	3·955	3·250	4·708
Minié Rifle	4·875	5·250	5·266	6·031	6·766	5·000	7·354

The foregoing experiments were carried on by Captain Lovell and Lieutenant Tilly, Royal Engineers, under orders of Colonel Harry D. Jones, the director of the Establishment.

REPORT ON THE PENETRATION OF VARIOUS PROJECTILES INTO SNOW.
ROYAL ENGINEER ESTABLISHMENT, CHATHAM.

14th February, 1853.

1. A bank of snow well rammed was constructed having the following section,—

	Ft.	In.
Thickness at base	11	0
do at top	5	9
Height	6	0

And as a thickness of 6 ft. was found shot proof, slices of six inches thick were cut off, and shots fired at the bank till it was reduced so that it was just penetrated.

The arms used were the following:—

Minié Rifle .... Powder $2\frac{1}{2}$ drams .... Ball 680 grains.
Sappers Carbine .... Powder $3\frac{1}{2}$ drams.............. Ball 480 grains.

Range of both 20 yards.

	Ft.	In.	
Minié Rifle, passed through at............	2	9	thick.
Sappers Carbine do	3	3	thick.

The weight of a cubic foot of snow ...... { rammed is $29\frac{1}{2}$ lbs. / loose ....$18\frac{1}{2}$ lbs. }

The snow to form the bank was collected by rolling balls till they became about 5 to 6 feet in diameter; owing to the snow being slightly frozen it would not easily cohere, and the centre of these balls was not so much pressed as when it was rammed in the bank.

Two of these large balls were dressed to even faces and rolled close together, and at 25 yards the Minié rifle bullet with the same charge as above passed through a thickness of 6 ft. 6 in.

Penetration of Round Shot.

16th February, 1853.

2. A bank of well rammed snow having been constructed, the section of which was as follows:

	Ft.	In.
Thickness at base	24	0
Do at top	20	0
Interior height	7	6
Exterior do	6	6
Base of interior slope	1	10½
Do. exterior slope	1	7½

The following field guns were tried against it:—

12-pounder, 9-pounder, 6-pounder.

Range ... 160 yards.

1st round	12-pounder	just through.
	9 ditto	ditto
	6 ditto	lodged several feet in bank.
2nd round	12-pounder	through, and rolled 81 feet.
	9 ditto	ditto ditto 25 feet.
	6 ditto	lodged several feet in bank.

Two more rounds were fired, but as they grazed either previously to entering, or when in the bank, their results are worthless.

Two rounds of *canister* were then fired from the 9-pounder at a range of 100 yards. The average penetration of eight of the 5 oz. balls was 3 ft. 6 in.

Some of these shot also struck a parapet of loose snow constructed similarly to a common single sap parapet (revetted with gabions) and passed through it without difficulty.

(Signed) J. W. LOVELL,

CAPTAIN ROYAL ENGINEERS.

18th February, 1853.

* As in some cases it may be desirable to construct parapets of *ice*, it may be useful to remark that I formed one at Montreal in 1840 of snow and ice, and 9-pounder shot penetrated only 6 ft. 6 in. Into it at 600 yards; and one was afterwards constructed of ice alone into which 24-pounder shot penetrated only 8 feet at 440 yards.—Ed.

PAPER XIII.

RECORD OF EXPERIMENTS WITH $5\frac{1}{2}$ INCH SHELLS,

MADE AT THE ROYAL ENGINEER ESTABLISHMENT AT CHATHAM, IN JUNE, 1850.

Communicated by CAPTAIN H. ORD, R.E.

BY PERMISSION OF THE DIRECTOR.

The Experiments described in the annexed table were carried on by order of the Inspector General of Fortifications, to ascertain the effect of the bursting of shells by repeated trials, the number and size of the splinters, their direction and force: for which purpose a blockhouse, 12 feet square and 10 feet high in the clear, was erected out of old ship timbers averaging 12 inches square in section, the sides of which were sunk 3 ft. in the ground, and rested on sleepers 4 inches thick and 12 inches broad: the roof and floor were composed of timbers similar to that of the sides. (See Plate.)

The shells used were $5\frac{1}{2}$ inches in diameter, and in the first three experiments were filled with powder of the weight shewn in the table.

At the conclusion of these three experiments the blockhouse was very much shaken, and splinters of wood detached themselves from the roof and sides.

In the remaining experiments the bursting charge was limited to the constant weight of ten ounces, which it appeared was quite sufficient to burst the shell, and with effect. The results however are far inferior to those of the shells *filled* with powder.

REMARKS.

The effect and number of splinters of the shells in the experiments vary so greatly under apparently similar circumstances, that it is quite impossible to derive from them any fixed rule upon which to rely; it appears however that, almost without exception, the splinters flew least in the direction in which the fuze was placed before bursting the shell. (See Plate.) The splinters also, with few exceptions, did not rise with very small angles of elevation (very seldom less than one foot in five feet even in extreme cases,) which supports the old theory that it is best to lie down with the feet towards the shell.

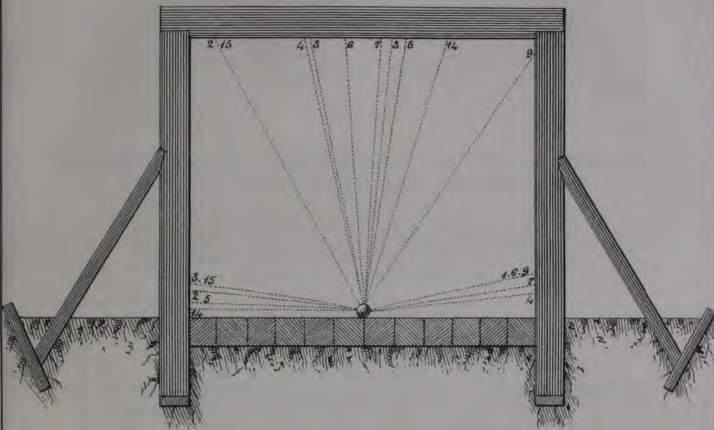
No. of Experiment.	Weight of Empty Shell.		Charge of Powder		Position of Shell.	Number of Splinters into which the Shell burst.	Weight of Splinters.				REMARKS.
							Greatest.		Smallest.	Average.	
	lbs.	oz.	lbs.	oz.			lbs.	oz.	oz.	oz.	
1	14	$5\frac{1}{2}$	0	$14\frac{3}{4}$	Centre of the floor, fuze pointed vertically upwards	24	1	$14\frac{3}{4}$	$\frac{3}{8}$	8·95	Three pieces of the shell buried themselves deep in the timbers (fir) weighing 1 lb. $14\frac{3}{4}$ oz., $5\frac{5}{8}$ oz. and 6 oz. respectively.
2	10	15	1	$2\frac{3}{4}$	Centre of the floor, with fuze to the door	33	0	$11\frac{1}{2}$	$\frac{7}{8}$	5·12	Effect very violent.
3	14	$12\frac{1}{2}$	0	$13\frac{3}{4}$	Ditto ditto	18	1	$11\frac{3}{4}$	$\frac{3}{8}$	11·58	Four of the splinters, weighing 1 lb. $11\frac{3}{4}$oz., 1 lb. $8\frac{3}{4}$oz., 3 oz. and $2\frac{1}{4}$ oz. respectively, buried themselves in the timbers.
4	14	12	0	10	Centre of the floor, fuze pointed vertically upwards	17	2	$3\frac{1}{4}$	$1\frac{1}{8}$	11·00	A piece of the shell weighing $4\frac{1}{4}$ oz. found fixed between two timbers.
5	14	$12\frac{1}{2}$	0	10	Centre of the floor, and the fuze pointed horizontally towards the door	33	1	$14\frac{1}{4}$	$\frac{1}{16}$	6·91	A piece of the shell weighing $11\frac{5}{8}$ oz. buried itself in the ceiling very firmly, and another piece weighing $17\frac{5}{8}$ oz. was found in the floor, just beneath the original position of the shell.
6	14	$12\frac{1}{4}$	0	10	Centre of the floor, fuze directed vertically upwards	16	2	2	$\frac{1}{2}$	13·3	Floor much injured and three splinters buried in it weighing respectively 11 oz., $9\frac{3}{4}$ oz., and 8 oz.
7	14	$8\frac{1}{2}$	0	10	Centre of the floor, fuze directed from the door	22	1	9	$\frac{1}{4}$	10·45	Effect of explosion very violent, lifting the timbers of the roof, three splinters weighing $1\frac{1}{2}$lb., $9\frac{1}{3}$oz. and 6oz., buried themselves in the timbers, the two first in fir and the latter in oak.
8	14	$12\frac{3}{4}$	0	10	Suspended from the centre of the roof in a cradle, fuze pointed perpendicularly upwards	17	2	0	$\frac{1}{8}$	13·7	Explosive effect not very great.

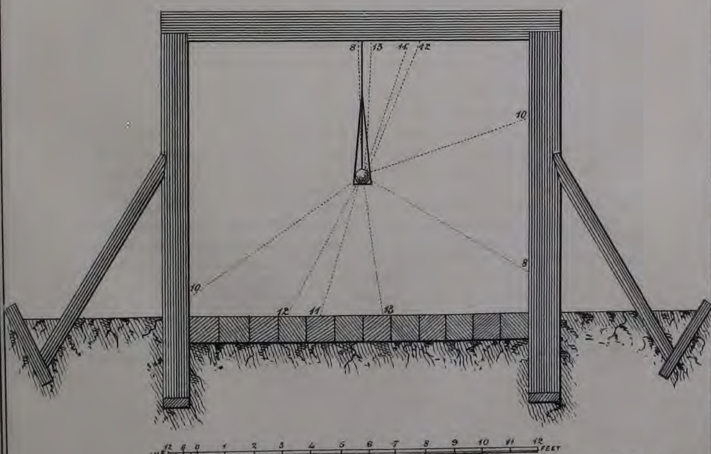
No. of Experi-ment.	Weight of Empty Shell. lbs. oz.	Charge of Powder. lbs. oz.	Position of Shell.	Number of Splinters into which the Shell burst	Weight of Splinters. Greatest. lbs. oz.	Weight of Splinters. Smallest. oz.	Weight of Splinters. Average. oz.	REMARKS.
9	14 10½	0 10	On the centre of the floor, fuze directed horizontally to the door	21	1 10¼	¼	11·00	Explosion detached pieces of the timbers from the outside of the blockhouse, and three splinters were found buried in the timbers.
10	14 15	0 10	Suspended from the centre of the roof, fuze pointing upwards	26	1 15½	½	9·01	The explosion of the shell caused pieces of timber to break off as in the last experiment, and two splinters stuck firmly in the timbers. The weights of the splinters were respectively 1lb., 15½oz. and 9⅝oz.
11	14 12¾	0 10	Suspended from the centre of the roof 5 feet from the floor, fuze pointed vertically downwards	27	1 10¾	⅜	8·66	One splinter weighing 8oz. buried itself in the side of the blockhouse at 4ft. 8in. high from the floor.
12	14 10½	0 10	Suspended from the centre of the roof, fuze pointed vertically downwards. ..	16	2 2¾	1¼	14·00	Explosion very violent, shook the blockhouse very much, several timbers forced back, and and large pieces of wood broken off the outside.
13	15 4¾	0 10	Suspended from the centre of the roof, fuze pointed horizontally to the door	20	1 13¼	¼	11·8	Blockhouse much shaken, four splinters weighing respectively 11⅛oz., 9½oz., 5¾oz., and 5¼oz. were found buried in the timbers.
14	14 14	0 10	Centre of floor, fuze directed horizontally towards the door	15	2 2	¼	15·86	Explosion very violent, bending back several of the upright timbers.
15	14 3	0 10	10 inches nearer the door than in the last experiment, fuze pointed horizontally towards the door	15	2 1½	⅛	15·00	Floor torn up by the violence of the explosion at the spot where the shell was placed, and a treenail which was in the timber driven in several inches, a splinter weighing 1lb. 6½oz. was found buried in a timber in the side of the blockhouse 6ft. above the floor.

N.B.—In each experiment the shell was exploded by means of a piece of Bickford's fuze for dry soil, 3 feet in length.

SECTIONS OF BLOCKHOUSE

exhibiting the result of each experiment by means of the dotted lines numbered accordingly, which shew the highest & lowest directions taken by the splinters produced by each.





Drawn by Andrew Callaghan
Serg.t R.l Sappers & Miners

PAPER XIV.

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MEMORANDA ON THE THEORY OF WAVES, AS AFFECTING UPRIGHT WALLS AND OTHER DESCRIPTIONS OF BREAKWATERS;

With a few Remarks on the Modes of Construction Adopted or Proposed, (Including the Diamond Pier Breakwater, described in the "Professional Papers" Vol. 3, 1853,) and on the Use of Caissons in Deep Water.*

By COLONEL COLE, R.E.

This important and difficult subject is made more interesting by the propositions and opinions of eminent mathematicians, nautical men and engineers, elicited by the "Select Committees on Harbours of Refuge," in 1836 and 1844, whose Reports came but recently under the notice of the writer, since their addition to the Royal Engineer library at the Cape.

As many of his brother officers may not have met with the volume, a summary of the subject, as far as is included in the above heading, may be useful in drawing attention to it, as well as to harbours in general. No other volume affords an opportunity of comparing the opinions of so many qualified persons, brought to bear on all the points necessary to a proper understanding of the requirements for Marine Works. The names which appear on the committees, or in evidence, are guarantees for its affording a useful and agreeable occupation for leisure hours—especially if an interest in the subject has been awakened by following up "business in great waters," or as in the case of the writer, by witnessing and combating hydrostatic power on such works as the Rideau canal, where the pressure on dams and masonry is only less formidable than that of the waves, which is felt only on the surface, below which disturbance is scarcely sensible, and hydrostatic pressure is counter-balanced, leaving little to consider below that level but the difficulty of execution, and the probably greater or less expense of first cost and repairs.

1. Before the present times, which afford so many practical sources of knowledge, greater reliance was necessarily placed on theory. Mathematics are now chiefly, in works of this nature, auxiliary in working out formulæ based on experiment. They clear the way as light troops, and cannot be dispensed with, but unless combined with the steady aid of experience, are not to be relied on in difficulties. Like fire, they are "a good servant, though a bad master." Even in applying a theorem or

* The diamond-shaped piers are proposed by Colonel Cole to be placed at intervals of 150 feet, they consist of strong wooden coffers having piles attached beneath, which are to be sunk and filled with masonry. See the details which are given at p. 119. Vol. 3. Prof. Papers. New Series.—Ed.

formula so based, great caution and judgment are required, especially in a subject so confessedly difficult as the action of waves, which is liable to so many disturbing causes, and is therefore so difficult to reduce to a formula, and which, to use the words of a distinguished and scientific General Officer in his "Dissent," Art. 2, of the above mentioned report, "is attended with great difficulties and anomalies." This may account for the extraordinary discrepancies in observations hereinafter quoted, which shew how much the want of systematic ideas prevails, and may mislead those in search of facts to be depended on. They are therefore quoted without any pretence to criticise, or decide.

It seems at least doubtful whether the theorem quoted in Art. 2 of "Dissent," which supposes a horizontal direction of the force, be applicable to a breaking wave, as it is to the even current of a stream, natural or artificial. On approaching the shore, to use the words of Professor Airy, "the waves become shorter and shorter as they advance, and acquiring increasing tendency to break as they come into shallower water, their faces will be nearly vertical when just preceding the broken state." The same is otherwise expressed by Captain Vetch and other qualified and practical observers. It is obvious that the wave in breaking, instead of continuing in this vertical form, falls over nearly perpendicularly on a low beach or artificial fore-shore: and with a slope of about 5 in 1, the sine of the angle of impact will be that of 90° instead of about 18°. Thus the unmitigated momentum of the wave under the laws of falling bodies will impinge at right angles on the fore-shore. It then, in its broken state, with less weight though with greater velocity, acquires the onward motion, rushes up the plane, impelled by its own force and that of the sea coming on behind it, and, as well as at the moment of impact, carries air with it into the hollows, blows up the face, and does other injury (only partially averted by filling in with small stones, and by careful execution): and the receding wave is scarcely less formidable.

On the other hand, the long wave in approaching a vertical wall in deep water will present a surface inclining backwards, and, as it progresses, bring the higher part of the wave into contact with the wall, and *vice versâ* as it recedes, producing the rising and falling motion in front of the wall, resembling, if not actually being, a mere oscillation, which Colonel H. D. Jones, Royal Engineers, (in the paper submitted to the Institution of Civil Engineers, and appended to the proceedings of the Select Committee on Harbours of Refuge), describes as occurring against the upright portion of the Cherbourg breakwater, and other similar works. The vertical portion of the works at Algiers formed of concrete, had not then failed from chemical action or inferior power of resistance, though they have since, according to French authorities, (partially at least), given way. Unless the nearly vertical action of waves in front of an upright wall in deep water can be disproved, the judicious propositions and profiles given in that paper can scarcely be deemed speculative, supported as they are by examples, and by high mathematical and professional authority.

Professor Airy says of the wave, "it will not strike at all against an upright wall —it becomes a stationary wave—a combination of a direct and reflected wave—it goes up and down without breaking—it is merely an elevation of the surface. I have been in circumstances when I had good opportunity of observing that practically, and I know that it is the case—a hydrostatic pressure only." Captain Vetch says, "There can be no breaking sea upon the pier, as at Plymouth Sound and Kingston. These laws are acknowledged from the times of Sir Isaac Newton, as shewn by Playfair, Bremontier, Webster, Scott Russell, and others. A wave will break only in shallow water, and if no shoal or shelving sea-wall be presented, there will be no breaker, or progressive motion in the water of the wave. The undulation of the sea will only rise and fall against a perpendicular or highly-inclined wall, and recoil." The "Dissent" quotes "with the greatest deference and respect any practical opinion of so eminent a man as Lieutenant-General Sir John Burgoyne," though supposing it "not to contain any very positive or confident preference of the upright wall." That opinion however is thus given in his evidence. "The effect against the upright wall I conceive will be far less. In deep water, the action of the waves, as I apprehend, is an up-and-down undulation, the water having very little forward motion, except when it breaks: a flat piece of wood, floating on the surface, and presenting no hold to the wind, would progress very slowly before the heaviest gale. Therefore I consider that there would be no blow or impulse generally on the upright wall, but merely the weight of the water from the top of the wave to its mean level to be supported. I should not expect that the wall itself would cause the waves to break, and even those that accidentally did so at that particular place would have much of their force caught by the receding of the previous wave, so as rarely to strike with much force against the wall itself. There can be no doubt that a slope could be given to a breakwater which would be very secure. In Holland, the shores even of sand are in many parts secured against the whole force of the North Sea by a surface coating of mere clay and straw—but then the inclination is exceedingly gentle, quite to deep water, not more I apprehend than 1 in 18 or 1 in 24: as the material is increased in size and weight it is to be presumed that this slope may be increased." This seems to embrace in a few words all that can be said on this part of the subject, as relates to sloping as well as upright walls, and with other extracts given will afford sufficient reason for not adhering to mere reference. Sir Charles Pasley expressed his conviction in favor of the upright wall, which affords an additional reason for reconsidering opinions in opposition to it. Those who have held them have also probably been converted, and may have come to the conclusion that the "Ram" against cliffs or lighthouses, and the broken wave or spray mounting to extraordinary heights, are caused by rocks or a shelving shore, or by the cavernous and broken face of the cliff, which catches the wave as it rises, and produces the blow and thundering sound remarked and urged by some witnesses. No such accompaniments will attend the smooth upright wall in deep water, as before stated.

One intelligent witness urges the effect of waves on a ship at anchor, which appears inapplicable, inasmuch as the ship, although without progressive motion, rises and falls, and opposes the full momentum of the falling bows to the rising wave, so as to carry the ship "bows under," and seas of course are then shipped.

The eminent Engineer who constructed the breakwater near Pen-man-Maur to protect the railway, which gave way, doubtless from encountering the force of the waves broken on a shelving shore, would now perhaps add the words "in shoal water" to his testimony as to being "convinced of the folly of erecting perpendicular breakwaters," as quoted in "Dissent," page 12. These examples shew that in making deductions from experiment, we must be as cautious as in applying a theorem to a particular case.

Whatever the profile of a continuous breakwater may be, there will be a considerable body of water in front and rear of it, having its length as a base, which will transmit no motion, except in some degree on the surface in windy weather. The main body of the fluid thus at rest, although it will neutralise but little the effect of the surface-water acting on the inclined plane, will tend to give stability to the vertical wall, without doing mischief on the surface.

In estimating the effect of the action of waves on breakwaters, we are naturally led to consider, not only the form of the movement, described by some as cycloidal (vide extract from a paper by Mr. Scott Russell—note, page 12 of "Dissent" which should be read throughout.) but also the rate of progression—the depth at which waves break—the depth of disturbance in deep water—the height of the wave—its force—and other general or local facts. The rate of progression has been so variously estimated as to suggest great caution in coming to a conclusion. Some high authorities have been before referred to, both for and against a high velocity. In a note, page 170 of Weale's Series Vol. X., the rate is estimated as high as 80 miles per hour. This seems to exceed even the effect of oscillation, the horizontal force of which in front of an upright wall is as little felt as the tidal wave of 1000 miles an hour, which gives no blow. What is commonly called "swell" or "ground swell" is probably of this nature, and is often opposed at different angles to the direction of the wind at the time of observation. Professor Minard of the "Ecole des Ponts et Chaussées" says (1852), "les vagues observées au large sur un navire, presentent des soulèvements des eaux de la mer, qui se suivent, et semblent s'avancer, en marchant le plus souvent dans le sens du vent. Mais ce mouvement de translation n'est qu' apparent en très grande partie, car, si on jette à l'eau un corps flottant qui suit fidèlement les mouvements des flots, on le voit s'élever et s'abaisser successivement, en s'éloignant très-peu de la verticale, à moins qu'il ne donne prise au vent lui même, ou qu'il n'y ait courant" which corresponds with the testimony previously expressed by Lieutenant General Sir J. Burgoyne. Mons. Minard rates this undulating transmission at 20 mètres per second, or 42 miles an hour, in the Bay of St. Jean de Luz. This, although only, as he says, apparent, is still excessive, but, supposing that some small error has not occurred in the second's observations which would become great in the aggregate, this may be partly accounted for by the accumulation of water in the angle formed by the coasts of France and Spain, after a north-wester, which in shoaling, without means of escape except by eddies or under-currents, causes a reaction upwards, and forms the swell so notorious in the Bay of Biscay, which cannot be progressive in a great degree, and therefore must be undulating. If it were otherwise, with the excessive height of wave sometimes imagined to exist, the banks of the Garonne and other rivers would be perpetually flooded, and the iron coasts in other parts would scarcely resist the force. With regard to the velocity of the surface-waves caused by the wind, he says they are "d'une vitesse notable," but that "les expériences à ce sujet n'ont jamais pu être faites bien exactement." Elsewhere he rates that velocity at three or four times less than that of the wind. This, in a storm of 45 miles an hour, would give ten or fifteen miles per hour to the wave, which is probably far beyond the highest rate in any gale, and at all events the increase of velocity would be less than in the arithmetical ratio of that of the wind. In sailing before the wind a wave may perhaps appear to pass the vessel slowly, but it will be observed to sink and recede apparently into the trough. The apparent onward motion is instantly renewed, but the undulation raises a fresh body of water; or as far as the eye can follow it the succeeding wave appears to take its place. A float on the water remains behind, shewing the movement to be chiefly one of undulating translation—and except in very long swells at sea 200 or 300 feet wide, the wave, although for a moment its motion seems to outstrip the vessel, has only an apparent motion, till it approaches the low shore, where its undulation seems to be lost, and it is projected in a continuous wave. By remarking the waves in passing a vessel at anchor in an open roadstead, it will be found that the apparent progress does not exceed from 5 to 8 feet per second according as the wind is fresh or amounts to a heavy gale, (or from $3\frac{1}{2}$ to $5\frac{1}{2}$ miles an hour); but in storms may exceed that limit. In harbours or open bays a common yawl will be found to outstrip the apparent motion of the waves in a gale—and the spray in a heavy gale, taken up from the crest of the waves, will outstrip the latter in a four or fivefold degree (however this is difficult to judge of exactly). The scud may therefore travel about 30 miles an hour in a gale of 45 miles per hour, and the apparent velocity of waves be about 6 or 7 miles.

The velocity of the water may be easily tested with a float, making allowance for tide, but that of the wave can scarcely be determined with great precision although sufficiently near for practical purposes, or to satisfy laudable curiosity, which can scarcely be deemed trivial, considering the importance of the subject in connection with breakwaters and harbours.

The undulating motion has been compared with that caused by throwing a stone into smooth water, when an undulation is transmitted with great velocity without causing any progression in the water.

The undulation or vibration said to exist in transmission of sound is similar, the air remaining also without progression from the impulse.

The share which each moving power may have in producing the complicated surfaces of waves is perhaps beyond reduction to form, commencing with the tidal wave, then the oscillation, broken by small waves, and arrested by the upright wall, or broken by the shelving shore.

The exact amount of onward force, if any, brought to bear on a vertical or highly inclined wall, may perhaps be more correctly ascertained by the Dynamometer, than by any other means, but will scarcely exceed the steady pressure of the advancing tide.

The height of the wave has been equally exaggerated—even to 40 feet, owing to some error in taking the actual vertical height from trough to crest, not including spray, or the height to which it is driven on a shelving shore. The writer has never seen any exceeding 11 feet at sea, or on bold shores in Europe, America, and South Africa, in the heaviest gales. Professor Minard rates the height at 3½ métres in the Mediterranean, and 5 or 6 métres in the Ocean in "très gros vents." Even this, supposing one-half to be below the mean level, would expose one fourth of the Plymouth breakwater, and form a cascade of 20 feet thundering on and over it

It is probable then, that no wave breaks on a shore with a vertical height exceeding 8 feet*—as may be tested at the Brighton or other pier—or at Plymouth breakwater, by taking twice the difference of level between the crest of the wave and the known mean level at the moment, not including spray, (verified by a level, if possible), for that between the crest and trough of the wave.

Cherbourg breakwater has a parapet of 3 métres above highest water as sufficient security against the broken wave, and the rush upwards after the break.

A work on embanking published by Weale (1852) estimates the height of single waves at 6 feet, and this is the maximum in Table Bay.

* The late Lieutenant-Colonel Alderson, R.E., observed the height at the Brighton pier in a severe gale to be 12½ feet, and the velocity of undulation to be 18 miles per hour.—Ed.

Since writing the above, Colonel Cole has forwarded the following note by Lieut. Fowler, R.E. for insertion here. "The following is the result of my observations on the rollers at East London (Cape Colony) which I had many opportunities of studying whilst employed in making the Ways for surf boats.

The vertical height from trough to crest independent of surf is full 12 feet, and the width from crest to crest 50 to 60 feet. They sometimes rise to a perpendicular height of 10 feet before curling over. I saw a surf-boat stranded at low water on the bar, and a roller broke over her with tremendous force breaking in the hatchway: the top of the surf appeared to be full 4 feet above the deck before falling, and taking the depth of the boat at 8 feet, and of the water 2 feet, the top of the roller was 12 feet above the bar or 10 feet above the level of the water in the trough."

Since writing the above, an official Report from a Naval Officer, dated August, 1853, has appeared in the local papers, and gives the result of an observation made by the Queen's Harbour-Master:—"Plymouth, September, 1841,—wind N.N.W. moderate. Near the east-end of the breakwater, the waves rose unbroken in a depth of 7½ fathoms to the height of 27 feet above the mean smooth water level." This, of course, in taking the height of the wave, should refer to the mean level at the moment, and consequently the wave must have been 54 feet high, and the trough of the wave must have bared the shoals near the breakwater. A ship of the line in entering must have struck her fore-foot, or even a frigate in plunging into the trough. Deducting the height of the breakwater above high water, there would have been a fearful cascade on the top of it. There is here most likely therefore some clerical error, especially as the wind is quoted "moderate" and N.N.W., which would make smooth water there. The wave is then assumed, in the absence of observation, to be two-thirds of this height, or 18 feet, in Table Bay, and the mean "tidal level" is taken instead of the mean level at high water, with reference to the erection of a pier—and the whole height of the wave is assumed to be above the mean level. On these data was grounded advice to raise the terreplein of the outer pier of a proposed harbour 15 feet above the highest tide, instead of 5 feet, as proposed by an able colonial engineer since dead. This is merely quoted to shew the necessity of taking a correct view of all relating to waves, as connected with Marine works, and that errors may creep into statements made by those best qualified to decide on the subject.

The depth at which waves break is also important in deciding upon the profile of the breakwater, if it be advisable to prevent the break. It seems to be generally received, that they begin to break when the depth of water below the trough equals that of the wave itself, as quoted in Captain Vetch's able report on Dover Harbour. The sudden shoaling on a rock, bank, or bar of a river causes an upward movement which forms rollers more formidable from their nearly vertical slope than from their actual height. Within a bar, unless the water is very shoal and causes breakers to a great extent, the rollers gradually disappear.

Waves seem to lose the undulating movement in coming to water of nearly their own depth, and assume more of the continuous action horizontally, until they fall over vertically. This renders rollers still more dangerous, as there is no relaxation of the onward movement. Monsieur Minard says, "Ainsi près des côtes ou il y a moins de profondeur, les vagues ont une action horizontale marquée, et se brisent violemment contre les obstacles qu'elles rencontrent; c'est ce mouvement aussi bien que la pression due à l'élèvation qu'elles acquièrent par ondulation, qui mine les ouvrages à la mer, et les renverse." This speaks strongly against a sloping fore-shore. He says, that the wave is reported to break over the Rock of Arta at St. Jean de Luz in a depth of 27 mètres, which break is probably only slight, and is rather a vertical movement caused in shoaling. The professor adds that the observations which have been made leave "encore beaucoup à désirer."

The depth of disturbance is stated by some to be at extraordinary depths, according to the view taken of it.

On the banks of Newfoundland, where the depth is 500 feet, the surface is discolored; this is probably partly caused by the Gulf-stream, and by the matter held by it in suspension, which is here met and turned to the eastward. Other observers remark discoloration over great depths, but the water may have been discolored nearer shore, or by rivers. As far as affects marine works, the disturbance may be limited to a little below the trough of the sea at low water, or at the most 10 feet. The 45° slope of the Delaware Breakwater commences at the safe depth of 15 feet below low water to meet extraordinarily low tides and storms.

The slopes formed by the action of the sea at the Cherbourg Breakwater are 5 to 1 or 11 to 2 between high and low water; above that slope have been placed large blocks at nearly 2 to 1 (185 to 100) to break the force of the surf against the parapet; below lowest water they are 3 to 1, and near the bottom 5 to 4. The lower levels have perhaps been rendered flatter by the bursting of the "cones" used at the commencement, and by the spread of the loose stones contained in them, and also by a subsequent experiment of throwing in small stones to form a continued coating, on which larger blocks afterwards slid downwards.

It has been assumed that the force of waves is in the ratio of the resistance of the the bodies moved by them, and that this resistance is as the cubic content of the body; but Mons. Minard gives instances of blocks beyond this ratio being displaced at Cherbourg and Algiers. A safe formula seems yet to be a desideratum, which must be supplied by experiment. M. Minard gives calculations of the force of the wave as equalling from 700 lbs. to 1,000 lbs. (at the least) on the square foot, judging from the weight and surface of the bodies displaced by the wave. Mr. Thos. Stevenson's Marine Dynamometer is said to give 6,000 lbs. to the square foot, referring no doubt to the falling wave. A work on embanking rates it as low as 95¾ lbs. The difference in the position of the bodies, in friction, and in vis inertiæ probably causes this difference in results. Those at Algiers seem to have been observed on the terre-plein, but whether on a smooth or rugged surface does not appear.

2. Whatever conclusions may be arrived at on a comparision of upright or sloping Breakwaters can scarcely affect the judgment on the Diamond Breakwater, which does not oppose whatever force may be brought against it, but by presenting oblique faces on top and sides, avoids concussion, and reflects the waves so as to neutralise each other. The reflection of the wave, by striking on a plane inclined to its course is natural and well known. Monsieur Minard (1852) alludes to disturbances caused by it even in inner harbours.

The Diamond Piers would turn this reflection to good account, and might therefore meet the views of the advocates of both systems, and even of the distinguished subscriber of the "Dissent," as it will, as well as ordinary upright walls, "answer in the sea for isolated and detached works, when no other mode of getting at foundations can be had." They would also meet objections against a continuous wall where deposit is feared, and where the heavy winds and seas arrive obliquely, as at Dover, would afford continuous shelter, without narrowing the openings if thought generally advisable, and render the existence in that case of a second line in chequers unnecessary. This line, if necessary, should have the salients not more distant from the front than the intersections of the faces of the first line prolonged. There can be no fear of their stability, especially on the part of the advocates of the upright wall. It also meets all fears of difficulty in execution, or of instability from that cause, as no working under water or joining and bonding is necessary.

Experience seems to have determined the cases in which the sloping breakwater of rockwork is incontestably advisable, and also the profiles and mode of construction.

The profiles formed by the sea at different depths have been already mentioned under the head of "disturbance."

In its formation, large and small stones are thrown in together, so as to prevent vacancies, which otherwise are found to amount to one-third of the mass, and are the source of damage as before adverted to. The size capable of resistance is found to be from 18 cubic feet upwards, according to exposure, and larger if of concrete. The stability of the latter seems a matter of doubt, and under any circumstances it should be placed below danger from action of the sea, and is perhaps not to be trusted at any depth, especially if formed with artificial cements. The Pozzuolano, and probably other natural hydraulic cements appear to stand the chemical action of the sea better.

The formation of the surface near the top at Cherbourg is with large blocks as before said, as a fore-shore to the parapet, and steeper than the natural slope formed by the sea. Its stability has perhaps yet to be tested. At Plymouth the surface is made smooth between high and low water, and as secure as possible from direct force, or blowing up. More water may perhaps be forced up and over it, than if rougher. The expense of construction and repairs at Plymouth and Cherbourg, with other information, is given in the official and private publications of those best able to afford them, and these are, for the most part, referred to in the "Papers" before the Select Committee.

It may be said that when the breaking of the wave cannot be prevented, as in shoal water, the sloping foreshore is preferable as a breakwater, by presenting an oblique surface to the surf—and, if sufficiently flat, breaks the wave in successive steps, so that the blow on the fore-shore is scarcely felt, as shown by Lieutenant-General Sir John Burgoyne in his testimony—but this requires a proportionately flat slope between high and low water, and causes a consequent expense.

The upright wall seems to have been first brought prominently forward in the paper read at the Institution of Civil Engineers before alluded to. It was recommended before the Committee by many of the highest mathematical and professional authorities, among others, by Mr. Cubitt, in the first instance with a proposition based on it; but he afterwards in some measure seceded from it with others, on account of its being untried in 17½ fathoms, (1844). If the wave be oscillating, or nearly so, as it appears to be in deep water, the upright wall will merely have to oppose whatever progressive force may be given by the wind, which can scarcely exceed seven miles an hour, and will be deadened by the body of water in front of the breakwater having no power of transmission, and by the receding wave. Even did the oscillation not exist at sea, it seems a necessary concomitant of the upright wall, which prevents the advance of the water in its front. The body of water in rear of the wall is a powerful backing to it. The sloping fore-shore, although possessing the same advantage, forfeits it by causing the wave to break—and by creating a new action between high and low water. With regard to execution it cannot be more difficult than the formation of upright or highly inclined pier-heads at the entrances of artificial harbours, which are essential for the passage of vessels and to allow a free current at the bottom to prevent silting up. The difficulty will probably be found to be less at a certain depth, than within the sphere of disturbance.

As regards artificial harbours, another instance may be quoted of errors which may be made by the best qualified men, either clerically, or by an unintentional turn of expression. A very intelligent and experienced engineer is made to say, (page 186 of evidence), "the quantity of silt which gets into the entrance must be manifestly due to the size of the entrance," as an argument in favour of small entrances, which are undoubtedly best as regards scour, though not for the reason stated. The same quantity of water and matter in suspension must get inside in forming a level equal to that outside, whether the entrance be wide or narrow; but, as in the latter case the velocity must be greater, there will be less deposit, which must be the meaning of the witness, although this is not apparent in reading the testimony literally.

The easiest mode of constructing an upright wall below low water will probably be by placing the stones on edge: they should be as large as possible, and well bonded horizontally and vertically, as was done in dams on the Rideau Canal. The stones should be closed and wedged with small stone, so that the cement would fill only the interstices, and no dependance should be placed on the latter, as it is destroyed mechanically and chemically by the sea: even if originally good it generally loses its virtue, unless better packed than usual.

The slope should be steep enough to prevent reaction upwards, even close to the wall, which might render the wave percussive as on flatter slopes.

To stop the passage of surf over the breakwater at Cherbourg and other French harbours (as the sloping breakwater there executed had partially failed), a parapet has been erected on the rock-work, carried up from below the water level, with a fore-shore of heavy blocks, as before stated, to protect the vertical wall; although they may be secure at low water when the waves may be broken up before reaching the walls, yet the sections shew that near high water (pages 26, 27, of Dissent) the wave will not break until close to the wall, which will receive its full percussive force horizontally, as it will not break till within its own depth. If the fore-shore of rock-work were flatter, the wave would break further off; but it would be more economical to have no fore-shore within a depth equal to the height of the wave, or to have a highly inclined wall as proposed by Colonel H. D. Jones. In the former case the vertical wall would be carried down to the rockwork or a little below, with an interior slope as usual of 45° to about the level of half-tide, or above high tide if for an artificial harbour, the water in which would support the wall against a force from the exterior if anything beyond oscillation be anticipated.

If the present Cherbourg breakwater should fail, it will prove nothing against the proposed wall built vertical from the bottom, or from a point below disturbance. The mixed profile is perhaps, to use the words of Professor Airy, "theoretically," if not practically, "without doubt the worst of all." The upright parapet has to meet the force of the percussive wave, broken it is true in part by the rock-work, which has a broad base at a level where no disturbance exists, which force the vertical wall at that level would not therefore have to encounter.

If the parapet be curved, it should be straight to near the top, so as not to lead the surf up, which would increase the spray within.

Mr. Reibel's section of a vertical wall is given in page 21 of "Dissent," based on Colonel Jones's proposition.

3. A distrust of Caissons has arisen, first from the failure of the "Cones" at Cherbourg, which would however have occurred from decay, in the part exposed occasionally to the atmosphere, even if it had not been hastened by storms.

The failure of Westminster Bridge from dependance on caissons seems to have confirmed the distrust. To affirm that this wholesome caution may have arisen from arguing "against the use from the abuse" would be rash, but it may be worthy of consideration whether in the former case, the hopes of success were well founded, and in the latter, whether the piles were sufficiently deep, strong, and close, to reach firm ground, or "bite," and to prevent the lateral escape of compressible matter from beneath the piers; also whether care was taken to remove such matter previously; and whether precautions were taken against the scour, by which, from the contraction of the water-way, the depth was increased, it is said, 3 or 4 feet; and against other probable contingencies.

The propositions before the Select Committee included one, which, considering the length of caisson, and its transport from a distance by sea when loaded, may be considered a very bold experiment, as well as ingenious.

There would undoubtedly be great risk in sinking piers of unusual length to form a continuous breakwater. The foundation might give way partially, in so great a length, and this, or the least sagging in the timbers of the caisson, would cause fracture in the masonry.

It has not been explained how any junction can be formed, as the caisson must remain until the masonry be on its site; and were that not the case, the least motion would prevent junction. Bond seems out of the question between successive portions of the line.

All these objections are met by the caisson of the Diamond Pier, which when loaded drives its own piles, of lengths to meet the inequalities of the ground, rock, or large stones, the nature of which is easily ascertained before sinking. The piles would be strong and close together, and would operate also as sheet piles; they might remain under low water mark, although the masonry would not depend on them above the foundation, where they could be safe from decay and the worm. It is manageable, yet of size sufficient, considering its shape, for masonry calculated to meet any force likely to be brought against it (though a larger caisson might from its size be yet more manageable in a swell), and it seems to meet all objections where a continuous pier is not required. Screw piles only could be driven in the same depth, and would in certain depths of soil form piers as a substitute for masonry, as shewn in Vol. 3, Professional Papers.

The piers would form sides to an artificial harbour where silting was feared, if parallel sides were necessary. The leeward side only might have detached piers to let the silt pass, and on the windward side the action of the surface water might be prevented by timber work between the piers, with a roadway from pier to pier.

The conclusions from the preceding seem naturally to be:

1. That the general motion of the sea is undulating as well against an upright wall as in the offing; but that a sloping fore-shore makes the waves break and become percussive, as against a natural shore.

2. That the velocity of the surface water cannot exceed seven miles an hour in the heaviest storm, and is reduced where the water in front cannot advance, and by the recession of the previous wave, at least in front of the upright wall, if not of the sloping breakwater.

3. That the vertical height of the wave does not exceed 10 or 12 feet at sea, and 5 or 6 feet in lakes, harbours, and roadsteads to leeward of a bank.

4. That the depth at which waves actually break and fall over is about equal to their own height above the trough.

5. That the depth of disturbance, as regards Marine Works, is shewn by the effects of the sea at different depths, producing the profiles formed of loose rockwork before described, and becomes nearly insensible at a little below the trough of the sea at low water.

6. That the force of the wave has been variously estimated, but may possibly be best determined by the dynamometer, and in front of the upright wall will scarcely exceed the ordinary and even pressure of a strong tide; but that on a sloping fore-shore the wave becomes percussive, and of infinitely greater power.

7. That the mixed profile, viz., the upright wall on sloping rockwork is not so secure as the wall built vertical from the bottom, as it has the force of the broken and percussive wave to encounter, instead of the steadier action against the upright wall, which includes only the hydrostatic pressure from the crest of the wave to the mean level, and the velocity of the wave diminished as before stated.

The very great discrepancies of opinion before quoted shew the unsettled state of the question on almost all points which are important in deciding on the profile best adapted to breakwaters; and will, it is trusted, serve as an excuse for the writer in calling the attention of his brother officers to a subject in itself so interesting.

P. COLE,
COLONEL ROYAL ENGINEERS.

Cape Town, December, 1853.

PAPER XV.

TOPOGRAPHICAL NOTES ON THE SEAT OF WAR IN TURKEY,

Translated by Captain Bainbrigge, R.E. from a pamphlet published at Vienna, 1854,

COMMUNICATED BY MAJOR-GENERAL LEWIS, C.B.

The war now raging on the banks of the Lower Danube is on many accounts of the greatest importance to the whole of Europe: if she trembled at the news of its commencement, was aroused and disturbed to the utmost by it, and watched every phase of it with the most lively interest, the cause of this was much less the fear of a general war which it may produce, than the gloomy yet well grounded foreboding that her destiny will be there decided.

The experience of the most ancient times teaches us that the best and safest road to the regions of the east lies along the Danube: and the direction of this stream, which, rising in the very heart of our fruitful quarter of the globe, rolls its mighty flood through so large a portion of its eastern regions, makes it the most natural channel for its trade and intercourse with Asia.

It is accordingly self evident that it cannot be unimportant what power commands the mouth of this, the greatest river of Europe, and if railroads are destined in some degree to supersede the natural channel, yet we know that this must have its limit, beyond which the stream must retain its rights and its importance; and the following notes relative to it, and to the country on each side of it may be useful in facilitating the comprehension of the military operations which have been carried on and are now in progress there.

MOLDAVIA.

If European Turkey* is considered in its relation to the frontiers of the Russian empire, and to the route which a Russian invasion must necessarily take, the first glance at the map will render it clear that the defence of Moldavia is quite hopeless; and that in the condition in which it now is, as regards its capacity for resistance in case of aggression by Russia, it cannot be held in any way.

Moldavia forms a narrow slip of land, the length of which lies north and south. The Carpathians form its western boundary towards the Siebenbürgen and the Bukovina, the river Pruth forms its northern and eastern limit towards Bessarabia, and lastly its southern boundary, where it is connected with the rest of the Turkish empire for a distance of nearly 100 miles, consists in part of the outlying portions of

* The best map of the seat of war is that published at Vienna in 21 sheets, and reprinted by Stanford on a scale of about 11 miles to an inch; but the map published by the Society for the Diffusion of Useful Knowledge will also be found very clear.—ED.

the Carpathians, in part of the little river Milkov, of the Sereth (which flows into the Danube near Galacz), and of a short portion of the Danube itself between Galacz and Reni. The Sereth which rises in the Bukovina, and, next to the Pruth, is the most important river in the country, runs through nearly its whole length from north to south.

Moldavia is for the most part a flat country, and only contains two ranges of mountains of small elevation which spring from the Carpathians of the Bukovina, and run from north to south. It is in general fruitful and pretty thickly inhabited, but in the low grounds near its principal rivers are extensive marshy steppes, which are thinly inhabited and only fit for grazing ground.

The country possesses no natural bulwark to check the advance of an enemy, for the Pruth is not important enough to present any great obstacle to an enemy accustomed to warfare.*

What makes it more difficult for the Turks to hold Moldavia in case of a defensive war, is hovever the circumstance that the only practicable entrance on its southern side, by which the communication with the rest of Turkey is maintained, is but 46 miles wide, namely from Fokszany to Galacz, so that troops operating in Moldavia, would be in danger of being cut off from Wallachia by an enemy advancing from Reni.†

If then the Turks intended to carry on war in Moldavia they could only do so with safety if they at the same time took up a position in Bessarabia, so that resting upon the Danube, the Carpathians, and the shore of the Black Sea as far as Akerman at the mouth of Dniester, they could secure their rear and maintain the communication with the rest of the Empire on the broadest basis. History also proves this, for since the earliest times it has been easier for the Moldavians to defend themselves against the attacks of the Turks from the south, than against their northern neighbours, by whom they have nearly always been conquered in battle, and rendered tributary.

Hence the southern frontier of Moldavia forms the first natural line of defence of Turkey against her northern neighbours; the second is formed by the Danube, which separates Wallachia and Bulgaria.

Wallachia.

This country forms a perfect natural fortress, separated on the north by the impracticable Carpathians from the Siebenbürgen and the Banat, with which it can only communicate by a few very narrow passes, (viz., with the Siebenbürgen by the Volcan pass, which leads by Borczen to Baidej, the Rothenthurm pass on the Aluta, the Torzberger pass between Rukuc and Kronstadt, the Tömezer pass between Sinoja and Kronstadt, and the Bozaer pass between Stana and Kronstadt) and connected with Moldavia only by the before-mentioned narrow tract; it is bounded in every other direction by the Danube, which separates it from Servia on the west, and from Bulgaria on the south and east, as that river, taking a sweep towards the south, and bending below Widdin and at Rassova, forms its boundary for a length of nearly 550 miles from Orsova to Galacz.

The nature of the river Danube is of great strategical importance. Below Orsova nearly as far as Rahova it is very rapid, and consequently affords few points where

* Colonel Chesney, R.A. in his "Russo-Turkish Campaigns," states that the Pruth is navigable throughout almost the whole extent of Moldavia: it is ninety paces wide at Falschi.—Ed.

† This shows how important the possession of Bessarabia is to the *security* of the Danubian principalities, as well as to the command of the Danube itself.—Ed.

large masses of troops can cross to the right bank; the most important of these is between Widdin and Kalafat. Lower down the river the current is less rapid, its breadth increases to between 2,000 and 3,000 feet, and it often divides into several branches and forms islands, which, when the river is full, are in general covered with water, so that it is impossible to form defensible positions upon them. It is also important to recollect that the right bank almost everywhere rises steeply; and is hence difficult of access, and is only in a few places low enough to allow of an enemy crossing to it; but at all these places there are fortifications on the right bank to protect it against an attack. Although this appears at first sight to facilitate the invasion of Wallachia from Bulgaria, the swampy nature of the left bank renders it impossible to cross except at certain points, which can be easily rendered defensible by art, and secured against surprise and assault.

The country itself lies high towards the north, and that part is intersected by the southern spurs of the Carpathians, but in the south below Bucharest (which lies about 255 feet above the level of the sea) it falls suddenly towards the Danube, (which at Brailow is only 46 feet above the sea), and especially towards the east at the bend near Rassova, so that there are in that neighbourhood extensive swamps and morasses.

The most important rivers of Wallachia are the Schyl, the Aluta, (which separates Great and Little Wallachia) the Argis, which flows near Bucharest, and the Jalonitza, which runs into the Danube near Hirsova.

Wallachia possesses no strong places except Brailow or Ibrail; nor any particularly important strategical points, with the exception of the passes on the northern frontier, and the crossing places on the Danube. Giurgevo, Oltenitza, and Turnu, which were formerly more or less fortified, have been demolished, during different campaigns, by the Russians, (as for instance Giurgevo was in 1829.) Bukarest itself, the capital of the country, is not fortified; Brailow also is not really a fortress at present, but is only a place strengthened by ramparts of earth; its fortifications were destroyed by the Russians in 1828, and were never rebuilt, which is a great disadvantage in the defence of the country, since it is not only so situated as to be capable of being rendered by art extremely strong, but can from its position with reference to Matschin its bridge-head, command the line of operations of any army which endeavours to advance from Moldavia into Wallachia, or from Bessarabia into the Dobrudscha;* this was clearly seen by the Russians in 1828, and the greatest exertions were made by them to make themselves masters of it.

Wallachia possesses no system of roads well constructed or strategically laid out. The requirements of traffic have produced but few lines of roads; of these, one begins at Orsova, and running through Czernez, is joined by the lines which lead towards the Banat, and ends at Krajova; from that place, which is the capital of Little Wallachia, one road leads to Kalafat, another to Turnu, and a third communicates with Bukarest. Another line leads from Fokszany, the frontier town of Moldavia, by Rimnik, (where Suwarrow gained a victory and the title of "Rimniksky,") Buzuo, Ploeszti, and Tirsova to Bukarest; from hence two roads lead to the two places of the greatest military importance on the Danube, which have hitherto in all wars served as crossing places from Wallachia into Bulgaria, viz., south-westwardly to Fratesti, Giurgevo, and Rustchuk, and south-eastwardly to Budesti, Oltenitza, and Turtukai. These two roads enclose a triangle, the apex of which is at Bukarest, and the base of which is the Danube, which tract is likely to be of great importance in

* The Dobrudscha is the tract enclosed between the Black Sea and that part of the Danube below Rassova.—Ed.

the present war. The two frontier towns of Orsova and Fokzany are thus united by the roads passing through Rimnik, Bukarest, and Krajova, which are joined by all those leading from the passes of the Siebenbürgen mountains.

Nearly all those roads however are in a very bad state with the exception of the two which lead from Bukarest to Orsova and Fokszany, which are rather better than the others; so that, although they are passable after a continuance of dry weather, they become quite impracticable for the transport of heavy weights, or for rapid travelling during the rainy season, on account of the deep ruts and the entire want of bridges over the raging mountain torrents, the banks of which are steep and high, and over the deep ditches used for drainage; hence also, all warlike operations become impossible during that period.

The country is quite open towards the south, and falls suddenly from the lines which connect Bukarest and Orsova and Fokszany, so as to become quite flat near the Danube. The mountains are covered with forests, but in the low country there is only a little wood along the Danube. The farm houses are generally miserable huts built of clay and wicker-work, and sunk in the ground. The soil is generally very fertile, but little cultivated; great portions of it are however sandy, swampy, and full of lakes and marshes.

The summers are very hot, but in the winter east winds prevail, often causing the temperature to fall very low, and such storms accompany them that warlike operations are rendered almost impossible during that season, (although in the winter of 1828-9 the Turks took advantage of its severity to make inroads against the Russians, and often with good results.)

Notwithstanding that the soil is so fertile that the agriculture consists only in sowing and reaping almost without any laborious preparation, this country does not under existing circumstances produce sufficient to supply a large army with food for a few months. It is this circumstance which considerably lessens the importance of this region in case of a war between Russia and Turkey.

Wallachia presents the necessary basis for Russian operations against the territories of Turkey, without which no results could be obtained, since the small extent of the frontier between Bessarabia and Bulgaria forms really only a defile, which, with proper caution, can be very easily defended by the Turks. But from the narrowness and remoteness of the entrance on the frontier of Moldavia, and the excessive extension of the strategical lines caused by the configuration of the country (its only pivot and point of support being thus at one extremity), the establishment of a large army of occupation is indispensable if any success is to be expected.

But Russia is obliged to bring out of her own territory everything necessary for the supply of her troops, on account of the before mentioned deficiency of produce, if she wishes to maintain an army of 60,000 to 100,000 men in Wallachia during several months; and this, on account of the badness of the roads, is only to be effected by the greatest exertions: it will be recollected that she had in the winter of 1828-9 scarcely 60,000 men in the country, and that of these scarcely two thirds escaped the effects of disease and starvation.

From all this it is evident that Wallachia is most accessible from the south, whilst almost insuperable difficulties stand in the way of her northern neighbours; hence the possession of that country is of immeasurable importance to the Turks in the present war.

Bulgaria.

The third line of defence is formed by the mountains of Bulgaria, especially the Balkan; and this leads to the consideration of that country, which is in many respects of importance to the possessions of the Turks in Europe.

In the first place they possess on the banks of the Danube, a belt of posts more or less fortified, which command all the communications and fords across that stream, from Florentin to its mouth in the Black Sea, and of these a great number must be taken if an enemy on penetrating into the country wishes to secure his rear. These strong places considerably increase the strength of the second line of defence; amongst them are many fortresses of importance, as Widdin, opposite Kalafat; Nicopoli, opposite Turnu; Rustchuk opposite Giurgevo, (which has been strengthened by the Turks with particular care by means of trenches,* ramparts, redoubts, and palisades); Turtukai opposite Oltenitza, (commanding one of the most important points for crossing the Danube); Silistria, opposite Kalarasch; and lastly Matschin opposite Brailow, and Isaktschi and Tultscha which protect the Dobrudscha opposite Reni and Ismail against an inroad from Bessarabia. Amongst the numerous places fortified by redoubts and earthen ramparts, the most important are Florentin above Widdin; Lom Palanka, Zibru Palanka and Rahova, between Widdin and Nicopoli, which command the communications with Little Wallachia; Sistova, between Nicopoli and Silistria; and Rassova, Hirsova and Dojan, between Silistria and Matchin.

Bulgaria surrounds Wallachia like a crescent, having a small projection on the west between the Danube and Servia extending to above Florentin, and a larger one on the east between that portion of the Danube below Rassova and the sea, extending as far as the mouths of that river so as to meet the frontier of Bessarabia.

The northern half of this last projection is rather broader than the southern end, where what is called Trajan's Wall, as well as a canal† communicating between Czernavoda on the Danube and Kostendji on the Black Sea, were formerly constructed, but of which scarcely any traces now remain. This district possesses great strategical importance, for as its southern half is level and the Danube has here a more gentle current and lower banks than it has higher up, the crossing and onward progress of large masses of troops are much facilitated. It is only in the end of autumn and in winter that almost insurmountable obstacles are opposed to all extensive movements of troops by its numerous swamps, morasses, and wide bleak steppes, where the cold, stormy, hurricane-like east wind destroys every living thing exposed unprotected, to its fury.

The Dobrudscha forms the high road for those armies which advance from the north against Constantinople, or vicê versâ, from the south against Bessarabia and Podolia, since it is the shortest and presents the fewest obstacles,‡ also in case they succeed in getting possession of a harbour on the Black Sea, they can be provided from thence most easily with the requisite warlike stores and provisions, and be supported by auxiliary troops.

It was in this direction that the Russians commenced their operations against the Turks in 1828 and 1829, but an army advancing here must be very careful to gain possession of the fortresses lying on the Danube, viz., Brailow, Matschin, Hirsova, Rassova, and especially Silistria, as otherwise they may be entirely cut off. Thus the Russians themselves, after having taken Varna, were obliged to turn towards Silistria in order to get possession of that place before they could think of crossing the Balkan.

Just as Bulgaria possesses on its northern side a natural bulwark in the Danube, and an artificial one in the strong places which cover its right bank, so she has

* "Laufgraben" is the word used.—Ed.

† From the best information as to the relative levels, &c., it seems impossible that any canal ever could have been cut throughout the whole of this space.—Ed.

‡ The Baron Von Moltke describes this tract even as far south as Bazardjik as "destitute of wood and water, so that troops marching across the middle of this district would have to struggle with a total want of all the necessaries of life during a march of about 120 miles."—Ed.

towards the south a natural protecting wall and frontier in the Balkan mountains, the ancient Hæmus, which stretch from the shores of the Black Sea across the whole country nearly in a straight line. They are not very remarkable for their height, but the geological formation of the rock (which rises in great jagged, riven masses, having flat table tops separated by clefts and abysses with perpendicular sides 100 to 200 feet deep,) is such as to render every approach to them difficult, so that throughout their whole length only some few passes exist by which their southern side can be reached. These mountains, especially the tabular tops above mentioned, are also covered everywhere with wood, not however with high trees, but with thick brushwood, through which a man can scarcely push his way, and each narrow pass forms a defile often extending for many miles between steep walls of rock, or through this scarcely passable brushwood. Besides this, vast tracts at their base, excepting in the neighbourhood of the villages, are covered with low oak underwood, which extends to the plains, and renders the march of troops across the country impracticable. The strength of the Balkan range lies therefore less in its extreme height, than in the difficulties of the ground, which being increased by art (particularly by placing abatis and field works at well selected spots), and being defended with bravery, render it capable of being held successfully for a long time by a small force.

That part of these mountains which lies next to the Black Sea on the direct road from Moldavia to Emineh-Dagh is the most accessible, and this has generally been chosen as the crossing point by all hostile armies endeavouring to make their way from the north towards Constantinople. It was on this side that Diebitsch pushed on towards Adrianople in 1829. This portion of the chain is of no great height; its highest summit may be about 6,000 feet above the level of the sea, and it contains in a space of about 46 miles three passes, which unite at one point on its southern side.

We will add a short description of these passes so as to give the reader an idea of this barrier which is fortified by nature itself, and which may be rendered impregnable by artificial obstacles, such as abatis and intrenchments.

The first of these passes connects Varna with Burgas and Karnabat; it leads close to the sea shore, branches close behind Varna into several forest roads which lead over the advanced range of Galata-burnu, and crosses the Kamtschik, which is about 50 yards wide, by means of a floating bridge. The banks of this river are from 6 to 12 feet high, and nearly vertical, and could be defended by intrenchments, as was attempted to be done by the Turks in 1828. The road then crosses the low land, extending for 4,000 yards beyond the river, which is marshy and thickly wooded; divides into two,* and runs over the eastern heights of Emineh-Dagh amongst the thickest underwood, in which no side-paths or cross-roads are to be found, and then it leads on to Aidos and Burgas across the deep valley of Korakdére, and other smaller ones, which in wet weather can only be passed with difficulty.

The second pass is called Kirk-getschid (or the Forty Fords) and connects Pravady and Aidos. There are two roads from Pravady, by Kioprykoi, and by Jenikioi, which unite upon the top of the mountain; on the first there is a rocky defile to pass, which is about 100 yards wide, and is shut in for a length of about 2¼ miles by perpendicular cliffs 600 feet high; and on one side of it is the bed of the Pravady river, which can only be crossed by means of portable bridges. A narrow rocky ridge projecting across this glen commands it, and may be easily formed by art into a fortress. Besides this, there is another deep and narrow valley 14 miles in length to pass

* One of these leads from Derwish Jowan or Kameskoi by Erkelsch direct to Burgas, and the other lies near the coast.—Ed.

through, which may become no less dangerous. The road by Jenikioi* is easier to traverse, but is steep, and is capable of being completely closed by abatis. The plateau also south of Tchenga, on which these two roads unite, may be very easily rendered impregnable, the more so as it is connected with Varna by a carriage road. It was through these two passes that Generals Roth and Rüdiger advanced over the Balkan in 1829, the first towards Burgas, the latter towards Aidos, and from thence pushed on towards Adrianople.

The third and most important pass† in the whole of the Balkan is that leading to Dobrol and Karnabat from Schumla, in front of which are united all the roads from Bessarabia by the Dobrudscha and by the fortresses on the Danube, viz., Rassova, Silistria, Turtukai, and Rustchuk. This pass is commanded by the almost impregnable Schumla, which the Russians endeavoured in vain to take. Between Schumla and Rustchuk lies Rasgrad which protects the road connecting the two former places.

The fourth pass, which is one of extreme importance also, and has been celebrated since the earliest times, is that of Demir-Kapu, or the Iron-gate; it lies exactly at the highest part of the Balkan, and all the roads to Constantinople from the fortresses on the Danube between Turtukai and Sistova lead to it. This pass leads from Stareka,‡ on the northern side of the Balkan by Selimno or Slivna on the heights, to Jambol and Adrianople, on their southern side.

The fifth pass lies between Gabrova and Kasanlik; at the former place the roads from Tirnova and Lofdscha unite, and into these all the roads from the places on the Danube between Rustchuk and Rahova lead. South of Kasanlik the main road divides into two at Eskisagra, one branch turning eastward and uniting with that from the fourth pass at Jambol, and the other leading southwards and ending in the road from Sophia by Mustapha-Pacha to Adrianople.

The sixth is a mountain-pass which lies between Trajan and Tatar Basardschik, and runs along the Osma through an uninhabited, wild, and woody country, and over steep heights, so that it is extremely difficult, and can only be passed through with great exertion.

The seventh is what is called "Trajan's gate," a pass which, (as its name indicates), has existed since the earliest times, and has been used for crossing the mountains by many invading nations. It is of the greatest importance, for two great roads lead into it, viz., that from the northern part of Bulgaria lying on the Danube, and that from Sophia and the south-western part of Bulgaria to Adrianople.

Bulgaria forms a series of terraces sloping down towards the north, and crossed by heights running in the same direction, between which are the beds of streams with high, steep, and rocky banks, rising in the Balkan and falling into the Danube; the heights are covered with forests, and the level portions with gardens surrounded by hedges, the cultivation of which is the favourite occupation of the Bulgarians.

Numerous roads cross the country in all directions, but they are in general only fit for pedestrians or horses, and not for carriages; hence an advancing army is forced to widen and level them,—thus General Roth was obliged in 1829 to add 4,000 workmen to his battalions of sappers in order to open the road, although there was no

* This is described by Colonel Chesney as winding through deep ravines and precipitous rocky passes, and he states that the rivers Kamtschik and Delli-Kamtschik are fordable in summer in many places near where it crosses them.—Ed.

† A road from Rasgrad and one from Eski-Dchuma unite with this to the north of Tchalikewak, which is a large village 30 miles south of Schumla, and is an important point, as roads also lead from it to Kasan and to Pravady by Tchenga.—Ed.

‡ There is also a road from Stareka eastwards to Karnabat by Kasan, where a road from Osman-Bazar joins it.—Ed.

enemy to interrupt him. The difficulties of the passage through it are also excessively increased by the before mentioned underwood, and by the clayey nature of the soil, which is rendered quite soft by the least rain.

It is clear that if an enemy succeeded in landing at any point on the coast of the Black Sea, all lines of defence to the north of that point would be liable to be turned; hence Varna, which has been strongly fortified, has always been considered as a place of great importance, and the Russians have in all their wars with Turkey endeavoured to get possession of it, because they saw that if they succeeded, the Turks finding the enemy in their rear, would be obliged to retreat, and the Russians would be spared the whole expenditure of men, time, and money required for forcing the passage of the Danube.

The difficulties which now exist to prevent the Russians succeeding as they did in 1829 in crossing the Balkan, render the possession of Wallachia of the utmost importance to them; if they have time to establish themselves there, to fortify the country, to organize magazines and to collect stores, it will be an easy thing for them to occupy it with an army strong enough to cross a frontier 470 miles in extent at the right moment, then advance towards the Balkan and make sure of victory.*

It must not however be forgotten that the Turkish army now contains many individuals, who, having learned the art of war on other battle fields, have brought with them discipline, experience, and knowledge; and the strength which these have given to it has already been proved by the history of its last achievements.

Bessarabia.

The Report of the Russian Statistical Department, presented to the Emperor in 1853, gives the following information relative to this district; and although it has lately appeared in the *United Service Magazine*, it may be useful to insert it here.

"Bessarabia presents a wonderful admixture of dry and sandy steppes with the most productive corn-fields, rich meadows, and gardens; the hills that are visible in the northern direction, crowned with thick bushes and woods, decline and disappear gradually on approaching the south and the shores of the Black Sea; the country becomes quite bare; here and there only a few shrubs are visible along the banks of the rivers, and a species of the common reed, growing to a great height, covers the lakes, moors, and saline marshes; but in the midst of these wastes lie rich pasturages and fertile fields which produce a great variety of the best description of corn and vegetables. The most productive districts are those bordering on the banks of the Pruth, where there are also considerable forests.

"The heat during the summer is often so scorching that all the smaller rivers that flow between the Dniester and the Danube are completely dried up, whilst during the autumn it is again so wet and damp that the uninterrupted rain creates new brooks and rivers, springs and lakes, and the effects of such atmospheric changes are very injurious to the health of the native population, but much more so to the new settlers."

* The possession of Silistria is of so much importance to an army thus invading Bulgaria that the Russians have sacrificed a great number of men lately in attempting to take it: but the Turks have, since 1829, constructed a chain of works on the heights overlooking the fortress; and these having been defended with great bravery, most valuable time has been gained by their means, not one of them having been taken during a siege of 40 days.—Ed.

PAPER XVI.

AN INQUIRY INTO THE APPLICATION OF THE VOLTAIC BATTERY TO MILITARY PURPOSES;

TOGETHER WITH AN INVESTIGATION OF THE GENERAL PRINCIPLES CONNECTED WITH THE DEVELOPMENT OF HEAT BY VOLTAIC ACTION.

By CAPTAIN H. WARD, Royal Engineers.

PRELIMINARY OBSERVATIONS ON ELECTRICAL PHENOMENA.

With respect to electricity generally, it should be borne in mind that, in common with light and heat, it is known only by its effects. There are many processes which give rise in bodies generally to properties which they do not manifest in their usual or undisturbed state. The friction of two substances, one against the other, is one of these processes; the exercise of chemical affinity, as when a metal is exposed to the action of an acid, another; the mixture of certain liquids a third; and there are several others.

These operations being performed, an *exceptional* state is induced in the substances subjected to them, which, as it is not lasting, is properly called an *excitement*, and also *electrical excitement*, from the Greek word signifying amber, a material which has the power of acquiring the state in an eminent degree.

The disturbances produced are made apparent in both the substances which serve for their production, as each acquires properties *equal* in intensity, though somewhat different in effects. By rubbing sealing wax, for instance, on cloth, equal excitements are developed in the cloth and the wax, yet the latter exhibits properties opposed to those generated in the cloth.

Again, by rubbing glass on cloth opposite excitements are produced in both, but here the glass assumes properties that are identical with those exhibited by the cloth when rubbed with sealing wax; and the cloth employed to kindle excitement in the glass displays a property identical with that made apparent in the sealing wax. These are mysterious opposite tendencies produced by a known cause, and the designation *electrical* is given them for want of a better. We are in the habit also of connecting the excitement with the notion of an *electric fluid*, but this is in reality nothing but a license of expression perhaps rendered necessary by our finite and material notions. All that inquiry can do is to trace out the several causes which produce these phenomena, to establish the modes of producing them, if possible, under every condition with the greatest economy, and to turn the product to the best account.

It has been said that friction produces *opposite* excitements in the substances rubbed together. Now in the examples just given, it will be perceived that the same substance, cloth, acquired opposite excitements according as it was rubbed by glass or sealing wax, but this is not the case with either the glass or the wax, each of these almost invariably displays the same electrical property, without reference to the objects against which it is rubbed. As moreover, each assumes opposite tendencies, the designations of the substances themselves have been used to furnish distinguishing expressions for the excitements. Consequently the property found after friction in glass has been termed *vitreous* electricity, and that in the wax *resinous*, and also positive and negative respectively, on account of their opposite characters.

Now whether before friction there was a *compound* fluid pervading the wax and the cloth equally, which after it, was *decomposed* into its constituent parts, the excited *elements* taking possession of the material for which each had most affinity, or whether by the friction the wax was deprived of a portion of a *simple* essence (which it and the cloth had previously uniformly possessed,) by its passing over to the cloth, the latter thereby becoming overcharged, is of no consequence to the subsequent inquiry. On either supposition a disturbance is occasioned and an excitement produced. Tranquillity also can be most readily re-established by bringing the two substances into contact, as each in an unusual degree possesses the property or element which can restore the other to equilibrium. The former is called the theory of the double fluids, the latter of the single. Each has its supporters. I prefer and have adopted the latter in my reasonings as the more simple, and, as far as I know, equally in accordance with recorded phenomena. Again, all chemical combinations are sources of electricity. If an acid is added to an alkali the former acquires positive and the latter negative excitement. If either acid or alkali is mixed with water, the acid acquires a positive influence, and the alkali a negative one, as compared with the water. If oxygen combines with zinc, the former is positive and the metal negative, and so in several other cases. The excitement produced can be made apparent by introducing a delicate galvanometer into the circuit, and it is generally accompanied by a change of temperature.

It is also well-known that when two metals are placed in a solution decomposable by galvanism, the one having a greater affinity for one of the elements of the solution than the other, as soon as connection between the two metals is made, otherwise than by means of the liquid, decomposition of the solution will take place. That metal which has the superior affinity for the one constituent of the liquid is said to be attacked by it, and the separation of the elements, before in chemical combination, is the cause of a sensible electrical excitement. This excitement, when made continuous by means to be afterwards explained, produces what is called, an *electro current*, and is termed "Voltaic" and sometimes "Galvanic," from its first discoverers, Volta and Galvani.

Turner in his Elements of Chemistry says, "Two metals are not absolutely essential to the formation of a simple circle. A current is obtained from one metal and two liquids, provided the liquids are such that a stronger chemical action takes place on one side than on the other. Nay, a plate of metal with two portions of the same liquid, but of different strengths, form a simple circle; and even the same liquid of but one strength, if one side of the metal be more rapidly acted on by it, than the other, will produce a current. This may be effected, for example, by having one side rough and the other polished."

It will thus be noticed that there are four distinct modes by which voltaic electricity can be produced, but only one of them is applicable to the object we have in view, (the instantaneous explosion of powder at great distances) that is the arrangement of two metals in one liquid—the remaining methods are not capable of exhibiting sufficient energy at any great distances from the source of supply, and they may therefore be passed by with the simple notice they have received.

In an arrangement of two metals and one liquid, it is necessary in the first place that one of the metals should be attacked more readily than the other, and this difference of vulnerability is a measure of the electric excitement obtainable. Also if two metals are placed in a liquid, each of which singly is influenced by the solution, though in different degrees, when they are brought into contact or the circuit completed, the effect is that the most vulnerable metal is attacked more than before, to the protection of the other which suffers less, and is in some cases wholly protected thereby. Hence in a voltaic circuit of this kind, the greatest effect will be produced when one metal is strongly acted on, and the other is indestructible: and even indestructible metals vary in their power of opposition. For all practical purposes zinc has been found to be the most assailable metal, and has been called the positive metal from its being the prime agent for producing the electric current: and taking this point as decided, it becomes a matter for consideration what metal should be placed in opposition to it. Experimental research enables us to decide this question; and we shall first consider zinc as opposed to copper in an exciting solution.

To produce a current of electricity with two metals and one liquid, it is essential that the intervening solution should be an electrolyte, that is a compound substance decomposable by electric agency, though it need not necessarily be water, for Faraday has found that some fuzed metallic chlorides, iodides and fluorides are capable of producing currents. To quote from Turner again, "No substance that is not an electrolyte can serve to excite a voltaic apparatus, and for the passage of electricity from plate to plate, through the intervening solution, the separation of substances previously combined in the required ratio is essential. Neither free oxygen nor a solution of chlorine can excite a current, though they attack the zinc and develop electricity, and in a voltaic pile (he is speaking of one of zinc and copper) excited by dilute sulphuric acid, the electricity set in motion is due to decomposed water and oxydized zinc, and not at all to the union of oxide of zinc and sulphuric acid."

To explain this, it is necessary to state that the actions which take place in an arrangement of zinc, copper, and dilute sulphuric acid when the circuit is completed are as follows. 1st. Water (HO) by the affinity of zinc for oxygen is decomposed into its elements oxygen and hydrogen. 2nd. The oxygen (O) combines with the zinc (Zn), and forms oxide of zinc ($Zn\,O$.) 3rd. Sulphuric acid (SO_3) combines with this oxide, making sulphate of zinc (ZnO, SO_3), and lastly the sulphate is removed by solution in water. Out of these four actions, the first only, viz., the decomposition, is found to *produce a current*, though they all generate electricity. I hope presently to be able to show why it is important to bear this fact in mind, that out of the four actions, to only one are we indebted for the force which circulates from plate to plate. If then pure zinc and copper are placed in very dilute sulphuric acid, the water being the electrolyte, the conditions above laid down are fulfilled, but unless the circuit is completed neither will be sensibly affected. The reason is this;—The effect of the zinc, (which is the most vulnerable) being attacked would be to cause part of it to be firstly converted into oxide of zinc, and for this it must obtain oxygen from some source, which it cannot do in the unconnected state because the affinity of the zinc for oxygen is less than that of the hydrogen for its oxygen constituent in the water, or of the sulphur for its three atoms in the sulphuric acid.

But put the two metals in contact, or, as it is called, complete the circuit, and now it will be found that the affinity of the zinc for the oxygen of the water is in excess of the retaining power of the hydrogen; for decomposition will take place, the oxygen going to the zinc to form oxide, and the hydrogen be evolved at the copper plate. The sulphuric acid now comes into play, and combining with the oxide, will form sulphate of zinc, which being readily soluble in water will be immediately removed, and fresh zinc exposed to attack. The same train of operations will now recur. The combination and decomposition will be repeated till either all the zinc has been destroyed, all the acid appropriated to form sulphate, or the remaining water saturated with the zinc salt, and if the first decomposition gives rise to an electrical excitement, the successive decompositions will render it continuous, so long as the several actions are kept up, and thus a *current of electricity* will be maintained. Now it is curious to observe, that though the separation of the constituents of the water, the oxygen and hydrogen, must take place at those points where the zinc is in contact with it; yet there is no evolution of hydrogen at the zinc plate, as might be expected, but at the surface of the copper plate, at whatever distance that may be from the zinc.

The explanation which has been given of this phenomenon is as follows:—

Let Z and C be two plates, and suppose a row of water particles to be between them. Each water particle is a compound of a particle of oxygen and a particle of hydrogen. On the closing of the circuit a particle of water No. 1 is attracted to the zinc by its oxygen constituent, and decomposed, the oxygen going to the zinc to form oxide of zinc, and the hydrogen particle being left positively electrified, the oxygen having a negative charge, which it communicates to the zinc plate. The positively charged hydrogen is attracted to the oxygen of the next particle of water, and its electric state adding to its natural attraction for this atom of oxygen, it overpowers the existing attraction that keeps the two elements together, combines with the oxygen and sets free the hydrogen of No. 2. The same process is repeated with atoms 3 and 4, till the last particle of hydrogen, namely that at the copper plate, having no water to decompose, imparts its positive charge to the copper plate and is evolved from its surface, the conduction through the water and the evolution of hydrogen at the copper plate being effected by a series of combinations and decompositions.*

In each successive stage of this process then there is a loss of electricity, the excitement created in the second particle of hydrogen not being equal to that previously possessed by the first, and if the liquid stratum be of some thickness, the electricity imparted to the copper plate must be diminished accordingly.

Whether this is the true explanation of the action which takes place or not is of no consequence; the fact of the hydrogen appearing at the copper plate is well known, and that is the point of practical importance.

The oxygen and hydrogen acquire on separation, in common with all other chemical decompositions, as has been previously stated, opposite states of excitement; the oxygen assuming the negative or resinous, and the hydrogen the vitreous or plus property, and as each, in coming in contact with its own plate, imparts its excitement, the plates may be considered simply in the light of metallic receivers.

* Note A—See end of Paper.

Now, assuming, as the most simple view, that the copper plate is overburdened with, and therefore anxious to get rid of an influence that the zinc has been deprived of and much requires, if we bring the two metals into contact, equilibrium will readily be restored. This is just what is done when the circuit is completed, only instead of directly connecting the two metals, we do so by the intervention of a wire along which the excitement passes by conduction. If the conducting power of this medium is ample and the medium uniform in quality, no sensible effect will be produced, as but little resistance will be offered to the passage of the electric fluid; if it is not ample but uniform, an equal disengagement of heat will take place along its whole length, the intensity of which varies in the inverse ratio to the bulk of the wire; if not uniform in quality, that is, if a conducting medium is used of different powers of conductibility, a greater amount of heat will be apparent on those portions which are inferior conductors, and provided the amount of circulating fluid is sufficient, a small portion of the wire circuit may be made of such inferior conducting power and of so small a bulk, that the heat developed in its passage will be sufficient to make the wire red hot or even to fuze it.*

This principle is taken advantage of when voltaic electricity is applied to the explosion of powder. A short and very thin metallic wire of inferior conducting power is made to pass through the powder to be exploded, and the electricity developed by the voltaic apparatus employed is compelled to circulate through this wire, the rest of the circuit being composed of metal of superior conducting power and ample in size; and it is therefore essential that the voltaic apparatus employed should be able to supply sufficient electric fluid to bring the thin wire in any determined length of circuit to the heat required for the ignition of powder. At the same time it is desirable that the prime conductors should be sufficiently ample not to waste heat by disengagement where it is not required; and if they are made sufficiently large, their temperature need not be raised above that of the surrounding atmosphere, or the covering in which these wires are usually encased, when no loss by disengagement would occur.

Before proceeding further it seems right to notice an erroneous idea that is shared in common by many, viz.: that in an electric circuit closed by a length of wire, one portion of which is made thin enough to develop great heat, the quantity of caloric disengaged from this thin portion depends on its situation in the circuit, whether in the centre or at one end, whether near the negative or positive pole of the voltaic combination. This is decidedly erroneous. For it must be borne in mind first, that no heat can be apparent any where *till the circuit is complete*, meaning thereby not the metallic connection only but the circuit of electric fluid; that is till a current is flowing through all parts of the arrangement, and the moment the circuit is destroyed the development of heat ceases; it is also, I think, clear that when a continuous current flows *in a circuit*, equal *quantities* of fluid must be passing through every section of it in the same time. The calorific effect on any portion of such a circuit must then be quite independent of the position relative to the poles of the voltaic combination, but dependent on the nature of the metal and its bulk, as before mentioned.

It has been said that all chemical combinations develop electricity, and that this is made apparent by means of a delicate galvanometer or by the change of temperature. It is not however sufficient for our purpose to generate the excitement, but also to ensure, first, that there should be a continuous and constant supply, and secondly that we should be able to make use of it by causing a display of constant heat on some part of an established circuit, as above described.

* Note B—See end of Paper.

There can be no constancy of heat where there is no continuous and constant flow, nor can the excitement be made available for our ends, unless we can make it travel over the part we wish to heat: now a chemical combination cannot be said strictly to fulfil either of these conditions. When an acid is mixed with an alkali, or oxygen combines with zinc, a new compound is formed, excitement is produced certainly at the moment of formation, and heat disengaged, but here there is an end of the matter, cause and effect; there is no continuous and constant flow of electric fluid.

It might be supposed that if the process of bringing the two substances together, for instance the acid and the alkali, could be prolonged by some means, that is, if one could be made to act continuously upon the other, an available current might be established, as each new combination would develope new excitement. It is true that electricity would be generated continuously as long as the two elements were combining; but it would not be possible to make the electric fluid circulate in a manner to be available for our purpose.

In the case of the two metals arranged in one liquid, electricity was developed by the *decomposition* of the water, and in consequence of the constituent gases appearing each at its own plate, a *separation* of the two elements differently excited took place, equilibrium being restored by bringing the plates mechanically together, either by placing their surfaces in contact or by means of a wire. When the latter plan is adopted, advantage is taken of the current passing from the copper to the zinc to produce in certain parts of the circuit an intense heat. But in the case of the acid and alkali, electricity is developed by *combination, not decomposition :* it is true that in this case the same excitement is produced, as if decomposition and separation took place, but as they now combine intimately, no sooner are opposite tendencies brought about in the first stage, than their close connection immediately restores each to equilibrium without permitting the arrangement of a special road for the passage of the electric fluid. It would be the same with two metals soldered together, and dipped into dilute acid; the destruction of the zinc would still take place, but the excitement produced could not be turned to account.

We thus see that electricity is developed by all chemical combinations as well as decompositions, but in the former case we are not able to turn to account the excitement produced, whereas we can do so when decomposition and separation take place.

Referring back to the actions that were stated to take place in an arrangement of zinc, copper, and dilute sulphuric acid—it will be remembered that first the water was decomposed, the constituent gases appearing at their respective plates; the zinc, whose presence is the cause of the decomposition, combines with the oxygen, forming oxide of zinc; the sulphuric acid now unites with the oxide, forming a sulphate; and lastly this is removed by solution in water, leaving all things in such a state that the several actions can be repeated. Here are four distinct actions, which all develop electricity, though it will I hope be clear from what has been said why the first only is capable of establishing a current serviceable for our purpose. Whatever states of excitement are generated by the last three, they then and there annihilate each other, and it is only that produced by the first which we are able to turn to account.

The water then in this arrangement is the first essential, as it is the source of the supply of electric fluid; but in order to insure a continuous flow of current, the other constituent of the existing liquid, namely the acid, is equally necessary. The water for example being decomposed, oxide of zinc is formed on the surface of the zinc plate, and if it remained there all further destruction of zinc must cease, as the oxide being insoluble in water, would protect the underlying metal, and could not itself decompose more water. The sulphuric acid however now combines with it, forming a sulphate which is easily soluble in water, and is quickly removed, leaving fresh metal exposed for further action. The acid is of still further use by increasing the conducting power of the liquid, and by its presence it heightens the affinity of of zinc for oxygen—that is the energy of the voltaic combination.

The acid used then should be one that is able to combine with the oxide and form *a salt soluble in the liquid.* This is essential for a continuous and constant supply of electric excitement.

With zinc for the positive metal in this arrangement we cannot well go wrong, as its salts thus produced are soluble in water; and those salts as carbonate, prussiate, oxalate, phosphate, silicate, and borate of zinc, which are not soluble in water, are not wanted in an ordinary voltaic arrangement; but if lead is employed for a positive metal, sulphuric acid should not be used; with tin, nitric acid should be avoided, and so on, sulphate of lead and stannic acid being insoluble in water.

To make a suitable mixture of acid and water for exciting a current, the above points should be borne in mind, as well as the several parts each substance in the arrangement has to play. The water itself acts in two different ways: one portion is decomposed and another has to dissolve the zinc salt when formed, and it would be possible to arrange such proportions, that the consumption of the zinc, the expenditure of the acid, and the saturation of the water, should take place together. This however, though very interesting in principle, would not be desirable, if possible, in practice; still the fact should not be lost sight of.

It has been shown that the flow of the electric current, in a closed circuit, can be made continuous by an arrangement of zinc and copper in dilute sulphuric acid. This was the first combination employed for that purpose, and is known generally as Wollaston's battery. It has however its disadvantages. For instance, though the flow of electricity in this arrangement is continuous, it is not constant; that is, equal quantities do not pass in equal times. This is a material objection, as, of course, the alteration of the quantity passing at any one time would have a corresponding effect on the amount of heat disengaged. The cause of the inconstancy is the tendency of the hydrogen to adhere to the copper plate. It will be remembered that on the decomposition of the water the hydrogen appears at the copper, and imparts to it its positive tendency. Now, if the first atoms of hydrogen could be immediately evolved, that is, could rise to the surface and escape as soon as formed, the plate would be ready to receive more electric fluid from the next atoms. But unfortunately, notwithstanding the lightness of the gas, its tenacity for the smooth surface of the copper detains it there sufficiently long to check the subsequent hydrogen atoms, in imparting their excitement to the metal. These latter have to discharge themselves through the medium of those before them; and as gas is a very indifferent conductor, there is great loss occasioned by the transmission, and consequently a diminution of the quantity circulating. Smee says, "To give an idea of the amount of hydrogen that will adhere to smooth metal, I have frequently seen platinum, the heaviest of all substances, rise by the force of the hydrogen to the top of the water after it had been in contact with the zinc."

This is however not the only objection to this arrangement of battery. After a while the water of the solution becomes, of course, impregnated with sulphate of zinc, and the hydrogen being obtained as above in a highly electrified state in this solution, reduces the sulphate to metallic zinc, water and sulphuric acid, the metal being deposited on the copper plate, at the surface of which the hydrogen is detained, and where consequently the reduction takes place. The copper thus, as action proceeds, becomes covered with a film of zinc, and as zinc becomes opposed to zinc, the voltaic energy diminishes and would probably at last altogether cease.

These two great objections caused Professor Daniell to arrange the metals zinc and copper somewhat differently. He employed two solutions, namely dilute sulphuric acid, and a saturated solution of sulphate of copper, separated from each other by a porous diaphragm that permitted the liquids to meet, but not to combine or intimately mix with each other. The zinc was placed in the dilute sulphuric acid, and the copper in its sulphate; for though I am aware that Professor Daniell put sulphate of copper mixed with dilute sulphuric acid in contact with the copper, as the dilute acid only increases the conducting powers of the sulphate solution, and so far aids its decomposition, the *principle* of the arrangement is unaffected thereby.

When the circuit is closed decomposition of the water commences as before, and by the method already described the hydrogen arrives at the copper plate, where we may conceive it in the act of being evolved. This gas however, now acting on the sulphate of copper, instead of as before on the sulphate of zinc, reduces it to metallic copper, water and sulphuric acid; the reduced metal being deposited, as in the former arrangement, on the copper plate, and thus a coating of its own substance is continually deposited on the copper, keeping it fresh and new.

The principle upon which this arrangement was devised consisted in this: that if the detained hydrogen must cause a deposit of any metal on the copper, it had better be copper than any other, as that would always maintain the same galvanic opposition, and so tend to establish constancy of action. This arrangement also, from the easy reduction of copper, enabled all the hydrogen to be removed on the point of evolution, and thus further contributed to maintain a constant flow of electricity. It is necessary however, for the display of constancy, that the sulphate of copper solution should be kept saturated, this is done by suspending crystals in it, which dissolve pari passu with the reduction of copper.

The diaphragm is necessary to prevent the sulphate of copper coming in contact with the zinc plate, otherwise a reduction would also take place on that metal, and action would ultimately cease by a copper surface being opposed to a copper plate. The diaphragm however should permit the voltaic action to pass from one metal to the other.

The second chemical action, viz., the effort expended in reducing the copper, causes (as may be supposed) an expenditure of power, and a less excitement is transmitted to the copper plate than if every particle of hydrogen was able to discharge itself directly there. But we have seen that this latter effect is by no means possible, and it may give an idea how great the loss must be from the tenacity of hydrogen for the copper surface, when it is stated, that, according to Wheatstone's experiments, the application of the above principle increases the resultant available energy of the battery by one-half.

The objections to Daniell's battery are, that the arrangements are complicated; it is difficult to obtain diaphragms that will act equally well in all temperatures, or to preserve them, when obtained, from fracture, on account of the liability of the sulphate of copper to crystalize in their pores; and it requires some time to prepare the battery for action, and also attention to keep the sulphate of copper saturated. It has the advantage however of keeping constant for many hours.

There is another battery, invented by Mr. Grove, of the Daniell type, but much superior to it in energy, far less complicated, more easily put into action, and if not quite constant, yet sufficiently so for our purpose, as it exhibits no practical difference in energy for six or seven hours. The arrangement consists of zinc and platinum for the metals, a porous diaphragm separating them; dilute sulphuric acid as before with the zinc, but strong nitric acid with the platinum. On closing the circuit, action commences as before, and the hydrogen reaches the platinum: but from this it is removed at once by its acting on and decomposing the nitric acid, deutoxide of nitrogen being evolved, which, coming in contact with the air, is converted into nitrous acid. Subsequently Dr. Maynooth, of Dublin, substituted cast-iron and other metals for the platinum, and also varied in some degree the exciting solutions, with what success will subsequently appear. The inconvenience of the complication necessarily accompanying the use of two acids and porous diaphragms caused many attempts to be made to get rid of the hydrogen by evolution, in preference to absorption. Cast iron and other metals, with roughened exterior, have been substituted for copper; the rough surface being formed to favour the evolution of the gas. But undoubtedly the best of all these is that of Professor Smee, who, taking advantage of the tendency of roughened surfaces to evolve hydrogen and using silver for his negative metal, precipitated on it the black powder of platinum. The infinity of points presented by such a surface chemically roughened, though it did not set free the gas in a perfect manner, produced comparatively speaking an excellent result.

Another principle of voltaic arrangement, and one deserving special notice, as possessing a high degree of excellence, is the invention of Mr. Dalgleish, of the Ordnance survey office, Dublin. He conceived the idea of placing zinc in opposition to platinum, both being immersed in nitric acid. A more particular notice of the ingenious arrangements to apply this principle will be subsequently given; at present it is merely alluded to, with the other combinations, to embrace in one general view every known principle for the production of voltaic currents, that may be supposed applicable to the end for which the subsequent enquiry was conducted. The investigation of the merits of these several combinations will be comprised in the second part of this paper; but I have thought it necessary, while avoiding all doubtful theories, and such as do not concern us, to bring the general reader, by an elementary sketch, up to the point where that enquiry commences, viz., to the consideration of the principles which govern the circulation of an electric current, when two metals are placed in a compound liquid, and connected by a wire.

The following paper will I hope make clear the mode of conveying any required amount of electric excitement to any distance from the source of supply with the utmost economy This will necessarily comprise an enquiry into the power obtainable, both by increasing the size of plates, and by their arrangement in series, and into many other points which will be best explained as we proceed. The inquiry, whether the explosion of charges of powder by voltaic agency could be made generally applicable to engineering purposes in the field, seems naturally to divide itself into the following heads:—An inquiry—

1st. Into the motive power.

2nd. Into the conducting medium or the means by which that power could be conveyed to a distance.

3rd. The construction of bursting charges to produce the desired explosion.

4th. How the power obtainable could be best applied to the explosion of a number of mines simultaneously.

Motive Power.

The inquiry into the motive power arranges itself under the following subdivisions:—

1st. The determination of the principle by which Voltaic action could, on the whole, be most effectually produced; that is, the determination of that combination of metals and acids, which, while it comprises such as are generally procurable at a moderate expense and are safe to handle, would exhibit the greatest power.

2nd. The most *economical* arrangement of these, as to size and numbers; so that the power required should be produced out of the smallest bulk, and at the least cost.

3rd. The general *simplification* of the arrangement of cells and plates, so as to admit of their easy repair or replacement; the arrangement to combine portability, facility in charging and dismantling; the whole to admit of being readily packed and put together: to be durable, having as few parts as possible liable to deterioration by keep or use, and those such as to admit of many spare ones being carried with the apparatus, and easily procurable any where.

4th. Above all to reduce the manipulation to a mere mechanical process, requiring in the application no chemical or scientific knowledge to work it effectually.

Conducting Medium.

The inquiry respecting the conducting medium naturally embraces, the best metal for the purpose and the most desirable thickness under every circumstance; a ready mode of ascertaining the conducting power of any description that might be procured on the spot in an emergency; the degree of isolation required to preserve the strength of the circulating current, the best covering to effect this perfectly, and the cost of the most approved.

Bursting Charges.

The most approved bursting charge to be ascertained; whether that formerly made with a thin platinum or iron wire, or that discovered by Mr. Brunton, of the Gutta-Percha Works, City-road, where an inflammable compound is obtained seemingly by a combination of copper, sulphur, carbon and gutta-percha.

In the former the best length and thickness of platinum or iron wire, and the most desirable construction for bursting charges under such circumstances; in the latter the most approved compound, and the readiest method of making it.

Simultaneous Firing.

How far the power obtainable by voltaic agency can be applied to the explosion of a number of charges simultaneously, by each description of bursting charge, and the best arrangements for this purpose; the rules deduced from scientific inquiry that should be the guide in considering such arrangements, and how far they must be modified in practice.

The above examination shows what an extensive field the enquiry presents, and in the following pages it will be seen how far I have gone into it; when the processes employed have been considered, it will be easy to decide if the conclusion drawn from the experimental results are satisfactory. As the whole of the investigation is based on the theory of voltaic circuits, propounded by Professor Ohm, of Nuremberg, of which a translation is to be found in Taylor's Scientific Memoirs, June 1840, I cannot expect to be generally intelligible, unless I preface the experimental results with a notice of the principles established by him, and the conclusions deducible therefrom.

In considering a voltaic arrangement of one pair, say zinc, platinum, and dilute sulphuric acid with the circuit closed; Ohm has shewn that the force of the current in circulation is directly as the sum of the electromotive forces, and inversely as the sum of the resistance to its circulation.

By the sum of the *electromotive forces* is meant the excess of affinity of the zinc for one of the elements of the solution, as, for example, the oxygen of the water in the above case, over all other counteracting agencies: this force therefore being *entirely independent of the size of the plate*, and subject solely to the nature of the metals and liquids in voltaic combination.

By the term excess of affinity it is understood, that if zinc is put in sulphuric acid and water, the zinc decomposing the latter, the cause of the decomposition must be that the affinity of the zinc for oxygen is in excess of that of the hydrogen for the oxygen, with which it is in the first place combined. It is this excess that in this particular case is called the sum. In many combinations of metals and liquids, as in a Daniell or Grove, this excess is the result of more complicated forces, but in all cases the sum of the electro-motive forces is intended to express this excess.

By *resistance* is intended the obstacle opposed to the passage of the electric current by the substances through which it has to pass. It is the inverse of what is termed conducting power. We are in the habit of talking of conducting instead of resisting power, but it will I imagine be acknowledged an equally accurate conception, to view all conducting media in the light of resistances opposed to the passage of electricity, as to consider them conductors aiding its circulation. No substances in nature are perfect conductors, consequently some electric excitement is lost in each step of the transmission from particle to particle; and it seems as rational therefore to ascribe the loss experienced to a resisting agency, as to attribute the quantity obtained to a favouring one.

Let F then represent the force of the current in circulation, which it must be remembered, from what has been before stated in the first part of this paper, is equal in all parts of the circuit. Let E = the sum of the electromotive forces, and R = the sum of the resistances.

$$\text{Then } F = \frac{E}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The resistance R in an ordinary voltaic pair is made up of two principal and some inconsiderable portions. The former include the resistance of the wire completing the circuit, and that of the liquid intervening between the plates.

The resistance of the conducting wire which we call w, varies directly as its length (l), and its specific resistance (s); and inversely as the area of its section (a).

$$\text{or, } \quad w = \frac{s\,l}{a} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The resistance of the intervening liquid, which we will call L, varies directly as its specific resistance (S), and the thickness of the stratum (T); and inversely as the surface of the plate in contact with it (A).

$$\text{or, } \quad L = \frac{S\,T}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

(By specific resistance is meant the resistance due to the nature of the liquid employed, and the term is used in the same sense as we speak of specific gravity.)

In fact, Ohm assumes that every atom, whether of liquid or wire, is capable of receiving excitement from the one before it in the circuit, and parting with it to the next in succession; that a loss occurs in the transmission depending on the differences of the electric forces existing in the two adjacent atoms; just as in the theory of heat, the transmission of caloric between two particles is regarded as proportional to the difference of their temperatures. From this the laws in equations 2 and 3 seem obviously deducible.

There are other resistances in an ordinary voltaic circuit, namely, that of the plates themselves, and of the metallic connections between each pair, when a number are combined in series: but the great sectional area and short length of them make their absolute resistance, when compared with the rest of the circuit, insignificant. They do not require a separate consideration.

The resistance R then consists of L and w, or

$$F = \frac{E}{R} = \frac{E}{L + w} \quad \ldots\ldots\ldots\ldots \quad (4)$$

Now, instead of completing the circuit by a wire, let *the plates* of a pair be connected by a medium whose resistance is insignificant, and equation (4) becomes

$$F = \frac{E}{L} \quad \ldots\ldots\ldots\ldots \quad (5)$$

representing the free circulation in a voltaic pair, when $w = o$.

If n such pairs are arranged in series, the first zinc and the last platinum being brought in contact by a substance whose resistance is insignificant, we shall then have n electromotive forces, but also n resistances; so the value of F will remain unchanged, for

$$F = \frac{n\,E}{n\,L} = \frac{E}{L} \quad \ldots\ldots\ldots\ldots \quad (6)$$

but there can now be added n times as much resistance of wire, as could be borne in equation (4), without diminishing the value of the force F below that which it represented there, for

$$F = \frac{E}{L + w} = \frac{n\,E}{n\,L + n\,w} \quad \ldots\ldots\ldots\ldots \quad (7)$$

When the galvanic circuit is divided and circulates at the same time through two or more branches, the force of the current through each will be in the inverse ratio of its resistance; thus if r and r' be the resistances of the two portions or branches of a conducting medium through which the current passes; $\frac{1}{r}$ and $\frac{1}{r'}$ will be the proportional force of the current in each, and their sum $\frac{r + r'}{rr'}$ will be that of the current passing through both, therefore $\frac{rr'}{r + r'}$ will represent the resistance of a medium that could be substituted for both, and not diminish the amount of circulating force.

It is very important to bear in mind the law relative to divided currents, as it particularly concerns arrangements for simultaneous firing. We are too ready to assume that electricity selects for itself the readiest path, utterly rejecting inferior means of conduction, but with respect to the circulation of voltaic currents, this idea is decidely erroneous, and the converse is capable of easy practical demonstration.

These are the points of Ohm's theory that most immediately concern us; let us now see what conclusions are deducible from it.

Referring to equation (1) $F = \frac{E}{R}$ it is evident that in a voltaic arrangement the nature of whose metals and liquids has been decided on, the force F is entirely dependant on the magnitude of R, or the resistance offered to the circulation of the current, as when R decreases F increases, and when $R = o$, $F = \infty$, which implies that whatever arrangement of plates and acids may be made, if the resistance can be reduced to o the power obtainable is infinite. Now is this true in point of fact? I conceive it is, and that it can be explained in this way. It will be remembered that it was shewn to be essential to the flow of a continuous current in an arrangement, for example of zinc, copper, and dilute sulphuric acid, that the zinc should be oxidized, the sulphuric acid should combine with the oxide to form a sulphate, and the salt should be removed by dissolution in water, leaving all things in *statu quo* for a new set of actions. Now, though, these are described as subsequent operations, where no restraint is offered, they all take place at the same instant.*

Now when $R = o$ the initial force F, if I may so express it, is dependant on the value of E, which represents the excess of affinity of the positive metal for one of the elements of the solution over all counteracting agencies, and is therefore limited, but if such an arrangement were made that the limited force should be developed again and again, independent of time, the resultant power, of course, would be infinite. At first view it seems as if the combination of zinc platinum and dilute acid above described is such an arrangement, and as far as the chemical action is concerned (if we leave out of consideration the adherence of the hydrogen to the negative plate), it certainly is, but there is one great check to the development, which can be diminished, but not got rid of altogether, viz., the resistance of the liquid to the passage of electricity from plate to plate. As there must necessarily be some liquid to produce excitement, so must there be a resistance R; let this but assume a value and F becomes limited.

The development of an unlimited force F would seem then to be prevented by the resistance offered to the circulation of the current. It may be considered that the zinc, for instance, on being continually attacked and finding a difficulty in getting rid of its excitement, becomes so charged that it resists a further disengagement of electricity, or, which is equivalent, resists further destruction, that is, loses its affinity for oxygen, till it can be restored to a certain state of quiescence. We have a case analogous to this in electricity produced by friction in an electrical machine, where, in order to obtain an unlimited supply of positive excitement from the glass cylinder to charge Leyden jars or for other purposes, it is necessary to connect the negative prime conductor with the ground, to carry off a portion of the high negative excitement produced in it by the friction; it being well known, that if this was not so connected, it would become so highly charged as to resist further disengagement of excitement. I have here given this theoretical view of the varying value of F to bring before the mind the fact, that the force of the current circulating is controlled only by the value of R, and that I conceive it to be true that, *without any limitation*, so long as R is decreased F will increase.

The value of R is, as has been stated, composed of two parts, viz., the resistance of the exciting liquid L and of the metallic wire (w) closing the circuit, and how these can be diminished in a simple voltaic pair, we shall find by referring to equations (2) and (3).

From equation (3) we can diminish (L), the resistance of the liquid stratum, by bringing the plates nearer together, by substituting an exciting solution whose specific resistance is less, or by increasing the size of the plates in each cell.

From equation (2) the resistance of the conducting wire (w) in a simple voltaic pair can be diminished, by substituting a metal whose specific resistance is less, by shortening the length of the wire, or by increasing the area of its section. There is another way of diminishing the value of w, which will be afterwards noticed.

Diminishing the distance between the plates in each cell by one-half or one-third, will permit us to diminish the size of each plate, *and therefore their weight*, by one-half or one-third without a loss of power.

* Note C.—At the end of this Paper.

Increasing the section of the conducting wire, or, which is the same thing, increasing its weight per yard will permit its length to be similarly increased, without diminishing the value of F.

In the equation $F = \frac{E}{L + w}$ taken as representing the condition of a circulating force F in a determined combination of metal and acid, we have seen that F can only be increased by the diminution of L or w, or both.

We have just seen the means by which L can be diminished, and supposing that by one of these it has been reduced to $\frac{1}{n}$ its value, the equation of the voltaic pair becomes

$$F' = \frac{E}{\frac{L}{n} + w} = \frac{n\,E}{L + n\,w}$$

With respect to w, every mode of diminishing its value, which has been before mentioned, is adopted in practice, that is, a metal (copper) is employed the specific resistance of which is the smallest known; such a size of wire is used as can with a due regard to economy be employed, and no longer length than is actually required would, of course, ever be placed in the circuit; but there is yet another mode of reducing the resistance.

For instance, if it is desired to reduce w to $\frac{1}{n}$th its present value, it is readily done by combining n voltaic pairs in series, and applying them to circulate the current through w, the equation then stands,—

$$F'' = \frac{n\,E}{n\,L + w} = \frac{E}{L + \frac{w}{n}}$$

There are here then two modes of increasing the force F, and the question is, which is the greater F′ or F″, that is—

$$\frac{E}{\frac{L}{n} + w} \text{ or } \frac{E}{L + \frac{w}{n}}$$

Their comparative values evidently depend on the respective values of L and w, for if L is greater than w, F′ is greater than F″; if equal, equal; and if less, less. From this we have the following rule.

When the resistance of the liquid stratum is greater than that of the wire, it is more advantageous to increase the size of the plates of a voltaic pair than to arrange a number in series. When the two resistances are equal, it matters not which is done, and if the resistance of the wire is greater than that of the liquid, the development of the force F is most economically obtained by placing several pairs in series.

This is a most important principle to bear in mind (as will be hereafter shewn) when making an arrangement for the explosion of a series of charges, for by a simple alteration of the disposition of cells, effects can be produced which without the knowledge of this principle would be unaccountable.

The rule above made evident is supported by practice. In electro plating, where the metallic portion of the circuit is short and ample in size, experience has taught that it is more profitable to increase the size of the pair in action. But in the explosion of charges of powder at long distances, where the metallic resistance is usually extensive, it is found more economical to arrange plates in series.

The explanation one usually hears given for the necessity of different arrangements for the two purposes, is, that in electro plating a quantity of electricity is required, while in exploding charges intensity is essential. If this explanation is generally intelligible, it seems to me to give a vague notion of what actually is required in each case. At all events it is, I believe, generally taken to imply that cells placed in series will alone produce intensity, and large plates quantity, which is decidedly incorrect. Intensity of heat (for this is one of the forms in which electricity can be made apparent) is a property partly dependant on the quantity of heat, and partly on the space it occupies. An increase of intensity can be obtained by putting the same quantity into less space. The same *quantity* of caloric applied to a twelve and a twenty-four pound shot would produce heat of various degrees of intensity. Intensity therefore is directly and entirely dependant on the space into which a given quantity of heat is compressed, not upon an arrangement of cells in series. It would be equally correct to say that increasing the size of a voltaic pair would increase the intensity as to ascribe that power to the accumulation of cells in series. In fact, both these arrangements have that power, as we can imagine the same force F being made to circulate by each mode in the same combination of metals and acid (though in one case by an arrangement in series and in the other by having one large voltaic pair), and through two wire circuits indentical in their size, length and conductibility.

In the former, assuming n cells to be placed in series.

$$F = \frac{n\,E}{n\,L + w}$$

And in the latter, w and E being of the same value as above,

$$F = \frac{E}{L' + w}$$

And for both these values to be equal it is only necessary that L′ should equal $L - \frac{n-1}{n}w$, which value is obtainable by a proportional increase of one pair of plates, as long as $\frac{n-1}{n}w$ is less than L. The same force F then, whether caused to circulate by the conditions expressed by $\frac{E}{L' + w}$ or $\frac{n\,E}{n\,L + w}$ will exhibit the same intensity on similar parts of two identical wire circuits, and the property of producing intensity is thus shewn not to be confined especially to either arrangement.

To produce any required intensity it is requisite to get the requisite quantity into the given space, and this can only be done by overcoming the obstacles to its transmission. There are two descriptions of resistance to overcome, viz., that of the connecting wire and that of the liquid, and it depends on their comparative power which it is most desirable to diminish; the former can be lessened most readily by accumulating cells in series, and the latter by increasing the size of the plates.

It is practically true that in the explosion of charges at long distances the required intensity can only be obtained by accumulating cells in series, but the reason of this is evident, viz., that in equation $F = \frac{E}{L' + w}$ even if the resistance L by the increase of the size of the plate be reduced to an insignificant value, that of w may still be too great to admit of the required quantity circulating through all parts, and then plates in series are essential to reduce the value of w, as by that means only can F now be increased.

The converse however is equally true, and deserves consideration. Imagine a combination of n cells arranged to overcome a resistance w, and that the number is so great that the opposition of w has been practically reduced to nothing, or the equation representing the value F standing thus,—

$$F = \frac{n\,E}{n\,L + w} = \frac{E}{L + \frac{w}{n}}$$

in which $\frac{w}{n}$ is so insignificant as to admit of its being left out of the consideration, then practically $F = \frac{E}{L}$. Now, if L is so great that its resistance alone will not permit of a sufficient quantity of force circulating, then if 1000 or 10,000 cells were placed in series, we could not sensibly increase the value of F, for it could only approach, but never could equal $\frac{E}{L}$; to obtain sufficient intensity in this case it would then be essential to increase the size of each plate in the series, for by that means only could F now be augmented. These considerations are important, for they shew clearly that there is a limit, in each case, beyond which we can get no appreciable increase of power: in the one no further increase of the size of the plates will increase the force, unless we at the same time increase the number; in the other we may diminish the size so much as to render a large number placed in series of no value.

Returning again to equation $F = \frac{n\,E}{n\,L + w}$. It has been shewn that, whatever the value of n, F *cannot equal* $\frac{E}{L}$ that is, *the electro motive force of one pair restrained by the resistance of the intervening liquid;* at the same time the combination $\frac{n\,E}{n\,L}$ has the power of circulating the force F through n times the metallic circuit which $\frac{E}{L}$ could, for $F = \frac{E}{L + w} = \frac{n\,E}{n\,L + n\,w}$. These two theoretical conclusions admit of the popular explanation, that in a series of cells, with plates, say of zinc and copper, each copper, while receiving excitement from the zinc of its own cell, restores to equilibrium the zinc in the next, or that to which it is metallically connected; that is, the first copper in the series tranquilizes the second zinc, the second copper the third zinc and so on; and then there remains only the first zinc and last copper, which require to be connected to permit each to return to a state of quiescence; of course then, any connection uniting these two, however small its resistance, cannot have so great an *amount* of electric fluid traversing it as that which one voltaic pair is able to produce, or that expressed by $\frac{E}{L}$.

At the same time, as Ohm has shewn that the quantity of electric fluid travelling by two paths to the same destination will proceed by each in quantities varying in the inverse ratio of their powers of resistance, let us imagine the quantity at the last copper plate in the series desirous to return to the first zinc, and that the zinc and copper is metallically connected, bearing also in mind, that this zinc and copper are connected by another means, that is, by the alternation of metals and acid solutions, both conductors, intervening between them, so that there are here two paths by which equilibrium can be restored; and now if we suppose, first the metallic resistance insuperable, the whole of the electricity will return by the liquid; if we suppose the liquid resistance to be insuperable, tranquillity will be restored wholly by means of the metallic road. But in reality, as neither resistance is actually insurmountable, the fluid does return by both roads in the inverse ratio of their resisting powers. Conceive then one voltaic pair with the circuit closed by a wire of any given length. In this position a certain amount of electric force is proceeding from the copper to the zinc by the wire, the remainder returning by the liquid, the proportion depending on the resisting powers of each; if then we increase the resistance of the liquid portion *n* times we can proportionally increase that of the metallic portion, without altering the absolute quantity proceeding by each path. In a combination of *n* cells the former is done, and then we are enabled to do the latter. When *n* cells are used in series, *n* times the resistance is opposed to the return of the electric fluid at the last plate by the liquid to the first, for it has to traverse *n* thicknesses of solution, and *n* pairs of metallic plates, and so we can add on *n* times as much metallic wire resistance without diminishing the quantity thereby circulating below that which would circulate through the original length, were but one voltaic pair to be employed.*

Proceeding on the principles thus developed by Ohm's Theory to enquire into the power of every description of battery; it will I hope be clear from what has been said that it was in the first place necessary to ascertain the comparative value of L and w in the equation $F = \frac{E}{L + w}$ before it could be decided whether the force F would be most economically produced; and secondly, the comparative value of E to shew the relative electro motive energies of the several known combinations.

Before proceeding to detail the experimental results which determined the choice of the motive power or description of battery for military purposes, I may enumerate those that have been submitted to examination, viz:

WOLLASTON'S—Zinc and copper and dilute sulphuric acid, and its modifications of zinc and iron, and copper and iron.

SMEE'S—Zinc, platinized silver, and dilute sulphuric acid.

GROVE'S – Zinc and dilute sulphuric acid, platinum with strong nitric acid.

DANIELL'S—Zinc and copper, with dilute sulphuric acid and sulphate of copper.

DALGLEISH'S—Zinc, platinum, and nitric acid.

DR. MCCALLAN'S Batteries, of which there are several varieties.

These several batteries can be classified under two heads – those in which an evolution of gas takes place on completing the circuit, and those in which, for the attainment of constancy, the gas is absorbed by a chemical process. To the former class belong Wollaston's and its modifications, Smee's, and Mr. Dalgleish's; and to the latter, Daniell's, Grove's, and McCallan's.

The advantages of the first class consist in the simplicity of the arrangements, the use of but one acid, the necessity for porous cells being thus avoided; while the second has the advantage of producing greater constancy by a chemical arrangement, though at the expense of simplicity.

Wollaston's, Smee's, Daniell's, and Grove's batteries have been for some time before the scientific world, and are well known. Dr. McCallan has organised several combinations of metals and acids which require notice. In one, cast-iron is simply substituted as the negative metal for the platinum of Grove's; in other forms he uses successively platinized iron, platinized lead, chromed iron, chromed lead. He also varies the exciting solutions. Now he employs concentrated nitric, and doubly rectified sulphuric acid in contact with the iron; then again, this solution is modified by mixing four parts of sulphuric acid, two of nitric, and two of a saturated solution

* Note D at the end of this Paper.

of nitre together. If, in this latter mixture, nitric acid is dispensed with, its place must be supplied by an addition of the nitric solution, which he states, need not be saturated. He also finds that nitrate of soda could be substituted for nitrate of potash, though with a loss of power to be repaid by cheapness of material. It was not possible without great expense to examine these several combinations; nor indeed did it seem desirable, for their proposer disposes of the merits of some of them in the *Philosophical Magazine*, No. 206 and 219, as follows:—

"Platinized or chromed cast iron answers as well as platinized lead, and cast-iron without being chromed appears to act as well as platinum." (No. 206.)

"After weighing well the relative qualities of lead and cast-iron, I prefer the latter principally because it does not require platinizing." (No. 219.)

From these remarks it seems just to infer that cast-iron not platinized (that is, plain) was, on the whole, better than platinized lead, platinized iron, or chromed iron; and if this is the case in the laboratory, it will be much more so in the field, for the platinizing process will, owing to the destruction of the iron, require to be frequently repeated, entailing much expense and trouble, and requiring scientific knowledge and practice. It was only necessary then to test the merit of the substitution of cast-iron for the platinum in Grove's, and the use respectively of nitric and sulphuric acid mixed, concentrated nitric and sulphuric acid mixed, and concentrated nitric acid alone, when applied to produce voltaic action. These trials have been made.

The battery made by Mr. Dalgleish, of the Ordnance Survey Office, Dublin, deserves particular notice. He employs zinc and platinum for the metals, and strong nitric acid, though it should not be concentrated, for the solution. Platinum cups containing nitric acid have suspended over them, attached to a bar, cylinders of zinc, which are kept from the influence of the acid by strong elastic bands. At the moment the voltaic action is required a pressure on the bar immerses the zinc, and at the same time, by an ingenious arrangement, completes the connection of the several cells. An action ensues, and the desired effect being produced, the removal of the hand allows the elastic bands to withdraw the zinc cylinders, and yet to keep them suspended over their respective cups from further destruction. See Pl. 1.

Though this battery is classed with those in which an evolution of gas occurs, they can by no means compare with it in energy. Its electro-motive force is very great, nor can I by description do justice to the ingenuity of the arrangement by which the zinc cylinders are kept out of the acid till their destruction is necessary; at the proper moment the pressure of the hand immerses them, and simultaneously makes the connection of the several cells.

With respect to Wollaston's battery of zinc and copper, and the modifications of it before mentioned, I did not submit them to any detailed examination, for I believe it is well known and generally acknowledged that Smee's principle is superior to them in *every* way. Having satisfied myself of the truth of this general opinion, I have tested more carefully the power of a Smee, and the result will shew how inadequate such an arrangement is for the intense and constant heat required for explosions of powder.

The plan pursued in the enquiry into the merits, or productive values, of these several forms of battery, was to ascertain first the most advantageous size and arrangement of plates to cause the circulation of the required amount of force in each, and then to select the one best for use in the field.

The principle on which I proceeded to obtain these values is the same as that pursued by Professor Wheatstone, as recorded in the transactions of the Royal Society, 1843, viz., by introducing variable resistances into the circuit, and bringing the force of the current circulating in each case to an equality; then by equating the two expressions obtained, we can arrive at the electro-motive force or resistance of the liquid, according to the conditions of the experiment.

I wish, before proceeding further, to state, that I lay no claim to originality of design in any of the experimental processes which follow; they can be considered but as modifications of those described by Professor Wheatstone in the paper above mentioned, and any merit or utility in the results I have obtained, are due solely to him, as without the aid of his valuable paper my progress in the enquiry would have been slow and probably unsatisfactory.

To apply the principles mentioned, it is necessary to have the means of varying the interposed resistance gradually between any required limits, and the instrument invented by Wheatstone, and called a Rheostat, (Plate 2 fig. 1.) I found of essential service.

The following is a description of it, *g* is a cylinder of wood, with brass termination, and *h* a cylinder of brass, both of the same diameter, and having their axes parallel to each other. On the wood cylinder a spiral groove is cut, and at one of its extremities is attached one end of a long copper wire of small diameter, which, when coiled round the wood cylinder, fills the entire groove, and is fixed at its other end to the extremity of the brass cylinder. The two springs *j* and *k* pressing one against the brass terminal of the wood cylinder, and the other against the brass cylinder *h*, are connected with two binding screws for the purpose of receiving the wires of the circuit. The moveable handle *m* is for turning the cylinders on their axes; when it is attached to the cylinder *h*, and is turned to the right, the wire is uncoiled from the wood cylinder, and coiled on the brass cylinder; but when it is applied to the cylinder *g*, and turned to the left, the reverse is effected. The coils on the wood cylinder being insulated and kept separate from each other by the groove, the current passes through the entire length of wire coiled on that cylinder; but the coils on the brass cylinder not being insulated, the current passes immediately from the point of the wire which is in contact with the cylinder to the spring *k*. The effective part of the length of the wire is therefore the variable portion which is on the wood cylinder.

A scale is fixed to measure the number of coils unwound, and the fractions of a coil are determined by an index which is fixed to the axis of one of the cylinders, and points to the divisions of a graduated scale.

The above is the description nearly in Wheatstone's own words. The instrument I employed was made on the same principle, though of larger dimensions, as more suitable to the enquiry in view. The cylinders were 10 inches long, and exactly 10 inches in circumference, the wire employed being about ·045 inches diameter, and weighing about 53 grains per yard. The wood cylinder when covered held 190 turns of such wire or 52$\frac{7}{9}$ yards; and I assumed it as the standard measure of resistance, estimating and expressing all other resistances in terms of this wire.

Some mode was requisite by which the force of the current circulating could be measured. A delicate astatic galvanometer, such as that described by Wheatstone, first occurred to me as suitable for the purpose; but I soon found that, though well adapted for the measurement of feeble currents in circulation, it was not so suitable for measuring those of such great energy as are required for the purpose of exploding powder. It seemed that the resistance of the liquid stratum and the electro-motive forces were, in some forms of battery, dependant in a degree on the amount of electric current in circulation, or when the quantity was so minute as to be accurately measured by a galvanometer the value of L was less than when a more energetic current was passing. On the other hand, when a sufficiently strong current was circulating, the deflection of the galvanometer needle was so great, that small variations in the extent of the circuit produced no effect on the variation of the needle. Frequent changes were also apparent in the magnetic intensity of the needle when acted on by strong currents, so that two equal degrees of variation could not be taken as indications of the same amount of circulating force. It was therefore no easy matter to ascertain when a current sufficiently energetic for the object of the enquiry was in circulation.

With an intention then of ascertaining the amount of resistance and electro-motive force in every form of battery, when a current of sufficient energy for exploding powder was circulating, and at the same time to have a certain indication that such was the condition under which I was making the experiment, I adopted the following plan. In some part of the metallic circuit I placed a thin platinum wire, ⅜th of an inch long, weighing 1·65 grains per yard. Gradually varying the metallic resistance, I ascertained the amount at which the small wire would just melt. As the same degree of heat would always be necessary to fuze the same length and thickness of platinum wire, and as that could only be obtained by the same force of current passing uniformly through all parts of the circuit, and moreover, as the fusion of this wire would readily ignite surrounding powder, I thus obtained a galvanometer which, at one view, gave all the information required.

It was an easy matter to design an instrument for holding the wire, or any number of wires, if required. I had one constructed, which also permitted of two wires being placed in successive parts of the circuit, or if necessary, of two sets of six, the wires of each set being arranged side by side. (The reason for both these arrangements will afterwards appear.) They were held firmly between parallel brass plates, and by means of screws, clamps, and a graduated scale with a vernier attached, any length from the smallest imaginable to 1½ inches, could be introduced in the circuit for the purpose of experiment. As it is an instrument for measuring energetic currents, it may be called an intensity galvanometer.

Plate 3 represents this instrument. s s is a wooden stand, resembling a flat ruler having two graduated scales v v of inches and tenths of inches, corresponding to the verniers on the bent down edges of the brass slides a a. In the figure the right slide is represented as drawn back, and it will be observed that it carries with it a vertical brass transverse plate, provided with slits for the reception of the platinum wires, which are then kept firm by the capping bar b d here represented open, but which turns on a hinge at b, and is secured firmly to the plate when down by the lever catch represented at e d. The other ends of the wires are received in slits of a similar upright piece, which forms part of the centre plate m, which is attached permanently by screws to the wooden stand. This upright piece has also a lid p d, which is here represented as closed on the wires. The left slide (a) consists of the same parts, but is here shown as closed in to the central upright piece on that side; the two uprights being covered by the cap C, which keeps up a metallic connection between the left and right slides, just as the platinum wires do on the other side. By removing the cap C the left slide becomes moveable to the left, and wires can be inserted, between the upright of the slide and that of the central plate, just as is exhibited in respect to the right-hand slide. f f are clamping screws to secure the slides in any required position. w w are screws for receiving the connecting wires of the battery. When it is only intended to use a single wire or a set of wires, from 2 to 6, arranged side by side, the cap C must be down on one side, either the right or the left, as here represented, but when it is wished to use two distinct wires successively in line, or two sets of wires in succession, the cap C must be removed. The instrument may be made to complete the circuit, if necessary, without the platinum wires, by closing up the slide on the right as on the left side, and covering the uprights by another cap similar to C.

I had, as I before stated, barely 53 yards of standard wire on the Rheostat, but it was generally necessary to introduce much greater resistance than this. The means of doing so were easily obtainable, for having on hand about two miles of thin copper wire, varying from 160 to 250 grains per yard, covered with gutta percha, in lengths varying from 75 yards to half a mile, it was only necessary to ascertain the resisting power of these in terms of the standard wire, and by Professor Wheatstone's instrument this was readily done. Thus with a piece 75 yards long, taking a Grove's battery I had by me, (though any constant battery would do equally well), I found that three of its cells were capable of fuzing the thin platinum wire before mentioned, when $119\frac{1}{2}$ turns of the standard wire coiled on the wood cylinder of the Rheostat wire, were included in the circuit; and the same three cells fuzed the same length of wire when a coil of wire of *another description* 75 yards long, together with $68\frac{1}{2}$ turns of Rheostat wire, composed the circuit. Now, three cells acting in series are expressed by $\frac{3\ E}{3\ L}$, that is, three electromotive forces divided by three liquid resistances, if L represent the resistance of the liquid of one cell. The other resistances are in the first experiment composed of $119\frac{1}{2}$ turns of standard wire, and the platinum wire, the amount of whose resistance we may call p: in the second, of 75 yards of coil, $68\frac{1}{2}$ turns of standard wire, and the platinum wire p. Under each condition of experiment the same amount of force was capable of circulating; calling this F,

$$\text{we have } F = \frac{3\ E}{3\ L + 119\tfrac{1}{2} + p} = \frac{3\ E}{3\ L + 68\tfrac{1}{2} + 75 \text{ yds.} + p.}$$

By which we obtain 75 yards = 51 turns; or the resistance opposed by the 75 yards of coil was equivalent to that of 51 turns of standard wire, and whenever this portion was introduced into the circuit it was considered equivalent to 51 turns of standard wire. Again, with a piece of greater length, eighteen cells of another battery were capable of fuzing the platinum wire, the current passing through an equivalent of $868\frac{3}{8}$ turns of standard measure, and when a piece 550 yards long was introduced, the same result could be produced through but $88\frac{1}{8}$ turns. The 550 yards piece was then $= 868\frac{3}{8} - 88\frac{1}{8} = 780\frac{1}{4}$ turns of standard wire: and to show the degree of accuracy attainable, each result (viz., $868\frac{3}{8}$ and $88\frac{1}{8}$) is the mean of eight observations; the first eight observations differing from the mean $868\frac{3}{8}$ as follows,—

$\frac{1}{4}$, $2\frac{3}{4}$, $2\frac{1}{4}$, $1\frac{3}{4}$, $2\frac{1}{8}$, $\frac{3}{4}$, $3\frac{3}{4}$, $4\frac{1}{4}$.

And the second eight from the mean $88\frac{1}{8}$ as under,—

$5\frac{1}{8}$, $6\frac{7}{8}$, $2\frac{7}{8}$, $2\frac{7}{8}$, $\frac{1}{8}$, $4\frac{1}{8}$, $2\frac{1}{8}$, $1\frac{1}{8}$.

The probable error of the mean difference resulting from these sixteen observations does not exceed 1·15 turns; that of a single pair of observations being within 3·3 turns. The galvanometer is however capable of measuring to a still greater degree of accuracy, if necessary. The above observations were made with a battery not particularly suitable to the purpose, and with less than the usual degree of care, in a period of less than a quarter of an hour; the coil in question not being required for the subsequent experimental enquiry. The instrument admits of a repetition of from 40 to 60 observations per hour with ease, and thus, in a short time, it would be easy to obtain a result free from any but an almost inappreciable error. In a similar manner the resistance of any length of wire could be reduced to a standard measure, and as the wires which I had covered with gutta percha, I was able to arrange them in coils round the table on which the battery stood, introducing such as were required by the nature of the experiment.

As the thin platinum wire before mentioned necessarily formed part of the circuit in *every experiment*, it was requisite to ascertain its resistance in terms of standard measure. This was done by first introducing one, and then two such wires, all of the same length, in different portions of the circuit, (for which, as has been described, the galvanometer was adapted), and producing a fusion in each case *by the same power of battery*. The amount of standard resistance or length of standard wire which had to be taken out in the second case to produce fusion, was equivalent to the resistance of one platinum wire. This was found, by the mean of 6 pairs of observations, to be $60\frac{3}{8}$ turns. The probable error of this result being = 1 turn, and that of one pair of observations = 2·3 turns, is equivalent, as the wire is but ·375 inches long, to ·00618 inches in the former case, and to ·0142 in the latter.

A ready mode of checking the correctness of this result is always at hand; it is as follows:—Find the utmost length in standard measure of the metallic circuit (not including that of the platinum wire) which will admit of any even number of cells in series, say twelve, fusing that wire. Ascertain the same with each half, or six of those cells. The sum of the circuits of the two sixes deducted from that of the twelve will give the standard resistance of platinum wire. This will be a true result, subject of course to corrections for errors of observation, however irregularly the cells may be working *inter se*, and a reference to the formula will easily explain the rule.

It might be supposed that the resistance of these several wires would be ascertainable by the formula $w = \frac{s\,l}{a}$, when the specific resistance, the length, and the area of the section are known, or if they are all of copper, the specific resistance being the same, that the length divided by the weight per yard should give the comparative resistance; but an approximate value can only be obtained by such measures. A small variation in the description of copper from which the wire is manufactured would affect the value of s, and the difficulty of obtaining in wires of small diameter a correct value for a, or, what is its equivalent, the difficulty of obtaining a long wire of a uniform weight per yard would increase the probable error of the true result. For instance, several portions of the same wire weighed 249·5, 233·5, 228·6 grains per yard, as ascertained by a delicate balance turning to $\frac{1}{500}$ of a grain, thus denoting an irregularity due either to the manufacture or to the quality of the copper.

It is therefore fortunate that Professor Wheatstone's Rheostat furnishes such a ready, as well as practical, mode of ascertaining the degree of resistance of all descriptions of wire *without a knowledge of any of the factors of the equation* $w = \frac{s\,l}{a}$.

The amount of error into which we may be led by determining the resistance from calculation instead of by experiment may be seen from the following table, in which that practically ascertained and that calculated, each in terms of wire weighing 53 grains per yard, are placed side by side.

Actual length of wire in yards.	Weight per yard in grains.	Calculated resistance in turns of Rheostat.	Actual resistance by experiment in turns of rheostat.	Per centage of error in calculation.	Per centage of probable error in ascertained resistances.	
75	233·22	61·3	51	+ 16·8	0·58	
125	228·66	104·3	$83\frac{3}{4}$	+ 19·7	0·53	
245	233·5	200·2	$172\frac{3}{4}$	+ 13·7	0·46	
495	249·5	378·5	$322\frac{1}{2}$	+ 14·8	0·34	
280	166·2	321·4	$401\frac{5}{8}$	− 24·9	0·41	

Thus the first four lengths (which, as before stated, are portions of one original piece, and were therefore probably manufactured from one description of copper,) are tolerably consistent among themselves, though differing on an average by more than 15 per cent. *plus* from the standard, whereas the last piece shews a *minus* error of nearly 25 per cent., making an aggregate error between the two descriptions of copper wire shewn in the table of about 40 per cent.

Here then is made apparent one of the probable sources of failure in demolition by voltaic agency. The different diameters of the pieces of 495 yards and of 280 yards though apparent on *close* examination, would not strike a casual observer; in fact they were purchased from the Gutta Percha Company as one description of wire, yet the resistance of the *shorter* length as compared with the *longer* is as 402 to 323! If, then, calculating on the experimental results obtained from the former, the same length of the latter wire had been used in any proposed demolition, the probable result would have been total failure.

The last column shows the probable error in the ascertained resistance, which averages under half per cent. These results are more than sufficiently accurate for the purpose of the enquiry, though by no means so near as it would be easily possible to attain, since it is within the compass of an easy day's work to ascertain the resistance of all these lengths to within $\frac{1}{10}$th per cent of probable error, and even to eliminate error altogether.

It was easy now to obtain the value of L or the resistance of the liquid stratum in any battery, as well as the proportional value of any electro-motive force The experimental results with each battery examined now follow, being prefaced with a description of the size and mechanical arrangement of each. I had in hand, for the commencement of the investigation that battery of Grove's construction which was employed in the demolition of Seaford cliff in 1850. It was supplied to the Engineer Department at Portsmouth as the best form and description of voltaic implement known for the purpose, and therefore deserves a description to shew how much such an instrument is capable of modification, when required solely for blasting purposes.

The battery consisted of ten cells, in each of which was suspended one plate of platinum, with two of zinc facing it, one on each side, at a distance of $\frac{3}{4}$ of an inch; the exciting solution being dilute sulphuric acid for the zinc in the proportion of one of acid to 8 of water, and strong nitric acid for the platinum, the two acids being separated by a porous earthenware diaphragm; the plates in action in each were two $9'' \times 7''$, of zinc, and one $6'' \times 6''$ of platinum; each cell requiring $2\frac{3}{5}$ pints of dilute sulphuric acid, and $\frac{3}{5}$ths of a pint of nitric acid. The cost of construction was £21, its weight when charged 168 lbs, of which 40 lbs. was due to solution, and 44 lbs. to zinc plates. The cost of charging it with sulphuric acid at $1\frac{1}{4}$d., and nitric acid at 6d. per lb. was 7s. 9d., which would last for a period of 24 hours; and its cubical content was 4560 cubic inches.

Each cell then had the power of circulating the standard force required, that is a force capable of fuzing thin wire, through a resistance of $66\frac{2}{3}$ turns standard measure, and cost in working about $\frac{3}{8}$ of a penny per cell per hour.

It was evident, on first sight of the instrument, that this battery would admit of considerable reduction, if the principles of Ohm's theory were correct, and that if the distance between zinc and platinum was reduced from $\frac{3}{4}$ to $\frac{3}{8}$ of an inch, one-half the weight of zinc ($= 22$ lbs.,) and a corresponding bulk of acid, could be dispensed with, without lessening in any degree the power per cell. With this consideration in view, and also wishing to compare an arrangement on Grove's principle with one of Smee's batteries, which I had also by me, I had one of the former constructed with 12 cells, two zinc plates $4'' \times 2''$ being in action in each cell, one on each side of a platinum plate 4" × 4" and at a distance from it of about ⅜ of an inch. I also had the platinum plates platinized; the original object of which was to work this identical battery as a Smee, by dispensing with the porous cells and nitric acid, but thinking afterwards that this might appear to some as hardly a fair trial of Smee's arrangement, I abandoned that idea, and used these platinized platina plates in the Grove's arrangement only. It will be seen subsequently that platinized platina opposed to zinc gives a stronger arrangement than platinum only; a fact which was, I believe, first noticed by Dr. McCallan. The cost of twelve cells of this battery from the same hand as the large one, was £10 10s.

I may here observe, that as the investigation was intended to find the power of the several voltaic combinations, when excited by ordinary agents, that is, those which might readily be obtained, I did not enter into an enquiry, except on special occasions which will be particularly noticed, as to the degree of power attainable by the use of concentrated nitric acid, doubly rectified sulphuric acid, or such reagents as are difficult or expensive to procure, or dangerous to handle, but confined myself to the task of ascertaining the power attainable from ordinary, or what are termed commercial, acids, which do not emit fumes destructive to health. The sulphuric acid was priced at 1½d. per lb.; and the nitric acid S. G. 1350, (the concentrated being 1500) at 6d. per lb.

The rule for ascertaining the merits of any voltaic combination is this. Arranging any number of cells in series, ascertain the metallic resistance that can be comprised in the circuit which will permit one platinum wire to be fused. With the same number in series, ascertain the extent of circuit which will admit of two platinum wires placed side by side in the galvanometer being fused: and these two experimental results may be obtained in 5 minutes at any time in the field as well as in the laboratory, with instruments which should always accompany the battery, by a single observation of each result with a probable error not exceeding two turns: whilst by a repetition of observations, all appreciable error could, of course, be eliminated. In making these trials, it is not necessary that the operator should have any knowledge of the metals or acids of which the voltaic arrangement is constituted. The experiment will shew him at once if the battery is to be trusted, and to what extent, and, if any disarrangement has occurred, how many cells to add to overcome the defect: indeed the constancy and duration of the heat made apparent on the wire is at once an infallible and ready test of the value of the battery for explosive purposes.

The demonstration is as follows: Taking n cells in a battery whose electro-motive force is E, and resistance of liquid L, suppose a metallic resistance w to be the extreme that can be interposed and yet enable a force to circulate that will cause the platinum wire to be fused; call this force F, then the equation stands—

$$F = \frac{n\,E}{n\,L + w}.$$

Now if the extreme metallic resistance, which we will call w', is ascertained which admits two identical wires, placed side by side, to be fused, it is evident that the same force F must be passing along each wire at that moment, or a force of 2 F along both together, and as the same quantity of electric fluid must be passing through every part of the circuit, the equation representing the conditions under which the battery is working will be expressed by

$$2\,F = \frac{n\,E}{n\,L + w'}.$$

Now as the numerator in both these expressions is the same, for in both experiments the same number of cells are used, the denominator in the last must be one-half of that of the first, or

$$n\,L + w' = \tfrac{1}{2}(n\,L + w) \quad \therefore \; L = \frac{w - 2\,w'}{n}.$$

Thus the average resistance of n liquid strata, or $n\,L$ can be obtained. The use of this value of L will be better understood when we come to consider the other numerical values in each case.

Again, suppose we have two separate combinations of battery, say a Smee and a Grove arrangement, of which it is desired to determine the comparative value of the electro-motive forces:

Let the electro-motive force be E and E′
liquid resistance .... L and L′

and the quantity of metallic circuit that each will bear, when n cells are combined, and yet permit the standard force, which we will in future call a force F, to circulate be w and w'. Let the amounts w, and w', require an increase or diminution $= a$ and a' of metallic resistance when a force F′ is required to circulate. We then have in the first case—

Smee. Grove.

$$\frac{n\,E}{n\,L + w} = F = \frac{n\,E'}{n\,L' + w'},$$

and in the second—

Smee. Grove.

$$\frac{n\,E}{n\,L + w \pm a} = F' = \frac{n\,E'}{n\,L' + w' \pm a'};$$

then of course E : E′ as the sums of the respective denominators in each case, but they are also as the differences of the denominators of their respective fractions, that is to say, as a to a',

$$\text{or } E : E' :: a : a'.$$

In all my observations the forces F and F′ have been in the ratio of 2 to 1, to simplify the calculation; and the equations under the conditions became—

$$F = \frac{12\,E}{12\,L + w} \quad F' = 2\,F = \frac{12\,E}{12\,L + w \pm a}$$

which being reduced, for the purpose of determining L or the liquid resistance, gave $12\,L = w - 2\,(w \pm a)$: and on these principles I took the observations that follow, the number of cells in series, in all cases, being twelve.

With the Groves having plates, 4″ × 4″, of zinc, and platinum in action in each cell.

1. The metallic resistance interposable for 12 cells, when one wire was fused .... } or $w = 775\tfrac{1}{2}$ turns.
2. Ditto ditto 2 wires .... or $w - a = 350\tfrac{1}{2}$ „

$\therefore\; 12\,L = 775\tfrac{1}{2} - 701 = 74{\cdot}5$ turns; the probable error in this value of 12 L, as calculated from the nature of the observations is $= 1{\cdot}7$ turns; that of $775\tfrac{1}{2}$ turns, similarly calculated is equal to 2 turns.

The electro-motive force of this battery, as compared with any other, would be the difference of these two observations in each case, that is to say, the difference of the denominators of the equations F and F′ as before stated. In the present case, this is $775\tfrac{1}{2} - 350\tfrac{1}{2} = 425$, having a probable error of 1·6.

The duration of the power of this battery or its constancy, as it is called, is deserving of notice. The results just given show its energy about an hour after charging, at which time, the porous cells being well saturated, it may be considered to have been at its maximum. During the day it was experimented with sufficiently to fire 300 charges, and at the end of seven hours the experiments above described were repeated in the same order. No. 1, gave $753\frac{1}{3}$ turns; No. 2, $332\frac{2}{3}$, from which $12\ L = 88$, and comparative value of $E = 420\frac{1}{3}$. Thus the resistance of the liquid had, as regards itself, increased 18 per cent., and the electro-motive force 1 per cent.; but the two together had reduced the available energy of the battery from $775\frac{1}{2}$ to $753\frac{1}{3}$ or not 3 per cent. This constancy is readily attainable by carefully amalgamating the zinc plates before charging, an operation occupying a few minutes, and it has been found on this, as well as on other occasions, that the battery will continue sufficiently constant for all practical purposes for a period of twelve hours. The small loss of power noticeable here is probably owing to the fact, that it was always my custom in charging the several batteries to mix the sulphuric acid and water immediately before filling the cells; this, as is well known, raises the temperature of the mixture above that previously sensible in either of the liquids, and as the temperature is heightened the conducting power of the solution is increased; but this power diminishes as the solution cools, which it gradually does. On the present occasion sulphuric acid and water, each at 40° Fahrenheit, when mixed in the proportion of one measure of acid to eight of water, gave a resulting temperature of about 70°.

When this battery is in its full strength, the amount of resistance commanded by 12 cells, that is, the amount of metallic resistance which can be added to the circuit for each cell in series, without diminishing the value of the circulating force below the standard necessary for fusion, is $= 775\frac{1}{2}$ turns for the 12, or $64\frac{5}{8}$ for one cell; but it will be remembered that the power of one cell in the large Grove did not exceed $66\frac{1}{2}$ turns, so that this small difference is the only loss per cell, by reducing the battery. In respect to the gain, the quantity of nitric acid to charge each cell has been diminished from $\frac{3}{5}$ to $\frac{1}{6}$ of a pint, and the dilute sulphuric acid from $2\frac{3}{5}$ to $\frac{1}{3}$rd of a pint. These two alone diminish the cost of charging 10 cells from 7s. 9d. to 2s.; but as this acid lasts only 12 hours, while the others are available for 24, the comparative cost should stand as 7s. 9d. to 4s. The weight of ten cells of this battery when charged was only 27 lbs., while that of the large one was 168 lbs. The cost of construction was less than one-half, and the cubical content less than $\frac{1}{7}$th. So that while but $1\frac{2}{3}$ per cent. of power per cell has been lost, the gain has been 50 per cent. in prime cost, the same in working, 600 per cent. in weight, and 700 per cent. in bulk.

Referring back let us substitute in the equation $F = \frac{n\ E}{n\ L + w}$, the value of $n = 12$, $n\ L = 74\frac{1}{2}$ and $w = 775\frac{1}{2}$, and we have

$$F = \frac{12\ E}{74\frac{1}{2} + 775\frac{1}{2}} = \frac{E}{6\frac{5}{24} + 64\frac{15}{24}} = \frac{E}{70\frac{5}{6}}$$

in which $70\frac{5}{6}$ represents the utmost amount of resistance in standard measure that this principle of battery will bear per cell, without reducing the amount of circulating force below the force capable of fuzing the thin wire, that is the force F, and in which $\frac{E}{5\frac{5}{24} + 64\frac{15}{24}}$ represents how this total resistance is apportioned between the liquid and metallic circuit, in this particular *sized* battery. But the same resulting force could be obtained by a battery working under any of the following conditions.

$$\text{viz.}\quad F = \frac{E}{24\frac{5}{6} + 46} = \frac{E}{70\frac{5}{6}} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\text{or,}\quad = \frac{E}{35\frac{5}{12} + 35\frac{5}{12}} = \frac{E}{70\frac{5}{6}} \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\text{or,}\quad = \frac{E}{70\frac{5}{6} + 0} = \frac{E}{70\frac{5}{6}} \quad \ldots\ldots\ldots\ldots \quad (3)$$

The first of these can be produced by a diminution of the size of the plates from 4″ × 4″ of surface in action in each cell to 2″ × 2″, and as this reduction of size would not diminish the power per cell 30 per cent., or from $64\frac{1}{2}$ to 46, while it might reasonably be expected that expense of charging, weight, bulk and cost of battery would be diminished at least 100 per cent., this modified form is evidently preferable.

No. 2 is, theoretically speaking, the most economical form under which any principle of battery can work for the circulation of the force required, which in this case is to fuse the particular platinum wire that we have been using, (that is, when the liquid resistance of each cell is equal to its available energy,) and in a Grove's combination the expression represents plates about 1·66 inches square in each cell.

The third expression represents a battery working under such conditions, that if one thousand cells were placed in series, they would not have the power of circulating the force F through a metallic circuit of one foot.

Theoretically speaking, as I have said, No. 2 is the most economical form of battery; but other considerations forbid its adoption. To obtain the power, $35\frac{5}{12}$ per cell indicated by the equation, each compartment must be carefully filled to the top, as failing to do this by a quarter of an inch would sensibly diminish the power per cell. Any deterioration in the strength of acid employed would have the same effect, and the whole quantity employed being so small, it would deteriorate soon after the battery was charged. It will be seen that the acids used in the Grove, of which the zinc surfaces in action were 4″ × 4″ in each cell, were available for but 12 hours, while that in the larger size was equally so for 24 hours. Reasoning from this, it could then hardly be expected that the small battery represented by equation No. 2, would remain efficient for one hour, or work economically for one quarter of an hour.

One more condition of this equation deserves notice, viz., $F = \frac{E}{0 + 70\frac{5}{6}}$. This cannot practically be attained by any construction, for the liquid resistance must be an absolute quantity, but it shews the important fact that *however large* the plates of a Grove's combination, such as the one we have been considering, are made, the force F could not circulate if in *each* cell was developed resistance equivalent to $70\frac{5}{6}$ turns, while *two* cells 2″ × 2″ can bear a resistance more than equal to this, and yet circulate the required force with ease, in other words that for the circulation of the force, we require two pairs of plates in series, each 2″ × 2″ in surface, which are more than equivalent in force to one plate even a mile square.

No. 1 arrangement having then been decided on as the best, a battery exactly similar to the former was made, but having zinc plates 2″ × 1″ overlapping platinum 2″ × 2″; the former facing the latter on each side, and thus giving a surface of each metal 2″ × 2″ in action in each compartment. This diminution in size permitted the zincs to be brought somewhat nearer, and instead of being $\frac{3}{8}$ of an inch from the platinum they were $\frac{5}{16}$th.

The experiments Nos. 1 and 2 were made with this battery, giving the following results as the mean of 8 observations of each, No. 1 $= 571\frac{13}{24}$; No. 2 $= 162\frac{7}{12}$; from which the comparative value of E $= 409\frac{5}{24}$, and the resistance of 12 L $= 245\frac{5}{8}$: the probable error in each result being 1·5. The diminution of the comparative value of E from 425 to $409\frac{5}{24}$ is attributable to the platinized platinum being used in the former case, while ordinary sheet platinum was employed in this, and not to a diminution of size, which does not influence E. The sum of the resistances of the liquid in twelve cells had increased from 74·5 to $245\frac{5}{8}$.

Now, remembering that the plates had been reduced to $\frac{1}{4}$th the size, but had been brought nearer in the proportion of 5 to 6; calculation from the first result would give the second $= \dfrac{74{\cdot}5 \times 4 \times 5}{6} = 248\frac{1}{3}$, whilst experiment gives $245\frac{5}{8}$. Assuming the value of $12\,L = 245\frac{5}{8}$ or $L = 20{\cdot}47$, and that of $w = \dfrac{571\frac{13}{24}}{12} = 47{\cdot}65$; the expression $F = \dfrac{E}{L + w}$ stands $\dfrac{E}{20{\cdot}47 + 47{\cdot}65} = \dfrac{E}{68{\cdot}12}$ shewing that when the platinum is *not platinized* a Grove will bear a resistance of but 68 turns of standard measure instead of nearly 71, as before, per cell.

Referring back to the largest Grove, viz., that with zinc plate 9″ × 7″ and platinum 6″ × 6″, we may consider the area of the mean section of the fluid on each side $= 49\frac{1}{2}''$, and the plates being $\frac{3}{8}$ths of an inch apart, facing the platinum on each side, the value of 12 L in this battery by calculation would be $\dfrac{74{\cdot}5 \times 16}{49{\cdot}5} = 24$ nearly, or about 2 turns per cell, and as the available energy of the battery is $66\frac{1}{2}$ turns, the conditions under which the largest Grove circulates a force F is numerically expressible thus—

$$F = \frac{E}{2 + 66\frac{1}{2}} = \frac{E}{68\frac{1}{2}}$$

which, admitting experimental error, is the same expression as that obtained from plates but 2″ square: thus shewing that increasing the size of plates does not increase the electro-motive energy, that is the value of E, for the superior available energy of $66\frac{1}{2}$ turns in the large Grove is merely due to the diminished resistance.

This principle has been established, both by Ohm's Theory and Wheatstone's experiments, and required no further demonstration except to bring the consideration of it to special notice as materially affecting a part of the following inquiry.

The batteries hitherto used, it will be borne in mind, were made with zinc plates *overlapping* the platinum plate, and facing it on each side. Thus the outer surface of the zincs was not directly opposed to any negative metal. To ascertain if this portion did any work, I carefully covered with a thick coating of sealing-wax varnish the outer surfaces, so that it was impossible they could be acted on, and then tried on a subsequent day the variation of E for 12 cells, as compared with former experiments, but I found no diminution of power. To make sure that this was not owing to any peculiarly good acid used on that day, I removed the varnish from each plate and reinserted them in the same solutions. The battery was found somewhat diminished in power, but very slightly, not more than 2 per cent., though if the outer surfaces had been acting it ought to have *increased* in power. This was probably owing to the longer time it had been in action. These trials evidently proved that no sensible power is obtained from the outer side of a plate, or from any other surfaces that do not directly oppose each other, for had there been 3 per cent. of increase it would certainly have made itself apparent. It is not, I consider, at all surprising that it should be so, for referring to the principles of the action, the electro-motive force, that is, the affinity of the zinc and liquid for each other, depending on their nature, and not their quantity, cannot be increased; the amount of electric fluid they can supply is unlimited and controlled solely by the resistance of the liquid to its transmission, this resistance varying directly as the distance between the plates; and hence it seems in due course that the whole of the supply should be obtained from the parts where it can be so done with the greatest facility, namely from those which are nearest to or directly opposing the platinum.

The result however must not be confounded with, or supposed contrary to those obtained when the zinc, being opposed on each side by a negative metal, the battery is found to exhibit greater energy than when the copper or platinum, or whatever the negative metal may be, is on one side only: for here the zinc is directly opposed by a negative metal on both sides, and, of course, supplies electric fluid from each side, though the negative metal is, in this case, not working to the utmost advantage. The fact however made evident, to whatever cause attributable, was of great importance, as it admitted of the battery being much simplified, of dispensing with many binding screws and of much unserviceable metal, as well as of an economy of size and weight, and an increase of power, for the plates could now be brought nearer together.

Adhering then to the same sized plates, a diminution of which seemed of no practical advantage, a battery was constructed with plates of zinc and platinum welded together in the simple style that zinc and copper used to be arranged in, one of each pair being in a separate cell, and the platinum immersed in nitric acid being, of course, separated from the zinc of another couple immersed in dilute sulphuric acid by the porous cell containing it and the nitric acid. A battery so made permitted the plates to be brought to an average distance of little more than $\frac{3}{10}$ths of an inch from each other, and by the simple contrivance of a lid, every pair and every porous cell was kept in its place, and could be thus transmitted as ordinary baggage by rail, without extra packing or precaution Fig. 2. Pl. 2. represents one of these batteries of six plates, and the connecting metallic straps are so represented as to explain the manner in which several of these batteries may be combined together; Fig. 3 represents a single pair of plates.

Six pairs of plates so arranged occupied a box not exceeding $7'' \times 4'' \times 4''$, substantially made for use in the field, including binding screws, and porous cells, and the reason for this arrangement of 6 cells in one box will be afterwards explained. The result of the fusion of one and of two wires by 12 cells, or two box batteries of this arrangement, gave on one occasion, No. 1 = 651; and No 2 = $240\frac{3}{4}$: from which $12\,L = 169\frac{1}{4}$ and the proportional value of $E = 410\frac{1}{4}$.

On another occasion No. 1 gave 641, and No. 2 gave $230\frac{3}{4}$, shewing that the total resistance 12 L was now $= 179\frac{1}{2}$, but that the value of E was unchanged: the variation in the resistance being due to the time at which the experiments were made, as the increase was probably owing to a different set of 12 having been used in each case.

If we adopt the mean of these two or $12\,L = 174{\cdot}5$, $L = 14\frac{1}{2}$ may fairly be taken to represent the resistance of the liquid when the battery is in its strongest action, viz., for the first three hours after it is charged. Also the electro-motive force of a Grove battery unplatinized may be represented by the numerical value 410, as on three separate occasions experiments have given it $409\frac{4}{5}$, $410\frac{3}{4}$, and $410\frac{1}{4}$, that of a platinized Grove being 425.

To ascertain how much the power of this battery diminished when left charged, the same experiments were repeated after six hours and No. 1 was then found $= 484\frac{1}{2}$, and No. 2 $= 104\frac{1}{4}$; giving $E = 380$ and $12\,L = 275\frac{1}{2}$. Thus the electro-motive force had diminished 7 per cent. and the liquid resistance had increased 35 per cent. These two circumstances combining, diminished the available energy of the battery per cell from $\frac{646}{12} = 53\frac{5}{6}$ to $\frac{484\frac{1}{2}}{12} = 40\frac{3}{8}$ or about 25 per cent.

For the first two or three hours the conditions under which the force F circulates in the battery is expressed by $F = \frac{E}{14\frac{1}{2} + 54} = \frac{E}{68\frac{1}{2}}$, which expresses that each cell commands a resistance, or has an available energy sufficient to overcome a resistance equivalent to 54 turns of standard wire. At six hours after charging, this command had decreased to $40\frac{1}{4}$ per cell, for the battery then worked under conditions expressed by

$$F = \frac{E}{23 + 40\frac{1}{4}} = \frac{E}{63\frac{1}{4}}.$$

The denominators $68\frac{1}{2}$ and $63\frac{1}{4}$ denoting the comparative strength of the electro-motive force at the two periods.

This, then, I conceive, is the most convenient form, size, and arrangement for a Grove battery intended for the explosion of powder; for though on looking at the numerical value of $L + \frac{w}{n}$ it may seem that the size of the plates could yet be reduced, it must be borne in mind, that though *a* forces expressed by $\frac{E}{68\frac{1}{2}}$ and $\frac{E}{63\frac{1}{4}}$ are sufficient at their respective periods for fusing the platinum wire when in the galvanometer, a still greater force will be necessary for the same fusion when that wire is surrounded by powder. A small platinum wire, not exceeding ·0056 of an inch in diameter, in contact with any substance, must be subject to a great abstraction of heat; but how much this is I have not been able accurately to determine, though supposing, as I believe to be the case, that about one-third is thus withdrawn, $\frac{E}{45}$ and $\frac{E}{42}$ would more nearly represent the force required to circulate, under such circumstances, to produce fusion, giving $46-14\frac{1}{2}$ or $31\frac{5}{8}$, and $42-23$ or 19, as the available energy per cell. Again, if a number of charges in a circuit are to be fired, a still greater amount of circulating force is desirable to ensure success, and overcome small differences in the lengths of the several platinum wires. Sometimes also a thicker platinum wire may be employed, which would require greater power to fuse. For all these reasons any further reduction is unadvisable.

Having thus decided that the size, form, and arrangement just described were the most convenient for a Grove battery, when required for the purposes of exploding powder, I proceeded to ascertain what increase of power I could obtain from it by using first concentrated nitric acid SG 1500, and then a mixture of concentrated nitric and sulphuric acids, in equal proportions.

With the former, No. 1 experiment gave 701.
,, No. 2 ,, 262.

From which 12 L was found = 177, and the comparative value of E = 439; and I therefore conclude that concentrated nitric acid, used in place of the commercial acid, increases the electro-motive energy of the battery about 7 per cent., but has no influence on the resistance of the liquid.

The mixture of concentrated nitric acid with sulphuric acid, in equal proportions, has for its object the strengthening of the former; as the sulphuric acid, from its powerful affinity for water, withdraws that, which is essential for the preservation of nitric acid in its liquid state. A combination of the sulphuric acid with the small quantity of water it finds disengages also a very great amount of heat, and the mixture gives forth copious fumes of nitric acid, which are destructive to health; the liquid at the same time in any but practised hands being dangerous to handle. It is desirable therefore that such a mixture should never be applied in the field, or be put into unskilful hands. Its effect in giving energy to the battery was however tried, and the result was that at first, while the acid was warm, it had the effect of reducing the resistance of the liquid, but gave no appreciable increase of electro-motive force. When the whole had fallen to the ordinary surrounding temperature, all extra power had vanished. The employment of concentrated nitric acid alone gave an increase of electro-motive energy of but 7 per cent. per cell, above that when common acid was used. The price of the former is about three times that of the latter, and its fumes are deleterious, while the latter hardly emits any. In no case therefore would I consider it necessary to employ these extraordinary re-agents, especially when any inferiority of power can be compensated by a proportional addition of cells.

It may be as well, before leaving the Grove principle, to show how much the original battery was susceptible of improvement for our particular object, and to do this I have arranged side by side, the expenses of keeping each charged during 24 hours, so as to be able at any time during that period to fire one charge through conducting wires weighing about 250 grains per yard, at the distance of half-a-mile, assuming what my experiments have shewn must be about the truth, viz. that when allowance is made for the cooling effect of the powder, a power represented by $\frac{E}{46}$ will fire instantaneously one charge, with platinum wire $\frac{3}{8}''$ long, and weighing 1·66 grains per yard.

	LARGE.		SMALL.
Price of acids (used to charge)	17s. 6d.	....	7s. 6d.
Weight of apparatus charged	386½ lbs.	....	36½lbs.
Size of ditto	6 cub. ft.	....	½-cub. ft.
Cost of ditto	46 guineas	....	under £10.

The inquiry into the power of Grove's principle of voltaic combination has been given in some detail, to show the mode of proceeding, and the conclusion to be drawn from experiment. It will not be necessary to follow the same course with the other batteries which were examined, so I will, as shortly as I can, state the results of the remainder.

Bearing in mind that the size of the plates has no influence on the electro-motive force, and that any diminution of them makes itself apparent only by an increase of the resistance of the liquid reaction, it will be seen that it was easy to obtain the electro-motive energy of any particular arrangement, by simply altering the metals and exciting solutions. Thus, if cast-iron was substituted for platinum, and experimental results 1 and 2 obtained, I had a complete knowledge of the electro-motive energy of one of McCallan's batteries, and also its resistance *when made of that size.* The former numerical result would stand true under any arrangement of cells and plates, and from the latter the liquid resistance of any arrangement could be deduced sufficiently near for all practical purposes.

With Daniell's battery I had but to substitute copper for platinum, and sulphuric acid and copper, in the proportions recommended by the author, for nitric acid, and I could obtain its power under every condition, and so on with any other combination. First, with respect to Daniell's arrangement, the metals were zinc and copper; and the solutions dilute sulphuric acid in the proportion of one of acid and eight of water for the zinc, and a saturated solution of sulphate of copper in dilute sulphuric acid of the same strength with the copper; the two solutions being kept apart by a porous diaphragm, whilst the temperature and conditions under which the trials were made were similar to those to which Grove's principle had been subjected.

The electro-motive force as compared with Grove's was as 235 to 410, though as these results were somewhat hastily obtained I do not submit them as wholly accurate, and the resistance of the liquid of 12 cells $2'' \times 2''$ was $242\frac{2}{3}$ turns, Grove's having been found to have $174\frac{1}{2}$ at the first hour, and $275\frac{1}{2}$ at the end of six hours.

Daniell's battery has the advantage of greater constancy, its liquid resistance, while the sulphate of copper is kept saturated, remaining the same at the same temperature. On the other hand, difference of temperature has considerable influence on the success of the battery, owing, I conceive, in a great measure, to the variation of the resistance of the liquid; the dilute acid at a high temperature taking up more sulphate, which, as the mixture cools, crystalizes in the pores of the diaphragm, and thus increases the resistance and diminishes the energy of the battery.

I have not tested what difference is due to changes of temperature, for a Daniell's arrangement being more complicated than Grove's, it was but necessary to compare them under ordinary conditions of temperature to determine their relative merits in the field, where means for raising an artificial heat cannot be generally accessible.

Grove's battery is not so influenced by changes of temperature; that indicated by 50° Fahrenheit being in all cases sufficient, and superior to this can always be obtained by mixing the sulphuric acid and water just previous to charging the cells. With more time at my disposal I should have ascertained precisely how much influence an alteration of temperature had on the electro-motive force and liquid resistance respectively, as a point of interest worthy of determination; but it was, as I have said, not necessary for a decision on this arrangement as compared with Grove's, so it was postponed for a future opportunity, which has not yet offered.

A trial was made to form an idea what difference of power would result if a saturated solution of sulphate of copper in water was used in preference to the same in dilute sulphuric acid. The electro-motive force shewed an increase of power throughout the day from 235 to 242, but the resistance of 12 cells $2'' \times 2''$ at the commencement was $605\frac{1}{3}$, or nearly $2\frac{1}{2}$ as much as in the former case. The latter, however, diminished during the day owing to the more intimate mixture of the two solutions through porous cells, the battery consequenty increasing in energy, and at the end of six hours it stood at 402 turns.

The solution, as recommended by the author of the battery, gave the stronger energy, the resistance of the liquid of 12 cells being about 248, and the available energy per cell equal to about 19 turns.

The condition then under which a battery having surfaces of zinc and copper $2'' \times 2''$ in action at one-third of an inch apart stands is this

$$F = \frac{E}{20\frac{1}{4} + 19} = \frac{E}{39\frac{1}{4}},$$

and as here the value of L is greater than w, it is evident that such a size of plates is disadvantageous for a Daniell's arrangement.

It will be now easy to infer the conditions under which a battery of the size and form recommended by the Professor, works. The amount of negative metal in his battery is that comprised in a hollow cylinder of copper $3\frac{1}{2}$ inches diameter, and varying in height according to the power desired. Suspended in the centre is a zinc rod, that employed at Chatham being $\frac{3}{4}$ths of an inch in diameter and 20 inches high. If then we take for the area of the mean section of the fluid the surface of a cylinder 20″ high, and $\frac{17}{8}$″ diameter, being the mean of the diameters of the zinc and copper cylinders, we shall have a total area of nearly 134 inches, at a distance of $\frac{11}{8}$ths of an inch; but it has been found above that a surface of 4″, at a distance of about $\frac{1}{3}$rd of an inch, opposes a resistance of $20\frac{1}{2}$, and hence a surface of 134 inches at a distance of $\frac{11}{8}$ths of an inch, would oppose a resistance of $2\frac{1}{2}$, leaving an available energy $= 39\frac{1}{4} - 2\frac{1}{2} = 36\frac{3}{4}$ per cell, when porous earthenware is employed as the intervening diaphragm.

Professor Daniell, however, remarks that ox gullet opposes less resistance than earthenware, and if we assume the resistance to be diminished by this substitution to $1\frac{1}{2}$ turns per cell, it will be giving the battery, I am sure, every advantage; and then the available energy per cell will be $37\frac{3}{4}$ turns, for firing the small platinum wire when placed in the galvanometer: or allowing as we did before that one-third greater force is required to fuze it when in contact with powder, the available energy per cell will be reduced to 25 turns.

Supposing, then, that the Daniell's battery, of the arrangement described by its author and the size above specified, is required to be applied to the explosion of a mine, its power per cell, as compared with the small Grove, would be about as 25 to 32, or 3 to 4 nearly. Now the weight of 10 cylinders of Daniell's battery charged, is (I quote from the Chatham records) 137lbs., whereas 10 cells of Grove's do not weigh 8lbs.: and further the Daniell is much more complicated in its arrangement.

Dr. McCallan's plan of substituting cast iron for platinum was tried. The electro motive force seemed to be about the same as in the Grove's; but as it seldom remained constant, owing to the dilution of the nitric acid and destruction of the iron, it was not easy to determine it with accuracy. It oscillated between 408 and 413, that of Grove's being 410. The resistance also of the liquid being at the commencement the same as in the Grove's, it might seem that iron, being cheaper, could be advantageously substituted for platinum; there are, however, some material objections to the substitution. The nitric acid destroys the iron during the whole period that the battery is kept charged, and the more so as the acid gets diluted, forming a solution of nitrate of iron in nitric acid, and thus is every moment deteriorating its own power of absorbing hydrogen, the battery consequently falling in energy. The nitrate of iron also impregnates the porous cells, and in dismantling the battery it is necessary to soak them for some hours in water, to be frequently changed, before permitting them to dry, otherwise the iron salt crystallising in the cells will crack the earthenware. In addition to this, the action of the nitric acid on the iron is sometimes so great as to cause the acid to boil over, necessitating a re-arrangement of cells.

All this trouble and uncertainty is dispensed with by the use of platinum, which is uninfluenced by the acid; and, though the first cost of a platinum battery is much greater, I am convinced that in the end it will be found both cheaper and more efficacious.

The substitution of a saturated solution of nitre and sulphuric acid in equal proportion was tried with the battery of Dr. McCallan. This also is a most troublesome arrangement; it is very inconstant, so much so indeed, as to be quite unsuited for circulating energetic currents, it is continually boiling over, and however well it may answer for experimental researches in a laboratory, it should never be trusted for the explosion of mines. Its electro-motive energy varies according to the amount of force required to circulate, but for the quantity necessary to fuze the platinum wire, it never exceeded ⅔rds of Grove's, and only came up to that occasionally. The object of this substitution of nitre for nitric acid is stated by Dr. McCallan to be economy, but it has been shewn that Grove's battery can be kept charged at a cost of $\frac{1}{12}$th of a penny per cell per hour, a sum so small, that the reduction in cost need hardly be considered.

If, however, nitre could have been trusted to excite a battery, even in an inferior degree, its application would have been worthy of further inquiry, as it might sometimes happen in the field that the supply of nitric acid should fail; but so long as gunpowder remained in store there could be no difficulty in obtaining a suitable solution of nitre, by simply boiling up powder and filtering it through blotting paper. The application of this ingredient however, as I have before said, gives very precarious and uncertain results, and should never be resorted to by any but those who have had long practical acquaintance with voltaic phenomena.

We now come to another class of batteries, viz., those in which but one kind of solution is employed, the use and complication of porous cells being thus dispensed with. It was on this principle that the voltaic battery known by the name of Wollaston's battery was constructed. The defects in its mode of action, which have been explained in the first part of this paper, suggested the employment of either cast or wrought iron as a substitute for copper; the rough surface thus presented to the evolving hydrogen, favouring its escape. Subsequently Smee substituted platinized silver, that is, silver on which the black powder of platinum had been previously thrown down, thus presenting an infinity of small points to aid the escape of the gas.

Of these three arrangements, Smee's is undoubtedly the superior one, its electro-motive force being greater, and its power of setting free the hydrogen also exceeding that of the other two. Probably for the circulation of currents of inferior energy, such as are suitable for electroplating, the operation of a Smee may be perfect, and no obstruction occur by the detention of the gas; but when a force necessary for fuzing platinum wire is required, the quantity of gas generated is by no means satisfactorily evolved. In fact, the battery, as it were, chokes itself by its own exertions; and if three or four successive demands are made upon it in the course of a few seconds, its power of igniting platinum wire entirely disappears,—nor does it return till the cells have been allowed to rest, and thus set free the hydrogen.

Under such circumstances, it was no easy matter to obtain the values of its electro-motive force and of the resistance of the liquid stratum.

The battery from which these experimental results were obtained was identical in size and construction with the second-sized Grove, before described, which, as I have stated, was made similar to this, for the purpose of ascertaining their comparative merits.

The electro-motive force of Smee's battery—ascertained when it was acting under the most favourable conditions—was, as compared with Grove's, 116 to 410, and the resistance of the liquid stratum of 12 cells = 35, that of a Grove of the same size having been found to be 74½. The available energy of 12 cells of this size = 197 turns. The equation then representing the condition under which this principle of battery circulates a force F, would be represented by $F = \frac{E}{3 + 16\frac{1}{2}} = \frac{E}{19\frac{1}{2}}$ that is, each cell has a command over $16\frac{1}{3}$ turns of standard wire, when a force sufficient for fuzing platinum wire in the galvanometer is required, and as $\frac{1}{3}$ greater force $= \frac{E}{13}$ is necessary for producing the same result when in contact with powder, the command would be diminished to about 10 turns per cell; a Grove of the same size commanding about 40 turns per cell and a Grove one-fourth the size about 30 turns per cell, which shews clearly at what expense (even supposing Smee's principle capable of being trusted for energetic action), we obtain simplicity of arrangement, and dispense with the use of a second acid. The size and form of the Smee with which the experiments were made is the most convenient if a Smee must be used for the explosion of powder, viz., a surface of metal $= 4'' \times 4''$ in each cell. And yet three pairs of this are but equal to one of a Grove, whose cells are but $\frac{1}{4}$th the size.

As the Smee is superior in every way to the Wollaston and to the zinc and iron battery mentioned above, it was of no use to examine the respective merits of the two latter forms of voltaic apparatus. One form of battery however remains to be examined, viz., that of Mr. Dalgleish. Its principle of action has been before noticed. It consists of an arrangement of 12 platinum cups $\frac{7}{8}$ of an inch diameter and $2''$ deep, over which are suspended, attached to a bar, 12 cylinders of zinc $\frac{5}{8}''$ diameter. The battery is charged very readily by putting into each cup $\frac{1}{3}$ of an ounce of nitric acid. At the moment voltaic action is required, a pressure of the hand on the bar immerses each zinc in its own cup to a depth of $1\frac{3}{4}$ inches, and at the same time completes the usual connections, causing an immediate and energetic action. The withdrawal of the hand allows the zinc to be removed from destruction by the elastic bands.

The electro-motive force of this battery as compared with Grove's, using the same nitric acid in each, was as 344 to 410, and the resistance of the liquid stratum of 12 cells = 66 turns or $5\frac{1}{2}$ turns per cell. The available energy of 12 cells = 622 turns or $51\frac{5}{8}$ per cell. The equation then representing the circulation of a force F stood $F = \frac{E}{5\frac{1}{2} + 51\frac{5}{8}} = \frac{E}{57\frac{1}{8}}$, from which it will be seen that while this battery is but little inferior to Grove's in electro-motive energy, it has an advantage over it in that its liquid stratum opposes much less resistance in proportion to its section, this being due to the absence of Grove's diaphragms.

Also in looking at the value of L as compared with w, it seems as if this battery could be advantageously reduced in size, but this I do not conceive it could be. The mechanical arrangements of the battery, which are somewhat complicated, seem crowded even now into as small a space as they can well be put in with safety; and I do not think that any diminution of cells that could be made would sensibly increase the portability of the battery, as the zinc and platinum comprise but a small part of the actual bulk. The small resistance of liquid in each cell is partly obtained by the extreme contiguity of the zinc cylinders to the inner surface of the platinum cups, the distance being but $\frac{1}{8}$th of an inch, and partly to the absence of porous cells. The successive wear and tear of the zinc will tend to increase the value of L, and diminish w. These several considerations induce me to conclude that the principle of action is now arranged as economically as it can be, and it remains but to compare it with Grove's reduced form. The advantages then of the Dalgleish principle are the simplicity gained by the use of only one acid, thus dispensing with the necessity for porous cells, and the extreme readiness with which it can be charged for action; it is however more complicated than Grove's in its mechanical arrangements, which require skilled labor of a higher degree than could generally be met with in the field, to effect repairs. It is also more liable to be damaged by carelessness or accident, as it presents more assailable points.

To charge the Dalgleish battery for the explosion of a few mines would cost not more than ¾d. per cell, while Grove's would cost ½d. per cell, and while the acid in the Dalgleish lasted, it is, I consider, fair to say, that their available energy per cell would be about equal; but as the acid in Grove's could be used for a longer period, though at a diminished power, I do not consider the difference in cost of working the two batteries would on the whole be of any consideration, though somewhat in favor of Mr. Dalgleish's. The power of each battery, taken in conducting wire of 250 grains per yard, (about 14 or 16 guage) which for reasons afterwards to be given, I have taken as the best conducting medium for general service, would enable one charge to be fired very readily at a distance of 250 yards, or in a circuit of 500, and if the requirements of a battery were limited to this, I should, where rough handling was not to be expected, prefer Mr. Dalgleish's battery to Grove's; but on service I presume far greater circuits will occasionally require to be overcome; if, for instance, a mine has to be exploded at a distance of half a mile, about 38 or 40 cells of each would be required to be placed in series, and then the arrangement of elastic bands and of the development of electric excitement by pressure of the hand becomes somewhat troublesome. The Grove is also more perfect in its chemical action, if I may so express it, as the hydrogen set free by the decomposition of the water is immediately absorbed by the nitric acid; and the consequence is that as soon as the circuit is completed we obtain the whole power of the battery. In Mr. Dalgleish's arrangement the power visibly increases after the immersion of the zincs, probably owing in part to the heat occasioned by the intense action of the nitric acid on the zinc. This property of the battery is detrimental to firing a number of charges simultaneously in a circuit, and can only be overcome by immersing the zinc cylinders first, and then making connection with the poles. These points will present themselves with greater force to any one operating with the two batteries, than they can be expected to do in any description on paper.

The actual cost of constructing the two descriptions of batteries will depend in a great measure on the price of the platinum, which is by far the heaviest item in each. Grove's battery hitherto, to save expense, has been made with platinum foil, and in this manner those I have as yet used have been constructed. I, however, prefer employing sheet platinum of about 120 to 130 ounces to the superficial foot for the negative. Whether foil or sheet platinum is used makes no apparent difference in the energy of the combination; but as the former is liable to tear, it would in the end be no economy to use it.

The approximate estimate of the cost of 12 cells of each description of Grove's battery, and that of Mr. Dalgleish's, is as follows;

PLATINUM FOIL BATTERY.

⅔oz. of platinum foil, 28s.	£0	18	8
12 porous cells, 4d. each	0	4	0
Troughs, zincs, and every other fitting, including workmanship	2	0	0
	£3	2	8

SHEET PLATINUM BATTERY.

3·63oz. platinum, 28s.	£4	18	0
Porous cells	0	4	0
Troughs, &c., as before	2	0	0
	£7	2	0

MR. DALGLEISH'S BATTERY.

0·96oz. platinum, 28s.	£13 18 $10\frac{1}{2}$
$\frac{1}{4}$oz pure gold, 85s.	1 1 3
Zincs, castings, fitments, framing, &c. &c., not less than ..	2 10 0
	£17 10 $1\frac{1}{2}$

These three prices are those of batteries exhibiting the same power at about the same cost of acids, though the advantage in the latter may be on the side of Mr. Dalgleish's principle.

Comparing the two Grove's, though the second is more than twice the cost of the first, I feel sure it will prove more economical on service, when it is considered that £5 worth nearly of material out of £7 2s. worth, is, with ordinary care, absolutely indestructible. Mr. Dalgleish's battery cannot cost less than £17 10s. per 12 cells, the arrangements requiring also more than ordinary skilled labour to complete. Assuming, then, the Grove's sheet platinum battery to be on the whole more economical, its cost per cell, as compared with Dalgleish's, is about 1 to $2\frac{1}{2}$.

The cubical space which they respectively occupy is as follows:—

12 cells of Grove's (in two box batteries) = 14″ × 4″ × 4″ = 224 inches.
12 cells of Dalgleish's .... = $11\frac{1}{2}$″ × 4″ × $7\frac{1}{2}$″ = 345. do.

Their comparative weights when empty are, Grove's 8 lbs., Dalgleish's $10\frac{1}{2}$ lbs.; the latter however would not require two-thirds of the weight of acid to be carried with it on service, and that only of one description, and though these differences may appear insignificant, they will not seem so when the quantity of available energy required in the field comes to be considered.

Assuming, as a basis of comparison, that it would be desirable to have always a power available for firing one charge at the distance of half a mile, through the conducting medium and with the bursting charge which, as the subsequent part of the report will shew, has been selected; and also that the same number of spare cells should be kept at hand to replace those fractured or undergoing repair; the following statements will shew the approximate cost, weight, bulk, and other particulars in each case.

	GROVE'S.	DALGLEISH'S.
Cost of construction of batteries..	£51	.. £110
Weight of ditto	54 lbs.	.. 70 lbs.
Bulk of ditto	1400 cubic inches	.. 2300 cubic inches.

Taking these several facts into consideration, I have decided on preferring Grove's battery, of the size and arrangement submitted, as the most suitable for general engineering purposes. At the same time I would call attention to the extreme ingenuity displayed in the arrangements adopted by Mr. Dalgleish, to carry out his principle for producing voltaic action, as, for example, in the ready method of withdrawing the zinc cylinders from the attack of a most destructive acid, and in the plan of making the connection of the several cells, which is, I conceive, most original, and cannot be done justice to by any description. He combines metals and acids, so as to produce a high degree of voltaic energy by a mode that may be considered perfect; and though, on the whole, his battery, as submitted, is not so perfect in its voltaic action as Grove's, is more sensible to rough usage, and for these as well as the other reasons stated, not so applicable to operations in the field, yet it so surpasses the batteries of every other principle, as to entitle the inventor to special thanks for the successful application of a principle which it has never before been considered possible to turn to account.

To close the enquiry into the motive power, the following, as far as experiments made with some haste tend to prove, are the comparative electro-motive forces of the several principles I have as yet thought it worth while to examine.

Grove, 410; Daniell, 235; Smee, 116; McCallan, 410; Dalgleish, 344.

The zinc, iron, and nitric acid battery is that intended by McCallan's.

Or, if we take E to represent the absolute electro-motive energy of Smee's.

$3{\cdot}54\ E =$ Grove's; $2\ E =$ Daniell's; $3{\cdot}54\ E =$ McCallan's; $2{\cdot}98\ E =$ Dalgleish's.

Now the mechanical equivalent for producing fusion in Smee's, was found to be $\frac{E}{19\frac{1}{2}}$, from which the several expressions for the other batteries may be deduced.

CONDUCTING WIRES.

With respect to the conducting wires, two factors are concerned in the power of resistance of any one length to the circulation of the current, viz., the metal of which it is composed, and the area of the section; the resistance varying directly as the specific resistance of the metal, and inversely as the sectional area.

Copper, it has long since been decided, is the metal whose specific resistance, where economy is taken into account, is the least; and it only remained to decide the area of the section, or the diameter of wire to be used.

Now, considering that by increasing the number of plates in series, we are able to overcome any amount of resistance, it is as well to reduce the diameter of the conducting medium till the value of the copper wire destroyed (some portion must always be expended in an explosion,) is reduced to a comparatively insignificant quantity, that is to say, such as would about balance the destruction of zinc and consumption of acid necessary to overcome the resistance consequent on a still further diminution.

The Gutta Percha Company in the City Road had at several times supplied me with copper wire covered with gutta percha, at prices from £9 to £21 per mile, the difference being due *solely* to the greater or less quantity of gutta percha covering, and not at all to the weight of copper furnished. The thickest of these averaged about 250 grains per yard, the smallest about 160 grains. As the former was, of course, the superior conductor, was equally portable, and of no greater expense than the smaller size, I assumed it as the best size for a conducting medium. It is about $\frac{1}{16}$ of an inch diameter.

This sized wire when covered with gutta percha is very flexible, and can be easily coiled on a reel; two miles in length would easily pack in a cubic yard; its conducting power roughly stated is such that $1\frac{1}{2}$ yards of it would be equivalent in resistance to one turn of the Rheostat wire, and making this allowance the measures before stated can be easily reduced to corresponding lengths in this wire.

The degree of covering required to ensure perfect action depends on the nature of the explosion required; if an explosion is to be made under water, when only one wire is required for completing the circuit, the most perfect covering is desirable, and the cost of the wire so covered would be £21 per mile, but for any explosion on land where a return wire is always necessary, that sold at £9, £10, and £11 per mile is sufficiently isolated, especially if the wires leading to the mine are not buried under the ground, or, if buried, kept as far apart as possible. In no case would I recommend lapping the wires, leading to and returning from the mine, side by side, as has hitherto generally been done, for whatever advantage the practice may possess, and I confess I can see none, the chances of failure in consequence, are many. If, for instance, in burying it the spade by chance should lay bare the surface of one, it would probably also do the same with the other wire; or, again, if from extraordinary heat the gutta percha should get soft, which it will do at a temperature of about 160° Fahrenheit, a twist in the rope may bring the two wires together, and the covering afterwards hardening would prevent their separation, and above all, if a fracture should take place it would be very difficult to find on which wire and whereabouts it had occurred.

Gutta percha, I feel no doubt, is the best covering for the conducting medium, as it is the only means by which (as far as I know) perfect isolation can be obtained under every circumstance.

BURSTING CHARGES.

There are two descriptions of bursting charges before the scientific world: one which has been long in use, and in which a thin platinum wire, forming part of the circuit, is brought to such a heat as to ignite the surrounding powder; and another which I believe is the invention of Mr. Brunton, of the Gutta Percha Works, in the City Road. This company had been in the habit of what is familiarly called vulcanizing the gutta percha which covered the wire, to render it pliable even in the coldest temperature, and this led to the discovery of the fuze in question. By the vulcanizing process sulphur, and, I believe carbon, become incorporated with the gutta percha in a manner, so to speak, almost chemically perfect. These two act on the enclosed copper wire, and in process of time produce on its surface a species of sulphide, portions of which, when the wire is withdrawn, remain adhering to the inner surface of the gutta percha covering. This inner surface, which before was simply gutta percha, and therefore a non-conductor, has now a feeble power of conduction given to it by means of the minute particles of sulphide of copper and carbon. The conducting power is however very feeble, and seemingly in no two portions the same: but whatever the amount of resistance may be, if it can be overcome sufficiently to circulate such a force as will ignite the sulphur and carbon, the desired effect is obtained.

That the degree of heat, or what is generally termed quantity, required for this, need not be any thing approaching to that for fusing a platinum wire, may be easily conceived if we compare platinum, which no amount of heat from a smith's forge will melt, and the elements sulphur and carbon, which are combustible at moderate temperatures; yet that the degree of resistance they offer to the passage of the current must be great, may be judged when it is stated that 48 cells, and even more sometimes, of Grove's reduced battery are required to inflame them close to the battery. These same 48 cells would explode a mine, by means of the platinum fuze, at a distance of ¾ of a mile very readily.

In order, however, to cause any sensible current to pass through these sulphides, it is necessary to close all other channels of communication, that is, to break the circuit of the copper wires; then with a sufficiency of power to overcome the resistance, a combustion with powder in contact will produce the desired explosion; and on this principle the bursting charge is made, a part of the copper circuit being broken and the sulphuret surrounding that part being laid bare and covered with powder.

Here then we have two modes of igniting powder at a distance,—viz. by the fusion of platinum wire, and by the combustion of a compound, which seemingly is a sulphuret of carbon and copper: in the former the medium being metallic, and, therefore, a good conductor, requires at the same time a high degree of heat to fuze it,—while in the latter, the sulphide though opposing a very great resistance to the flow of the current, ignites even when a considerably less quantity is actually passing.

Now bearing this in mind, and also Ohm's theory or law regulating the circulation of divided currents, viz., that the quantity flowing by each of two or more portions simultaneously is in the inverse ratio of the resistance of each, the following characteristics of these two descriptions of bursting charges, which have been *practically* ascertained, will be easily understood.

1. To fire a platinum bursting charge, a return wire, where water cannot be made available, is always necessary, for I have found that the resistance of $\frac{1}{4}$ of an inch thickness of ordinarily moist earth substituted for it could not be overcome by 48 pairs of Grove's, which would fire the same charge at the distance of $\frac{3}{4}$ of a mile, or through a circuit of $1\frac{1}{2}$ miles of copper wire of No. 14 guage: and this shows that the substitution of earth for metallic wire increases the resistance so much as to diminish the quantity circulating to such an extent that the necessary heating effect is not produced.

2. Whatever number of cells (roughly speaking, for of course it cannot be accurately true,) it is found necessary to arrange in series to produce ignition in Mr. Brunton's fuze at the distance of one foot will produce the same effect through a copper wire circuit of one mile; and an addition of about one-fourth that number will permit of one-half this copper circuit being replaced by ordinarily moist earth.

These two results show that the absolute resistance of this fuze is so great that the addition of a mile of copper wire or a large quantity of earth effects no material diminution in the quantity actually circulating: that is, if E = the electro-motive force, r the resistance of the fuze, and R that of the sum of all the other resistances in the circuit, then $\frac{E}{r}$ is very nearly $= \frac{E}{r + R}$.

The same number of cells in series of a battery furnished by the Gutta Percha Works Company, that would ignite Mr. Brunton's fuze at the distance of one mile, did not produce any visible heat in the platinum wire of the other bursting charges at the distance of one foot; and this will be easily understood from what has been said before, for if, by increasing the resistance of the liquid stratum L we make $F = \frac{E}{L}$ represent a force generated by one plate, which is not capable of heating platinum wire, any number of such cells in series will not heat that wire, as $F = \frac{n\,E}{n\,L + w}$, must be less than $\frac{E}{L}$. At the same time if the force required to circulate be less than $F = \frac{E}{L}$ or $= F'$, and L remain constant, the combination of cells in series will have the effect of diminishing w, and ultimately, of producing the required force F′.

From this we also learn, that the force required to circulate for the ignition of Mr. Brunton's fuze is considerably less than that for the platinum bursting charge, and this is still more apparent when we find, as we do, that it does not produce any sensible heat in the platinum wire, much less fuze it.

The battery that gave these results was one that was supplied by the Gutta Percha Company as the best then known for igniting these fuzes. It was a common zinc and copper arrangement, each pair 4″ × 4″, and each compartment filled up with sand moistened with acid. One hundred plates were required to ignite a fuze with certainty, and even three hundred would not produce a sensible heat on platinum wire, and this I have said is due to the amount of resistance offered by the intervening stratum, in this case composed of sand and dilute acid: but as sand is no conductor, the only reason I can assign for its use is that it enables the batteries to be carried about without spilling the acid. The average resistance of the stratum of sand, supposing it to have been entirely moistened by dilute acid, when a force F was circulating, was found = about 12·8 turns at the distance at which the plates stood, and the available force per cell = 6·7 turns, making the equation representing its action $F = \frac{E}{12{\cdot}8 + 6{\cdot}7} = \frac{E}{19{\cdot}5}$. By the employment of sand, certainly not one-fourth the quantity of liquid can be used, consequently the resistance L must be increased at least four fold, or = 51·22, which renders it impossible that the force, which we have called F, can circulate in any such arrangement. The use of sand also prevents the evolution of the hydrogen, and so reacts in controlling the electromotive force. These figures are not given as strictly correct; it was my intention to have ascertained the comparative value of the forces required to produce ignition in Mr. Brunton's fuze, and fusion of the platinum wire, but no opportunity having offered itself I am sorry that I cannot be more accurate in these general statements, though I am confident that I do not over state the results.

4. It is easy then to see that the diameter and description of metallic conducting medium for the platinum charge are matters of material consequence, and its standard resistance should in all cases be known; but with Mr. Brunton's fuze it is of no consideration to know it, and in this respect Mr. Brunton's fuze presents singular advantages.

5. The isolation of the conducting medium to Mr. Brunton's fuze must be *absolutely perfect*, whether the explosion is to take place on land or in water; with the platinum wire charge it need not be so in either, and this, so far as I have been able to ascertain, is the worst feature of the Gutta Percha fuze, and will, I am afraid, unless some mode of protecting the covering be devised, lead to constant failures from no assignable cause. The abrasion of the covering may be so small as hardly to be discovered by the eye, and yet it will be sufficient, if in contact with the earth, to cut off the circuit almost entirely from the bursting charge. From Ohm's law for divided circuits this is easily accounted for. The resistance of the fuze being by far the most considerable one in the whole circuit, any way by which the current can return to the battery, without passing through the charge, will be taken advantage of for that purpose, by just so much the greater portion of the galvanic excitement generated.

When we consider the chances of a covering like gutta-percha (and this is the only covering that is known, which can be employed in practice, and at the same time give perfect isolation) being cut by a flint or by a workman's spade while being buried, and know that however minute the cut no power of battery will be able to overcome the obstacle it forms, or make up for the loss of fluid it occasions, the necessity for adopting some efficacious protection over the gutta-percha, before the mode of firing by Mr. Brunton's fuze can be successfully applied in military operations, will be admitted.

That this perfect isolation is not necessary for the platinum wire fuze is well known, as, even in water, the loss occasioned by a bare wire can be overcome by extra power of battery. The reason is obvious; the resistance in the bursting charge is metallic, and consequently much less than a liquid resistance. The conducting power of iron, which is certainly not superior to that of platinum, is estimated to be to that of water, as 400,000,000 to 1, and therefore even supposing the proportion of copper surface exposed, on the wire leading to and returning from the platinum bursting charges, to be in this proportion to the area of platinum wire, if their surfaces were brought to within a distance of ¾ths of an inch of each other, which they never would be in practice, only one-half the quantity of the electric fluid would be cut off from the bursting charge; and if to the distance of one foot apart, not $\frac{1}{16}$th part of the force would be arrested in its passage through the platinum wire. As any thing approaching this amount of abrasion can never occur, with ordinary care, in practice, no fear of a failure from a diversion of the currents need be entertained.

It was only a week before I was called away from the investigation of the comparative merits of the two bursting charges that Mr. George Southby, a manufacturer of fire works in the Kent Road, informed me that he had frequently fired Mr. Brunton's fuze by means of a current induced in a secondary coil of wire wound round the primary wires on a helix. The wire leading to the bursting charge having been attached to the two ends of the secondary coil, a few plates of a Grove's battery circulated a sufficient current through the primary wires. The usual contrivance of a temporary magnet, for making a breaking contact, was employed for obtaining intermittent sparks in the fuze.

With this helix, and four plates of Grove's battery 4″ × 4″, it was easy to explode a bursting charge at the distance of 1300 yards from the operator, the longest I ever found space for trying, *the return circuit being made through the earth*. It was but necessary to leave one of the wires of the bursting charge in contact with the earth, the other being attached to the wire leading to the voltaic arrangement, with which it was connected. A wire from the other end of the secondary coil led to the earth, which, if touched, was sufficient to explode the charge. There is no doubt that this helix arrangement greatly simplifies the apparatus required for the explosion of these charges, for without it about 120 cells are required to produce with certainty the same explosion. The fact that a return wire for completing the circuit may be dispensed with is a great recommendation for the adoption of this fuze; though at the same time, it must be remembered that perfectly dry earth will resist the flow of any current. In a bucket full of dried sand I put two plates of copper, one foot square, at a distance of one inch apart, and the whole power I could apply could not overcome the resistance interposed. Probably, however, in practice no such absolutely dry material would intervene; but experience alone can determine that. My explosions with a single wire were made in the marshes at Woolwich during the winter months, and I found no difficulty in overcoming the resistance of the most extreme range I could there obtain; nor do I feel any doubt that these charges in such soil could have been fired by a single wire connection, at a distance of three or four miles, with apparatus sufficiently portable for engineering purposes in the field. Should, however, practice point out that it is unsafe to trust to an earth return circuit, this return, if made metallic, need not be isolated. A bare copper or iron wire, of small dimensions, will be sufficient for all purposes, and it may perhaps be so arranged that a metallic covering, such as thin iron or lead tubing should encase the other wire, covered with gutta-percha, so as to protect it from flints or the workman's spade, and ensure the return of the current. Mr. Statham, the obliging director of the gutta-percha works, has indeed lately shewn me specimens of such wires encased in lead, and in spiral wire, which he informed me would cost from £30 to £35 per mile.

With respect to firing a number of charges simultaneously, with each of these fuzes; the platinum charge, as may be supposed, has the advantage, for on account of the great resistance added to the circuit, where a second gutta-percha fuze is introduced, the force before circulating is materially diminished, and can only be brought up to the original strength by a great addition of power. The practice I have had with this fuze is not sufficiently extensive to give me confidence in its application to simultaneous firing, but I will state what has been done. 120 plates of the sand battery before mentioned, or 10 batteries of 12 each, fired one charge well through a circuit of five miles of copper conducting medium, about No. 16 gauge: 96 did the same feebly; 72 could not fire it; 216 plates were required, roughly speaking, to fire two placed in the same circuit; 216 fired three in a circuit of one mile: 360 fired six, and 480 fired eight in the same circuit.

These experiments were made in Mr. Brunton's presence, the wires being under water in the canal basin by the gutta-percha works; but it should be remembered that the whole of the circuit was not metallic, a few yards of the return portion being through earth and water, which however, when compared with the great extent of wire, may be considered to have no sensible influence on the result. From them it will be seen that these fuzes are capable of being exploded simultaneously when placed in a circuit; but it requires more practice to determine if they can be so trusted, and it is apparent that each additional one requires a large addition of cells. With the platinum wire fuze, an addition of two plates for every charge inserted is all that is necessary to establish the circulation of the required force. The platinum charge possesses a great advantage over the gutta-percha fuze, in that its resistance being metallic is uniform, while that of the gutta-percha depends upon the degree of action that has taken place on the copper wire, and especially on the extent of sulphuret circuit; for its resistance is so great that an additional length of one-eighth of an inch causes a great diminution of force in circulation. This last circumstance, combined with the degree of action that has taken place, tend to make the resistance so variable that sometimes 12 plates have been able to ignite a fuze, though as I have said, it is not safe to apply less than 100 plates of the sand battery. With the platinum charge two plates are always sufficient to overcome the resistance. The gutta-percha fuzes are also liable to deteriorate by exposure to the air, sulphate of copper forming where the sulphides were, and the fuze losing in consequence its inflammable properties. Several modes have been tried, by some of my brother officers, of making these fuzes, some requiring six months to mature, and others only half an hour; but the respective sorts seemingly present this property, that the sooner they come to maturity the easier they deteriorate. Both descriptions of fuze have their peculiar advantages. The one may be issued ready made, as an article of store, and the other would sometimes turn to account in an emergency in the field, when the store supply had been exhausted. In fact, the range of enquiry with respect to this description of fuze is very extensive, and well worthy of pursuit. There seems no reason why the degree of force required to ignite it, the actual resistance of each charge inserted, the most approved method of making it, and the most convenient voltaic arrangement to inflame it, should not be brought to the same degree of mechanical exactness, that I have endeavoured, when treating of the motive power, to shew, may be attained in respect to the platinum fuze; and the ultimate result may be that it will supersede the metallic bursting charge. I have endeavoured to show the points where it possesses advantages, and where it is less to be trusted, but in the present state of our knowledge respecting it, I cannot recommend its adoption for general engineering purposes in the field; for though it has the power of being ignited at distances which may be estimated in miles, without in ordinary circumstances requiring a return circuit, and without requiring any minute attention to the conducting power of the wire; yet as I apprehend, such enormous distances will not be necessary in the field; as the cost of the return metallic circuit can be made up by a less expenditure of gutta percha in procuring isolation; as the resistance of any wire employed can be ascertained with sufficient accuracy and hardly any labor in a few minutes; and, as I hope to shew, the power required for any proposed explosions, simultaneous or otherwise, can be calculated with far more correctness and confidence than, with respect to the gutta percha fuze, it is as yet possible to do; and above all, as the casualties that ordinarily attend the laying out and burying of the conducting medium will have no sensible effect on the platinum fuze, while they have a most important one on the other, it seems right to conclude that, as far as our experience goes, the platinum fuze possesses greater recommendations for use in military engineering, and this is my conviction.*

Having thus decided on the most suitable battery, conducting medium, and bursting charge, it remains yet to point out the rule for calculating the number of cells necessary for exploding any arrangement of charges with them, and at any distances that may be required. The length of the platinum wire of the bursting charge will, of course, influence the resistance of that part of the circuit. From practice I have found, that a wire $\frac{3}{8}$ths of an inch long gives sufficient heat, with the least expenditure of power, and it therefore seems desirable to use that length, as it is as well to adopt some one length whatever it may be, though I see no reason for always rigidly adhering to it. A length of $\frac{3}{8}$ths of an inch, weighing 1·65 grains per yard, offers a resistance of nearly 61 turns of standard wire, which is equivalent to about 90 yards of the selected copper conducting medium, weighing 250 grains per yard, and any extra length employed must be allowed for in the same ratio.

Referring back to the equations representing the working of the reduced Grove's battery, it will be seen that $F = \frac{E}{46}$ is assumed as the mechanical expression representing that each cell of the battery, in fair working order, may be subjected to a controlling resistance equal to 46 turns of standard wire, and yet will fuze the platinum wire in the midst of powder: and that $\frac{E}{68\frac{1}{2}}$ represents the conditions of fusion when no powder surrounds the wire: but as it is the rule for the explosion of powder which we have now to consider, the expression $\frac{E}{46}$ most concerns us, and this expression for the power in strong action, that is, during the first two or three hours, is represented by $\frac{E}{14\frac{1}{2} + 31\frac{1}{2}}$ where $14\frac{1}{2}$ is the average liquid resistance per cell, and $31\frac{1}{2}$ is the energy available for overcoming the metallic resistance.

I have said that, roughly speaking, $1\frac{1}{2}$ yards of the established conducting medium of 250 grains per yard is equivalent in resistance to one turn of the rheostat, therefore the available energy per cell would be equal to about 46 yards of the conducting medium; and the resistance of a platinum wire $\frac{3}{8}$ of an inch long, and 1·65 grains per yard, being 60 turns, would be equal to, say, 100 yards of the wire. For firing a mine at any distance when the battery is in good work, we have then this simple rule:—Take the whole circuit in yards, including distance up and down shafts, add to it 100 yards for every charge in the circuit, and divide by 46 for the number of cells. This is the rule that theory points out; it will not be advisable to draw it so fine in

* Note E see end of this Paper.

practice, but my object at present is to show the principle which regulates the calculation.

Again when the battery has been six hours in action, $\frac{E}{42}$ and $\frac{E}{63\frac{1}{4}}$ are shewn to be the mechanical expressions representing the resistance which each cell has the power of bringing under control whilst circulating a force sufficient to fuze the wire, in and out of powder. Taking $\frac{E}{42}$ which concerns us most at this moment, we find by referring back that 23 of the 42 turns are consumed by the liquid resistance of each cell, and only 19 per cell are left to overcome metallic resistance, in fact $\frac{E}{42}$ being $= \frac{E}{23 + 19}$. These 19, expressed in turns of the established conducting medium, $= 28\frac{1}{2}$ yards per cell; having now therefore but $28\frac{1}{2}$ yards of available energy per cell, instead of 46, the rule for calculating explosion must be modified as follows:—Take the whole circuit as before in yards, add to it 100 yards for every charge placed in the circuit, and divide by $28\frac{1}{2}$ for the number of cells; and it will be seen that these two rules give widely different results: as for instance, if a mine were required to be fired at a distance of half a mile, the former would give 41 cells and the latter 66 cells as requisite.

If at any time an economical use of cells is of consequence, it is desirable to have a ready mode of ascertaining what condition the battery is in, for it matters not what that may be, provided we can ascertain it, and apply the proper rule. Fortunately there is a very ready mode of ascertaining with sufficient exactness the power of any arrangement of cells in series at any moment, and of determining the number of cells necessary at any period between the first charging and 6 hours after. We have, for instance, seen that when the battery is in good action $\frac{E}{68\frac{1}{2}}$ is the force necessary for firing one platinum wire placed in the galvanometer, that double this force or $\frac{E}{34}$ will be required to fuze two side by side; similarly, a force represented by $\frac{E}{23}$ is required for firing three, $\frac{E}{17}$ for four, $\frac{E}{13\frac{2}{3}}$ for five, $\frac{E}{11\frac{1}{2}}$ for 6 wires, and so on: these results all depending on the figure $68\frac{1}{2}$, which at this period represents the electro-motive energy of the battery in turns of standard wire.

Whatever may be the number of wires that can be fuzed side by side, the resistance of the liquid stratum cannot be affected by it, and while the electro-motive force per cell remains at $68\frac{1}{2}$, the fact of being able to fuze any number of wires side by side, shows that the resistance of the liquid stratum cannot be so much as the denominator of the fraction representing the force required for such fusion. For instance, if 5 wires can be fuzed, side by side, the resistance of the liquid cannot $=$ $13\frac{2}{3}$, for if it did, the force $\frac{E}{13\frac{2}{3}}$ would be exactly balanced by the resistance, and could not circulate; if six, it cannot equal $11\frac{1}{2}$. Having thus ascertained that five wires can be fused, and not six, it would be quite safe to call $L = 13\frac{2}{3}$, and as $\frac{E}{46}$ represents the force necessary for fusion in powder, it is perfectly certain that at that moment the available energy per cell, for an explosion, in turns of standard wire, cannot be less than $46 - 13\frac{2}{3} = 32\frac{1}{3}$ turns $= 48$ yards of selected medium. Similarly, if but four wires can be fused, it will be perfectly safe to allow 44 yards of selected medium per cell; or if but three, 35 yards per cell, the resistance of the liquid at this period approaching 23 turns.

At the end of the day of six hours it has been seen that the electro-motive force has fallen in the proportion of 68½ to 63. And the available energy per cell will be reduced as follows: if 4 wires fuze and not 5, to 39 yards; and further, if 3 wires fuze and not 4, to 32 yards; and it would not be possible to fuze 5 wires, with electric energy at 63, at any intervening period, but an allowance of 1½ per cent. per hour for the diminution of the electro-motive force will give the available energy per cell at that time.

This detail has been given to shew the principle of the rule and its amount of accuracy, but in practice the whole may be combined into this simple one. Previous to firing a mine, when all the plates are arranged and connected, insert 5 wires in the slits of the galvanometer, and place the whole series on to fuze it. In all cases it is desirable to put on the *whole* number of cells you intend applying to the explosion required; as by this means you obtain a practical proof of what that combination, with all the errors the manipulator may have committed in arranging the battery, is able to perform; and you must take care *not to touch the connection* of the battery after you are satisfied as to the power it presents for your use. If a fusion takes place, allow 44 yards of circuit for every cell; and if the number of cells employed do by calculation cover the range, reckoning the charge as 100 yards, you may feel confident in the explosion taking place as soon as the connection is made—if there are not sufficient cells, add one for every 44 yards over. If only 4 wires fuze, allow 39 yards per cell; if only 3, 32 yards.

The trial should be made with all the cells that it is proposed to use, and, if any are subsequently added, it should be repeated; for the more cells there are in combination the more accurate is the result. The advantage of the trial is that the result immediately points out any mistake that has been made in charging the cells, or in arranging them, and also if that mistake is of any material consequence; and it may be assumed that the same series of this size of plates that will fuze 5 wires side by side, will as surely command a circuit of 44 yards for every cell.

It is customary previous to an explosion to test the wire circuit by a galvanometer needle to ascertain if the circuit is entire, but it seems to me equally necessary to test the power of the battery. The test I have explained does not require two minutes to apply, and infallibly points out the available force at that moment.

As the diameter of the conducting medium is of great importance, as well as its specific resistance, it is fortunate that the rheostat, by a mode essentially practical, enables us readily to determine the absolute conducting power of any diameter or description of wire. The mode of doing this has been explained before, and need not now be repeated: it will be sufficient to say that the probable error of a single observation with Grove's battery does not exceed 1½ per cent., (for which an allowance can always be made on the safe side); and that any one accustomed to use the instrument could in an hour ascertain the resistance of any platinum wire that may be obtained on the spot, or of two or three miles of conducting medium, as well as every particular concerning the battery, so as to be able to apply them with certainty to explode any arrangement of charges that may be desired.

Though I consider that a rheostat should be kept at the depot or head-quarters of an Engineer establishment to measure the power of unknown materials, it is by no means necessary in the field. It would indeed be easy to supply the Gutta Percha Company with bare wire of a given weight, which they might cover, and before issuing them for service they should be proved at some depôt, and their conducting power in proportion to some recognised standard, (which should be preserved at Chatham or other head-quarters), should be determined, and a report might accompany the issue of the wire if found necessary. I do not myself consider that this report could be necessary; as the same description of wire being supplied from the same quarter would conduct for all practical purposes with the same facility, and this would reduce the calculation of the number of cells for an explosion to the single rule before given.

I consider it, however, essential that every portion of conducting wire issued on service should be proved first. Let there be one description of wire kept at the depôt, which should weigh for the sake of accuracy, somewhere near 250 grains per yard, and be covered with gutta-percha; but beyond that no precaution is necessary, nor is it essential to know the precise diameter or weight of it. A rheostat *rated*, so to speak, from this standard should be supplied to each branch depôt or head-quarters, and batteries and wires similarly rated should be also furnished in quantities sufficient to meet the probable requirements.

Thus, if any portion of the supplies for voltaic purposes should fall short, if the expenditure of all the platinum wire should render it requisite to employ fine iron wire, if it should be necessary to use a different conducting medium in the place of the established one, or a different battery of different acids, or, in fact, if any alteration, should be rendered imperative from local circumstances, we shall have a ready mode of calculating the allowance to be made in consequence of the substitutions. And above all, we shall have the power of comparing practice in different parts of the world, and of estimating accurately the merits of any new combinations, by a report of the experiments of half a day

The task of perfecting the details of these arrangements must necessarily devolve on those who may be directed to continue this inquiry; as I have merely touched on the advantages that I consider attainable from them.

Simultaneous Firing.

I would say a few words on the simultaneous firing of a number of charges or mines by one battery, and point out how theory guides us to a just conclusion as to the number of plates necessary for any number under any arrangement. Reasoning then from the results obtained from Grove's battery, which I consider to be allowed to be the best, we have found,

1st. That a force represented by $\frac{E}{46}$ is required to circulate, in order to produce an explosion of one bursting charge made with platinum wire $\frac{3}{8}$ths of an inch long, and weighing about 1·65 grains per yard.

2nd. It is also, I presume, admitted that when any force circulates in the manner that a voltaic electric force does, the quantity passing at any one time in all parts of the circuit is the same, but that the heat developed at particular parts depends on the quality of the metal, its diameter and conductibility. If then we place in the circuit any number of short platinum wires, identical in weight and length, and cause a force $\frac{E}{46}$ to circulate through it, we are led to expect that they will all fuze at the same instant, and if they do so, the explosion will also be simultaneous. Now, in order to cause such a force to circulate, it is only necessary that cells should be added capable of overcoming the resistance added by introducing each charge, or cells equivalent to 90 yards of selected conducting medium; that is, when the battery is strong, two cells per charge, and at other times three cells per charge. This theory, if practically applicable, is productive of great economy, both in cells and wire, for supposing twelve charges to be exploded simultaneously at the distance of one seventh of a mile, or in a circuit of half a mile; by the rule before given, when the battery is in strong condition 44 cells would do the work easily with an expenditure of but half a mile of conducting medium; whereas, if each had to be fired by a separate battery, we should require 22 cells and half a mile of wire for *each* charge, making in all six miles of wires and 264 cells. It is apparent then how desirable it is to perfect this mode of firing, if perfected it can be, and of this I do not feel any doubt. I am sorry that I am not able to place before my brother officers in this report, an account of experiments by this mode sufficient to convince them of its practicability; but I have no doubt that those who carry on the enquiry will soon be able to do so. It was for some time thought, that minute differences in the lengths of the several platinum wires were of material consequence; but this I can confidently state is not the case, for though it is true that if they occur one length will fuze before the others, yet if the difference is not palpably great, the unfuzed wires will be so near fusion as to be much more than sufficiently hot for exploding powder. A far greater cause of error lies in the difference there may be in the thickness of the wire in each charge, as a difference not discernible to the eye, except by close comparison, will be sufficient to produce a failure. For instance, I had two platinum wires, one weighing $2\frac{1}{2}$ grains per yard, and the other $1\frac{2}{3}$ grains, and the same power which fuzed the latter produced only a dull red heat in the same length of the former, hardly sufficient to fire powder. Fortunately the accuracy with which a metal like platinum can be drawn, enables us to eliminate this source of error, and renders platinum superior for this purpose to iron, which is liable to rust and to deteriorate. It is only therefore necessary to know the wire we are using in every case, and to take care that it shall always be the same.

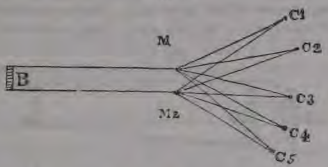
I am somewhat doubtful as to the best thickness for the platinum wire, and for this reason; I have repeatedly fired bursting charges, made of wire of $2\frac{1}{2}$ grains per yard, placed in a circuit varied according to the power of battery I employed; and when a circuit has once been established as effectively under command, I have repeated the experiments day after day without a single failure. It would be tedious to record all the experiments; but, it may be said that seven charges have constantly been exploded in a circuit of a thousand yards of wire $\frac{1}{5}$th of an inch thick by twelve cells of the larger power, and I have not on record one failure in this trial. In *none of these cases did I measure the length of platinum wire, I was satisfied to judge it by the eye.* Latterly however, having expended the thick wire, and thus having to employ that weighing $1\frac{2}{3}$ grains per yard, the following failures occurred: when I attempted to fire eight guns at the proof at Woolwich, through copper wire $\frac{1}{10}$th of an inch thick, and through a circuit of 800 yards, by 24 of Grove's small cells, only five exploded: 48 cells were then put on, and the whole eight were fired as one shot: but on another day eleven were tried with 48 cells, and only seven exploded.

There is an item of error which enters into such trials as the above, which it seems fair should be considered. The whole of the arrangement of the bursting charge, so to speak, has to be comprised in a quill tube, $\frac{3}{8}$ths of an inch in diameter. And it is then necessary, to ensure explosion, that two copper conducting wires should, while kept asunder, enter this tube and be connected by a platinum wire $\frac{2}{8}$ths of an inch long, this latter being in contact with some easily inflammable substance; for, if not, it may be fuzed and yet not set fire to the tube. The above failures may then have been due to my want of skill in effecting so delicate an arrangement, and not to defects of principle; yet they seem sufficient to raise a doubt as to the efficiency of the wire thus arranged.

At the close of the latter day I arranged twenty charges in a circuit of 800 yards, and endeavoured to fire them by forty-eight of Grove's small cells, when only fifteen exploded. Twenty charges, it will be seen by the rule given, were more than the battery of forty-eight cells could bear; for allowing one cell for each forty-six yards of circuit, and two for every charge, would give fifty-seven cells as necessary; but, as I had not that number, I tried forty eight and failed. In practice it is always best to be on the safe side of the rule, and even to add a dozen cells to the estimated quantity to make sure.

Such is the imperfect practice which I have had with the smaller description of platinum wire in the bursting charge. I do not think it sufficient to condemn the use of the small wire, more especially as it possesses the advantage of being more easily fuzed; but I must leave future practice to decide, if, on the whole, it is more advantageous. I will presently sketch out the rules for guidance in making future trials; but I will first notice the following mode of simultaneous firing, which has been before greatly recommended for its safety, and I believe often practised.

Fig. 2.

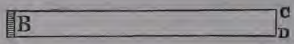


Supposing B to be the battery, and C_1 C_2 C_3 C_4 C_5, five mines to be fired. At a convenient distance from B two mercury cups M M_2 should be placed, a wire from each mine leading to each cup, and a pair of wires from the cups to the battery. This mode of arrangement has the advantage of connecting each mine directly with the battery, and making its explosion independent of any error that may have occurred in any of the other mines. So far it has great advantages, and we also save five pairs of wires, which would have been required to cover the five distances, B C_1, B C_2, &c., and it only remains to determine, by reference to the preceding investigation, what power of battery is necessary to explode the five simultaneously.

As it is evident that the battery B must (when the distances C_1 M, C_2 M_2, &c., are all equal) circulate the same amount of force through each of the bursting charges C_1 C_2 C_3 C_4 C_5, and as each platinum wire must be brought to a state of fusion in surrounding powder, the force to fuze all, or that flowing along B M and M_2 B must be five times that for fuzing one. Now $\frac{E}{46}$ in standard measure is assumed as a representation of the force for fuzing one wire in powder, therefore $\frac{E}{\frac{1}{5}46}$, or say $\frac{E}{9}$, will be that required for fuzing all. With the reduced Grove arranged in series no number of cells could circulate this force; because, as before stated, the liquid resistance is more than 9 or $= 14\frac{1}{2}$; and it then follows that, unless we can reduce this resistance L, we cannot, with the Grove in question, explode these five charges simultaneously.

There is however the following ready mode of reducing the amount of this resistance. Imagine a current of electricity flowing through a circuit of wire B C D, the parts of which B C, C D and D B, being identical in all respects, will oppose an

Fig. 3.



equal resistance for equal portions to the circulation of the current. Now let the portion C D be increased to double the size, or what is the same thing, along that portion of the circuit let another wire identical with C D be placed, carrying the electric fluid from C to D concurrently with C D, the effect will be that the resistance of the length C D of the circuit will be reduced to one-half, or if a third wire be added it will be reduced to one-third, and so on.

Now, altering this disposition of the circuit, let us imagine one battery B, say of 12 cells, circulating a current B C D as before, having another, identical in all respects, placed alongside of it, the two zincs being connected, as also the two

Fig. 4.

platinums, and the current circulating in the direction Z P D C. Banishing for a moment from the mind the idea that the electricity is being generated there, which circumstance cannot affect the reasoning, it will be seen that if the resistance of 12 cells before was 12 L, the resistance by this new arrangement *of this part of the circuit* has been reduced to 6 L, or imagining the two batteries B and B, each of 12 cells, to be now one battery, the resistance of the 12 cells of this new machine is now but one-half of what it was in the old one, and if a third battery was put along side, the resistance of the combination would be 4 L, and so on. We can therefore make a battery, *without any more trouble than that of altering the modes of connection*, which shall give a resistance of liquid of any degree we please; and therefore we can circulate *with economy* any amount of force, or in fact form a battery suitable for *any* purpose.

In the case we have taken, we require to circulate an amount of force expressed by $\frac{E}{9}$ in standard measure, where $R = L + w = 9$. The most economical mode, theoretically speaking, to circulate this, is to make a battery in which $L = 4\frac{1}{2}$, leaving $4\frac{1}{2}$ of standard measure for each cell's available energy, but on practical considerations before noticed, L should be somewhat less than w.

The resistance of each cell of the Grove battery adopted has been shewn to be about $14\frac{1}{2}$. Now 5 batteries arranged abreast will reduce this to $\frac{14 \cdot 5}{5}$ say 3, leaving $9 - 3 = 6$ turns $= 9$ yards of adopted conducting medium, as the available energy per cell, and if, in the case before us, we suppose the distance M B to be one quarter of a mile = 440 yards, and the distances M C_1, M C_2 &c., each = 100 yards, the mode of calculating the number of cells to produce instantaneous explosion of these five thus arranged would be: circuit M C_1 M_1 including platinum fuze = 200 + 90, then the resistance of 5 concurrently would be $\frac{290}{5} = 58$: to this add 440 × 2 (= 880) giving 938, and dividing by 9 yards, the available energy per cell, will give 104 cells for the number in combination 5 *deep* in series, or 104 × 5 = 520 cells in all.

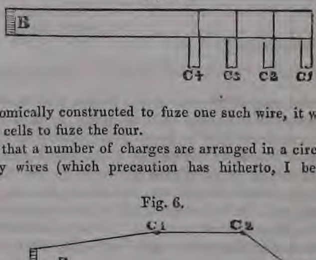
Now, by the other mode of simultaneous firing, a much less number of cells will be necessary; any one of these charges could have been fired by an arrangement of 30 cells with ease, and as many more introduced into the circuit at the rate of 2 or at most 3 additional cells for each charge.

The reason for this immense difference in the number of cells necessary in the two modes, is that, in the case where all the platinum wires are placed in one circuit, it is not necessary to increase the *amount* of circulating force, because the quantity flowing through one charge helps to raise the heat of all; but in the latter arrangement, it is necessary to supply heat sufficient to melt 5 platinum wires, of one thickness, simultaneously, and as they *share* the electric current established *between them*, 5 times the amount of force is necessary. If then an equation $\frac{E}{L + w} = F$ represents a battery in which L + *w* are economically arranged to produce a force F, then $\frac{E}{\frac{L}{5} + \frac{w}{5}} = 5F$ represents a disposition for fuzing 5 such wires. Now $\frac{L}{5}$ it has been shown, can only be produced by placing 5 cells abreast, and as $\frac{w}{5}$, representing the available energy per cell, is only *one-fifth* of what it was before, it requires that five times as many should be arranged in series, end on, to overcome any given resistance.

These are the only two principles of firing simultaneously that are practised, for the following arrangement is but a modification of the second mode, as will be easily apparent, and the same mode of calculation applies to it. We have, by the second principle of arrangement, a mode of exploding any number of charges simultaneously, and from the principle itself it is evident that a failure cannot take place, for each charge will be quite independent of the others. At the same time it is very doubtful if any economy is secured by this arrangement. Supposing BMC_1 in fig. 2, page 161, to be 540 yards as before, $\frac{540}{23} + 2$ gives 26 cells as quite sufficient for exploding that one mine, and therefore 26 × 5 = 150 cells would be enough to explode all five simultaneously, if *each charge* had a pair of wires leading to B: now to economise *four* pairs of wires along M B, or to save the trouble of laying out two miles of wire, we are obliged to employ 520 − 150 = 370 extra cells, and it becomes a matter for consideration whether the extra expenditure of trouble and acid, at the source of supply, does not more than counterbalance the labour of arranging the wires. In fact, I have long since made up my mind that the first principle of simultaneous firing, viz., that of placing all charges in one circuit, is the *only* economical mode, and that it requires but a knowledge of the principles which I have endeavoured to make clear, without any finessing in practical details, to ensure success with it on every occasion. I had hoped, by a series of experimental results on a large scale, to have shewn this, but failing in obtaining an opportunity, amidst my other duties, I must leave it to those who may take up the inquiry to carry it to a successful result. The great cause of failures in simultaneous explosion has been the want of sufficient power; and if any one will take the trouble to examine, as I have for my own satisfaction done, on the principle of Ohm's Theory, the statistics of recorded failures, they will see that they all thus occurred from a manifest want of power; so that instead of disappointment at their want of success, they will wonder how they ever succeeded. I have done this in every case I could find on record, and with the same result: it would be tedious to examine all these in this paper; but it may bring back many who have rejected the use of Voltaic batteries for explosions to a confidence in their agency, if we mention a few points shortly that have helped to acquire for the voltaic principle the character of extreme mutability.

It has generally been the habit, as a matter of precaution, to solder two wires side by side in a bursting charge, in case one should break; would any one unacquainted with Ohm's Theory imagine that if a battery, economically constructed for fuzing one wire, were used to fuze two side by side, it would not be able to produce even visible heat in either of the two, or in fact, that it would require four times as many cells (arranged as explained before) to fuze these two wires? yet sometimes I have heard that three or four have been so placed. Sometimes two charges are placed thus, C_1 C_2 in one powder box, each (C_1 and C_2) having two platinum wires. If a

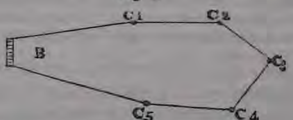
Fig. 5.



battery were economically constructed to fuze one such wire, it would require nearly 16 times as many cells to fuze the four.

Suppose again, that a number of charges are arranged in a circuit thus, each with two precautionary wires (which precaution has hitherto, I believe, been always

Fig. 6.



adopted), and that while the battery is powerful enough to fuze the double wires all round, one of the two wires in one charge (C_1) is broken by some mishap: it is then rendered *positively certain* that, however strong the battery power may be, this (C_1) will be the only charge which will explode, for the *one* wire left in it will fuze before the other pairs will arrive at any visible heat. Ohm's Theory, if I have made it understood, explains the cause and points to this as the certain result.

Again, the conducting wire hitherto used for explosion has been generally ⅛th of an inch thick, and the platinum wire in the bursting charge sometimes 1½ inches long;

now, can it be supposed that it was generally known that the introduction of one such bursting charge in the above circuit was equivalent to adding 1200 yards of the thick conducting medium, or that an equivalent to this resistance in cells was ever added to compensate for the diminution of force?

These, and many other extraordinary results depending on the principles regulating the circulation of a voltaic current, have given this agent the character of extreme mutability and uncertainty, which it does not deserve, as they were the consequence of an imperfect knowledge of those principles.

From what then has been shewn above, as the result of the use of a second platinum wire in the bursting charge, it will be apparent that I condemn its application; since in firing charges simultaneously in a circuit it is worse than useless, and is indeed ruinous in its effect. The precaution being resorted to, implies a belief that in case of a single fracture in any one charge, a second wire is at hand to complete the circuit and ensure an explosion of all: but the reverse is the case, as has been shown, and the second wire, the first being fractured, ensures that this charge is the only one which will explode: and yet the usual testing of the circuit by a galvanometer needle, previous to connecting with the battery, will delude one with the hope that all is right; whereas, if only one wire had been used in each charge, the fracture would have been made apparent at once by the breaking of the circuit, and thus a warning given to repair. In no case would I attempt to place more than one platinum wire in a bursting charge, and that charge should be *only* connected with a pair of conducting wires leading to the surface or end of the tamping; place a second charge, if it is thought desirable, and before finally connecting *either* of them with the wires intended to lead to the battery, test each by the galvanometer to see if the circuit to that point is complete, and then connect only one of them to the main wires leading to the place from which the mine is to be fired.

I have thus endeavoured in this paper to present clearly for consideration the several processes I have employed, with the aid of Ohm's Theory and Professor Wheatstone's interesting researches, in order to ascertain the most approved voltaic materials of every description, which should accompany an Engineer Establishment into the field: and I am sorry I have not had time to establish on a firm basis, by more numerous experimental results, the superiority of the mode of firing with the batteries and bursting charges, which I have recommended. Failing in this, and being about to proceed to a distant country, I have endeavoured to present, in greater detail than I otherwise should have done, the view I take of these varied phenomena, that whoever may take up this subject may have no difficulty in starting from the point where I leave off, and conducting the enquiry to a successful result. From that point it will be only necessary, after having put to the proof the rule given for calculating any number of explosions simultaneously, and having modified it if required, to devise modes by which wires leading to charges placed any where (whether in the midst of a channel, as a catamaran, or in any other position) should be protected from destruction. Practice alone can determine these points, and the Establishment at Chatham offers peculiar facilities for these experiments.

If I have made the preceding portion of my paper clear, it will be seen that for whatever purpose voltaic agency may be required, and whatever principle we adopt, to circulate the amount of current required, there is a certain size of plates which will do it to the best advantage, depending on the mechanical equivalent representing the value of that force. In the present case, the force required was found to be best produced by a Grove's arrangement of the size submitted. When a Smee was tried, though from its simplicity it was preferable to a Grove, it was found that it choked itself, as it were, in its endeavours to circulate the amount required, and consequently its circulation was not constant and not suitable for our purpose; at the same time its electro-motive energy being low, more bulk was necessary for producing any effect. Daniell's battery certainly circulated a constant force of the degree required; but it was inferior in electro-motive energy to Grove's, and, being at the same time more complicated, was rejected, and so with the others.

Now, in electro-plating, the mechanical equivalent representing the degree of force desirable then can be circulated by a Smee with constancy; and therefore its simplicity renders it preferable for that operation, but we have no scientific demonstration that the size of plates that are employed in such operations do circulate it to the best advantage, that is with the utmost economy. It would be very desirable to obtain the equivalent expressing this force which would determine the size of the plates. Similarly with magnetic effects, electric light and other voltaic phenomena, we only know that one battery, and that of a particular size, produces these effects better than another kind of battery or another size, but we are yet ignorant of the mechanical equivalent, representing the value of the force in each case to produce these effects, and therefore cannot know the best size of the battery; these enquiries would tend to economy in all these processes, and would rank voltaic electricity among the exact sciences, presenting its varying phenomena as unity to the mind.

The following suggestions are intended to serve as a guide to further enquiry respecting voltaic phenomena as applicable to military purposes, and are combined with a statement of those points which seem to me to be satisfactorily decided, and of the conclusions which still require furthur proof to establish their adoption.

The success of any arrangement for an explosion by means of voltaic agency depends on our knowledge of the materials employed for that purpose, and I have endeavoured in the preceding pages to shew how, and by adopting a standard measure in the shape of wire coiled on a Rheostat, this knowledge can be readily obtained, and at the same time how erroneous a conclusion in some cases a simple eye-judgment is likely to lead to. I have also recommended a certain size and description of battery, a conducting medium in the shape of a wire weighing about 250 grains per yard, and a platinum wire weighing 1·65 grains per yard and $\frac{3}{8}$ of an inch long, to be employed in the manufacture of the bursting charge.

I have shewn that the simultaneous explosion of any number of charges of powder can be obtained, if we can at the required moment establish the flow of such a constant current of electricity as shall produce a fusion heat in every platinum wire placed in the circuit.

It is advantageous however that this circulation should be produced with the utmost economy, consistent with certainty; and I have shewn in the report that the economical consideration is theoretically satisfied when (E representing the electro-motive energy of the combination, L the resistance of the liquid, w that of the wire, n the number of plates, and F the required amount of current) in the equation $F = \frac{n\,E}{n\,L + w}$, $n\,L = w$, or $L = \frac{w}{n}$; but that practically, for reasons given, L should be somewhat less than $\frac{w}{n}$, the expression $\frac{w}{n}$ representing the available energy per cell of the voltaic combination.

Now the battery submitted has been constructed to satisfy these conditions, with the platinum wire which I recommend. But it will be evident that any alteration in the amount of current required to circulate, would require a corresponding modification of the battery. For instance, if a platinum wire double the thickness of that recommended were substituted, more heat would be required to fuze it, and therefore a greater current must be caused to circulate. This can only be brought about in the equation $F = \frac{n E}{n L + w}$, where E and L are constant, as they are in any *determined* form and principle of battery, by a diminution of w; and if this diminution reduces w in value below n L, the amount of current required is no longer economically circulated. Nor can it be so till the value of L is also reduced, the principal mode of affecting which is by enlarging the size of the plates. The *diameter* of the platinum wire is therefore an *essential* consideration in determining the size of the plates in any voltaic arrangement to produce its fusion, as very small differences in the diameter of the platinum wire will lead to gross errors in calculating the number of cells necessary for an explosion, and uniform success can never be obtained in the field if the platinum wire has not been carefully selected, and tested as hereafter suggested before its issue from store.

The *length* of the platinum wire employed in the bursting charge is not a matter of the same importance; as a battery of the same sized plates can economically circulate the force required through any length of platinum wire. For it must be borne in mind, that by adding lengths of wire we do not call on the battery to circulate a *greater amount of force*, but merely to overcome a *greater resistance* to the circulation of the *same* amount, which can readily be done by increasing the number of plates in series. For if in the equation $F = \frac{n E}{n L + w}$, we increase w to $w + a$, and so diminish the value of F; we can immediately restore the equation to its former value by adding cells $= \frac{n a}{w}$, and the force F will circulate as economically through a resistance $w + a$ by the combination expressed by $\frac{\left(n + \frac{n a}{w}\right) E}{\left(n + \frac{n a}{w}\right) L + w + a}$ as it did in the first case through w by the combination of n cells.

It is thus quite open to any future operator with the battery submitted, to introduce any lengths of platinum wire into his bursting charge, merely remembering to employ the thickness recommended, viz., 1·65 grains per yard, a specimen of which has been handed in; though I am satisfied that $\frac{3}{8}$ths of an inch is sufficiently long for all purposes, and possesses the advantage of less liability to fracture than greater lengths.

With respect to the copper conducting medium, I have recommended that weighing 250 grains per yard, covered with gutta-percha; but it is not *essential* that any particular metal should be employed, or that the wire should be of any particular weight, as I have described a ready mode of ascertaining the resistance, in standard measure, of any material of any length.

Copper, however, from its superior conducting power, is recommended to be generally adopted, and for the sake of avoiding calculations, I advise that wire of one uniform thickness, and if possible obtained from the same manufactory, be employed. The particular copper which I used, opposed, roughly speaking, for every $1\frac{1}{2}$ yards of its length, a resistance equivalent to one turn or 10 inches of standard measure, and on this datum it was shewn how simple a rule for firing any number of charges simultaneously could be deduced; but as the value of the rule would depend on the even texture of the wire, it is necessary that every precaution should be taken to ensure it, and I conceive that a determination to have all the wires supplied from the same quarter, would be a sufficient precaution.

As it is very possible that whoever may pursue the enquiry which I have had in hand will find it necessary to purchase wires of various diameters, and of different texture and quality of metal, I prefer giving the following suggestions for conducting future experiments in terms of the standard measure, from which it can always be transposed to lengths of the wire actually employed.

It will be perceived, from my reasoning, that I advocate but one mode of simultaneous firing, viz., that of placing all mines in one circuit, for it is very questionable if any other mode is economical, though undoubtedly safe. The rule I have given in terms of *standard* measure is this. Add to the whole wire resistance of the circuit 66 turns for every charge introduced into it, and divide that by 30 for the number of cells to be employed. This rule is theoretically correct to any extent, but as I have not had the opportunity of testing it on a large scale, I do not submit the divisor 30 as undeniably the best. Let this be tested by numerous trials, altering the divisor till one is found, which, while being the greatest, at the same time gives a result uniformly successful.

I have expressed some little doubt as to the best thickness of platinum wire to be employed; if a thicker one is ultimately found desirable, it will but be necessary to find the value of the mechanical equivalent which represents its fusion in powder, and then, if necessary, so to modify the size of the plates as to adjust the values of L and w in the fraction $\frac{E}{L + w}$ economically. I should have gone into the details before constructing the battery of the size submitted, had not the short time I had to remain in England urged me to hurry on.

I have submitted that all copper conducting media should be obtained of one thickness, and from the same factory, with the expectation that they would all oppose equal resistances for equal lengths; but I will now suppose that, even when this care is taken, they are not found to do so, and that consequently such careful selection is unnecessary. I then submit the following plan for a general organization of an electrical department; and I would even suggest that such an organization would at all times be advantageous, as it would render us independent of the material employed, and thereby much contribute to success.

Let every battery for military purposes be issued from a central depôt, say Chatham; where there should be a Rheostat with a wire, as a standard measure, coiled on it, and from this any extra lengths, as supplementary coils, could be accurately reduced to standard, and preserved in the establishment for measuring any degree of power. I had indeed an idea at one time of having these supplementary coils made of a thinner description of wire, so as to permit of their being coiled in a smaller space; and probably some modification in this way may be beneficial; but it must be borne in mind, in adopting this idea, that the thinner the wire is the greater will be the heat given off from its surface, whilst a fixed amount of current is passing along it, and that this will tend to reduce the amount visible on the small platinum wire in the intensity galvanometer, and so lead to erroneous conclusions, as to the amount actually circulating; for the sake of accuracy, therefore, and when portability is not of urgent necessity, I would have the supplementary coils of the same guage as the conducting medium issued for service.

It has been shewn how, by two simple experiments, the conditions under which any battery can supply the force required to circulate for the fusion before mentioned is determinable. Having ascertained this, it is but necessary to stamp on the battery its conditions. Suppose the Grove's battery I have submitted has been tested, and that $\frac{E}{46}$ is the force required to fuze the wire in the midst of powder, (the number 46 representing so many turns of standard measure), also that the average resistance of the liquid in each cell varies from 14 to 20 turns during the first four hours, which is the utmost time a battery is likely to be kept charged for use. I would, taking as a matter of safety the larger value of L, and for the same reason adopting $\frac{E}{45}$ instead of $\frac{E}{46}$ as a representation of the force for fusion, stamp on the battery $L = 20$, $w = 25$. These figures would shew that for every cell introduced into the series I might add a resistance of 25, and yet obtain a force $\frac{E}{L + w} = \frac{E}{45}$ which I know would be sufficient for fusing the platinum wire proposed to be always issued from the depôt.

If for any reason I wish to circulate a greater force, say $\frac{E}{25}$, economically, the value of L is a guide in combining cells for that purpose, the mode of arrangement and the reasons for it having already been given in this report.

An instrument, called an intensity galvanometer, has been submitted, by means of which, and of a single trial of the number of wires capable of fusing side by side, the value of L at any particular moment can be approximately ascertained, and thence the available energy per cell or w.

The conducting wires would probably be issued in lengths of half a mile, their *actual* length and the *standard* resistance of each piece being notified at the time of issue, probably by a piece of parchment attached to each length conveying the requisite intelligence. Suppose, for example, the piece of 500 yards which, as mentioned in this report, had a resistance = 323 turns of standard measure, and another piece of 280 yards whose standard measure was found to be 402 turns, were to be issued, I would, making an allowance for resistance on the *safe* side, attach a ticket to each coil, thus: No. 1, length 500 yards, resistance 330; No. 2, length 280 yards, resistance 410; and this information would be an infallible guide to a correct result, the first figures shewing the distances the wires would reach and the second the degree of resistance of each. The above resistances are those of two coils I actually had on hand, and, as will be seen, are not proportional to the lengths, the diameters of the two wires being different, but, notwithstanding this, the information attached makes an operator independent of any knowledge of weight, or thickness, or even of the nature of the metal.

The amount of resistance to be allowed for the platinum wire should accompany its issue, and also the force requried to fuze it with the battery issued: with that used, I found $\frac{3}{8}$ths of an inch equivalent to about 60 turns of standard measure. As regards its diameter we are fortunate in having to deal with a metal which can be very accurately drawn to the degree of fineness required. Saying then that wire of 1·65 grains per yard is the most approved, the following figures would put an operator in possession of every information respecting it. Force for fusion in powder $\frac{E}{45}$; force in galvonometer $\frac{E}{68}$, resistance 1 inch = 160. The force for fusion in galvanometer is given to serve for a guide in testing approximatively the liquid resistance of the battery at any moment, as explained before, and thence deducing its available energy per cell.

As the mechanical equivalents $\frac{E}{45}$ and $\frac{E}{68}$ depend on the nature of the battery and the platinum wire used, they of course must be issued from store, and none but those acquainted with the principles governing voltaic action should be trusted to repair or modify the batteries, while I would make it imperative that but one description of platinum wire should be used in all parts of the world.

All these figures should be in terms of one standard measure to be kept permanently at some central depôt, but branch depôts may also have their standards, with rheostats rated by the general one, and thus in several parts of the world, with due organisation, comparable results under every condition of experiment would be attainable.

This plan could not only be applied to enquiries respecting voltaic phenomena, as applied to blasting, but might be extended to enquiries on electric telegraphs, electro-plating, electric light, and every process founded on an agency subject to such simple laws.*

The head quarters of an army in the field might also have its standard and rheostat, and an Engineer conversant with the principle of voltaic action would know when and where to substitute other materials than those issued from home, and what modifications in the mode of firing should attend such substitutions.

The acids I recommend to be used with Grove's battery are *nitric acid* (common), S G 1375 or thereabouts, price 6d. per lb. wholesale, and 9d. retail; it should, for the sake of the platinum, be free from hydrochloric acid, for which a small crystal of nitrate of silver is a ready test: also common sulphuric acid, from 1¼d. to 2d. per lb., diluted with about 8 parts of water to one of acid when used, and of about S G 1846 when concentrated. I consider all charges of more refined concoction both pernicious and expensive without adequate advantages.

I thus leave the inquiry that I have been pursuing with some parts necessarily imperfect; having, however, no doubt as to Grove's principle of battery being the best for engineering purposes, nor as to the copper conducting medium, of the thickness recommended and cased in gutta percha, being the most desirable. The best thickness of platinum wire is not in my opinion *decided*, though I feel that the thinner wire which I have recommended should be sufficient, and upon this decision depends the most approved size of plates, which it may be found advisable to increase from 2″ × 2″ to 2½″ × 2½″. On the arrangement of the plates as submitted I feel quite decided, for it dispenses with many binding screws without any loss of power, and I am equally satisfied in my own mind as to the arrangement of boxes of 6 cells each. With respect to the modes of simultaneous firing, I am of opinion that if that of arranging charges in one circuit is not found successful, no other will be desirable: and if by some means a number of charges must be exploded at one time, it must be by a *pair* of wires leading to *each* mine, and to *separate* batteries, the whole of the circuits being completed by word of command by several operators, or by some simple arrangement, such as has been frequently practised in the *battery house*.

With all its imperfections the object of my report will be attained, if it has succeeded in presenting the different voltaic phenomena to the mind as unity. I do not know if it has been so with others, but with me it has always been a matter of sur-

* Note F—See end of this Paper.

prise and wonder, to find that taking three *principles* of battery made *identical in size* ; No. 1 should be superior in magnetic effects ; No. 2 in the process of electro-plating, and No. 3 in the production of an electric light, as is often found to be the case. I hope this paper has accounted for these extraordinary results which we see noticed and appealed to, as standards of comparison, when any new principle of voltaic action is submitted to the notice of the scientific world. Each of these phenomena has its mechanical equivalent, representing the amount of force which must circulate to produce the desired effect; to produce any one of them economically, *each principle* of battery requires a *different* size : and to produce any of them *at all*, the size of each battery must not be below a certain limit. Appealing to the case we have examined, though it has been shewn that Grove's principle can be reduced in size to plates of about 2″ × 2″ in each cell, and yet circulate a force for fuzing a certain wire *economically*; it has also been shewn that a Smee or a Daniell of that size will not produce the same force *economically*. It has moreover been shewn that, below a certain size of plate, *any* number of cells in series is physically incapable of producing the required force, and yet may economically produce a lesser degree of force with greater economy than any other principle of battery of the same size. These considerations being borne in mind, at once account for the varied displays of power before noticed, and at the same time leave an impression on the mind of the vagueness and unsatisfactory nature of the results so recorded, unless accompanied with the further information of the electro-motive force, and of the resistance of the liquid of each voltaic combination, necessary to enable us to infer the value of the mechanical equivalent representing the advantageous display of each of the phenomena referred to, and which it seems to me are therefore worthy of accurate determination.

E. W. WARD, Captain, R.E.

NOTES BY COLONEL PORTLOCK, R.E.

Note A. Page 116.

Although the laws by which electrical action appears to be conducted, have been now successfully studied, it cannot be said that the ultimate cause of such action has even yet been rescued from obscurity; and it must still be admitted that we know electricity, as we know heat, light, and even gravity, by its effects only. Captain Ward adopts in the text the idea that the development of the electrical current is due to the chemical decomposition of the electrolyte, and that the oxygen gives its negative electricity to the zinc plate, and the hydrogen its positive electricity to the copper plate. This mode of explaining the course of the phenomena, first proposed by Grotthuss, has been generally adopted; but it is by no means certain that the action commences in the electrolyte, and it is even as probable that it takes its origin in the metallic elements of the pile. We know nothing of the true nature of the force of affinity, and therefore we must still be uncertain, whether such force is, or is not, the result of certain electric conditions; but at the same time we know that the force of affinity is at least greatly modified or affected by electric action. It is thus that others have explained the phenomena by referring the decomposition of the electrolyte to the electric current, considering it the effect and not the cause. In this mode of reasoning it is supposed that the atoms of the zinc plate, when immersed in the electrolyte become polarized towards each other, and that a similar condition is induced in the ultimate particles of the electrolyte, the atom of oxygen being negative, and the atom of hydrogen positive. In this state, however, though a condition of polarity has been established, both through the electrolyte and the metallic element, no decomposition of the electrolyte can take place, as the forces of attraction are balanced; and the same is the case, though in a reverse order, in respect to the copper plate. But now let the circuit be completed by a wire connecting the two plates, and the polarization propagated from each plate simultaneously through the wire to the centre, where the velocity of transmission is the same from both plates, or at some other point where the velocities are different, the opposite states of polarization neutralizing each other, and the molecules returning to their ordinary condition. The balance is now destroyed, and the neutralization extends backwards through the wires, until it is completed at the zinc plate by the combination of a negative molecule of oxygen with a positive molecule of zinc, and at the platinum by the evolution upon its surface of a molecule of hydrogen. If the oxide of zinc were to remain undisturbed, or were the surface of the copper to continue fully protected by a film of hydrogen, the action would cease, and the molecules of the metallic elements, as well as those of the electrolyte, would remain at rest; but the equilibrium is again disturbed by the removal, by solution, of the oxide of zinc, and the same effects are again repeated, and will be so until the zinc shall have been destroyed, or the electrolyte have ceased to dissolve the oxide of zinc formed. In describing this mode of explaining the phenomena, I have not used the terms "positively electrified" and "negatively electrified," but have spoken as if the properties were intimately connected with the molecules themselves; but, of course, it must be understood that the condition of polarity so often observed is equally inexplicable as the positive and negative fluids of electricity.

NOTE B. Page 117.

The obscurity which exists as to the true nature of electricity has rendered it almost unavoidable to adopt such terms as excitement or excitation, and to speak of the metallic elements as if exercising a certain amount of volition. On the principle explained in the preceding note, the heat produced would be due to the rapid movements of the molecules of the conducting wire, as they assume alternately a polarized and an unpolarized condition in respect to each other.

NOTE C. Page 125.

Rapid as may be the succession of these operations, they cannot be considered as instantaneous. The quantity of sulphate of zinc formed in a given time is finite, and the formation of every particle of it, however minute, must have occupied a finite portion of the whole time. The velocity of transmission of electric action may be taken as a measure of the velocity of its development, and this, however nearly approaching to instantaneity, is not absolutely instantaneous. Pouillet states $\frac{1}{2400}$, $\frac{1}{5000}$, and $\frac{1}{1000}$ of a second, as the results of several experiments, and deduces from them the result, that if the action were propagated through a column of water one metre in length, in $\frac{1}{5000}$ of a second, it would pass through a copper wire of the same section, 2,000,000,000 metres in length, or 1,242,803 miles, in the same time, and therefore with a velocity 10,000 times greater than that of light. Faraday, Wheatstone, and others, have given estimates, which shew that the velocity varies with the circumstances or condition of the action, and Riess states it at 62,500 geographical miles in a second; the velocity of the light of Jupiter's satellites, in its passage to the earth, being 41,500. I do not here reduce the geographical miles of Riess to their English equivalents, as I only quote the numbers to shew that he considers the velocity of electricity to be $1\frac{1}{2}$ that of light, as reflected from Jupiter's satellites: Professor Wheatstone considers the velocity as about the same as that of light; but from the passage of Pouillet, quoted above, it would appear that he there estimates the velocity of light at 1,000,000,000 metres per second, or 3 times that of the ordinary estimate of that velocity, which is about 191,000 miles per second. The variation in the velocity of this action, whether considered a fluid in motion or as a movement of the molecules themselves in assuming the polarized state, will produce a difference of intensity, and lead to corresponding effects in the development of heat. It might even be suggested that this velocity once ascertained affords the means of approximation to the weight of the atoms of bodies, as it exhibits a period of time during which the first combination of atoms on the surface of the zinc element had been effected, and may be compared with the total time during which a distinct weight of sulphate had been formed; at least it would give a weight which the atom could not exceed, although it might be below it.

NOTE D. Page 129.

This passage is not perhaps quite clear, as it would imply that an increase of the liquid resistance, taken by itself, would allow an augmentation of the wire resistance also. At page 128, the formula explains it, as it is shewn that—

$$F = \frac{E}{L + w} = \frac{n\,E}{n\,L + n\,w}$$

$\frac{E}{L + w}$ representing the conditions of a single pair, and $\frac{n\,E}{n\,L + n\,w}$ that of a series of n pairs, in which L having been increased n times, w has also been increased in the same proportion; but the numerator or electro-motive force has been likewise increased n times.

Note E. Page 156.

Captain Ward has, in this paper, directed his attention principally to the simple voltaic battery; and there can be little doubt that where such a battery is to be used the simple platinum wire is the best mode of effecting the explosion. The induction coil however is now assuming so improved an aspect, from the more perfect insulation of the wires in the coil of Ruhmkorff, of which the large size costs £7, and the small £3 10s., that it may fairly be expected that it will soon be adopted as the most efficient instrument for military purposes; and if so, the platinum wire will not then be the means of effecting the explosion, as it should be done by developing a spark and not by heating a wire. It is in this way, as interposing an imperfect conductor in the circuit, that the bursting charge described by Captain Ward most probably acts, as some able men doubt the theory of its application, as stated in this paper. Professor Wheatstone has pointed out to me another example of the use of an imperfect conductor in bridging over, as it were, the space left between the ends of the wires, and thus facilitating the passage of a spark. It has been adopted at Cherbourg for exploding the large charges of powder, required for excavating the new docks, and is thus managed: a cork is dipped into sulphuric acid, and a very thin layer, being carbonized by the action of the acid, is carefully removed, a small fragment of this carbonized cork is then interposed between the ends of the conducting wire, which is cut at the intended point of connection with the charge, and afterwards well secured in that position. The charcoal being an imperfect conductor just aids, and no more, the passage of a spark, and the powder is thereby exploded. Professor Wheatstone has himself also tried iron filings mixed with the powder; but, in this case, he observed that a failure was possible should the filings touch each other, and thereby form too good a conductor. He further tried the simple powder itself, and finding the spark readily developed under such circumstances, he considers that mode the best, the ends of the divided wire being, of course, at a very short distance from each other. In all cases, let it be assumed that the platinum wire bursting charge should be used with the simple voltaic battery; and some form of spark-developing charge with the induction coil.

Note F. Page 170.

It should be stated that the mode of estimating the voltaic force by heating a wire has been before adopted in statical electricity, and is even strongly condemned by Sir Snow Harris, who observes, "the fusion of wire has been resorted to as a measure of the force and extent of electrical accumulations on coated glass. Independently of this method being uncertain and tedious, it is in many instances quite inapplicable to many refined enquiries." This opinion, however, does not appear referable to the voltaic action of the pile, and the instrument, as improved by Captain Ward, is both simple and easy of application, and has the advantage of determining the force in direct reference to the object to be performed.

CONCLUDING REMARKS.

I cannot but regret that Captain Ward should have been called away before the publication of this paper, as he would have doubtless added much to it in its passage through the press; and before he had been able to extend his researches to the other branches of the enquiry. I have endeavoured to do justice to him by carefully revising the paper in its passage, and I trust it will tend to support the high character he bears amongst his brother officers, as a careful observer and experimenter, in fact, as a man of science. The further progress of the enquiry should be conducted on the model of this paper, as rude experiments made at hazard, and without reference to scientific principles, generally confuse, rather than elucidate a subject, as they frequently mix together various sources of error, and use results affected by them as if perfectly true. In any such enquiry it would be well to associate some one fully acquainted with every thing which has been done on the Continent, and no one could so effectively afford this assistance as Professor Wheatstone, who has assured me that he would willingly co-operate with the officer or officers conducting it; indeed, I cannot too warmly express my grateful sense of the readiness with which the Professor opens out his stores of practical knowledge in such matters. He has thus explained to me many novel and ingenious contrivances, such for example, as the introduction of a small clock-movement by which the discharge should be effected at any interval of time, from a few minutes upwards, so that a charge of powder might be left to explode of itself at a definite time, or if encased in a floating case might be allowed to drift against a ship or other object, and would explode at the instant the circuit became closed by the action of the clock-work. Professor Wheatstone has also assured me that a question on which I consulted him, some years ago, when he felt satisfied that it could be done, has been solved on the Continent, by the explosion of gunpowder by a current induced by a magnet, without the intervention of a voltaic battery. At the time to which I refer, Professor Wheatstone pointed out to me that by this mode chemical action had been produced in electro-plating; but the explosion of powder had not been effected by it. These remarks I make, because I feel satisfied that the best results would follow an enquiry conducted under such guidance; and the British Ordnance would be enabled to take the lead in improvements depending on the application of scientific principles to the purposes of war.

J. E. PORTLOCK.

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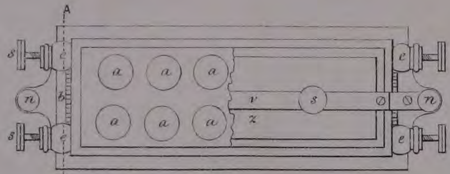
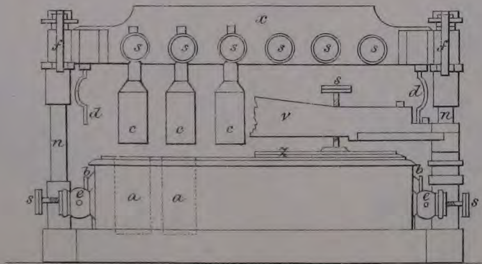
Pl. 1.



Plan.

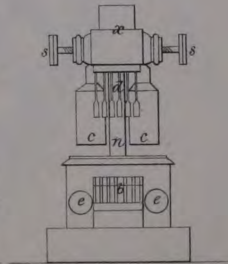
Scale ¼ nat.l size.

a. a, Platinum cylinders in metallic communication with the Platinum connectors b. b.
c. c. zinc rods in communication with the Platinum connectors d. d. When in action d. d. press lightly on b. b. thus connecting each Zinc rod with its corresponding Platinum cylinder.



Elevation

N.B. The right hand Zinc rods are omitted to shew more clearly the mode of closing the cylinders with the lid z. when not in use.
f.f. straps of india rubber, which are intended to raise the bar x when pressure is removed, so as to stop the action.



Section on A.B.

with portions of the Battery in Elevation
e. e. poles of the Battery. v. Bar to secure the lid.
s. s. screws. n. n. pillars on which the bar x. slides.

Drawn by Captn H. Scott, R.E.

Fig. 1.

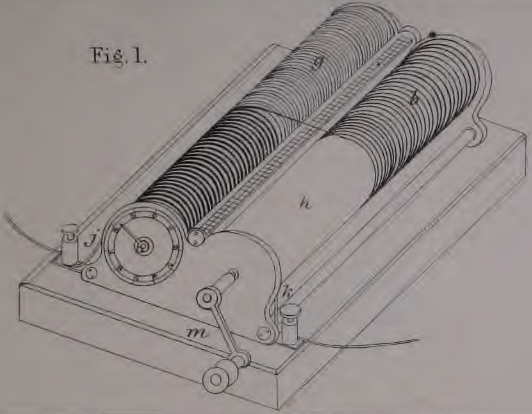


Fig. 2.

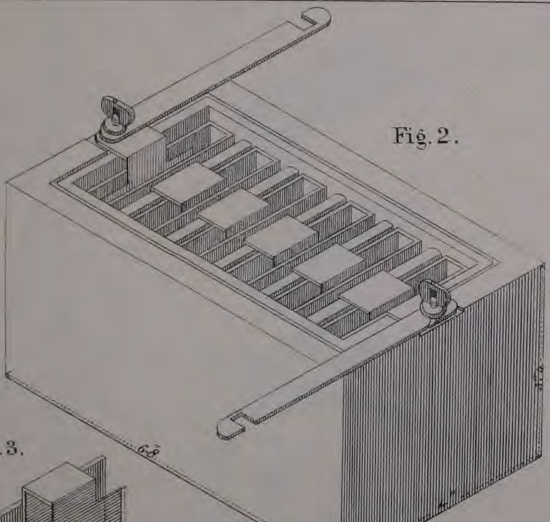
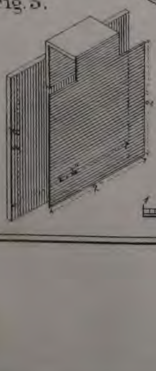
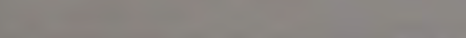
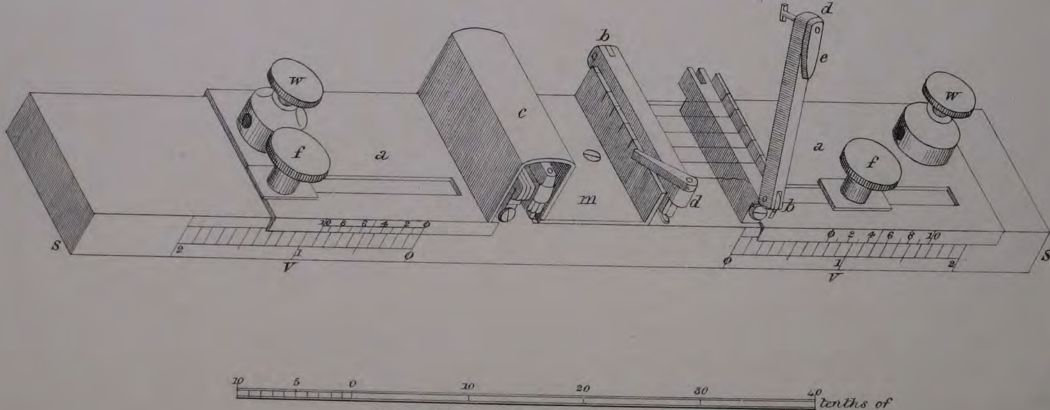


Fig. 3.







Isometrical Scale, (full size.)

Drawn by
Captn C. S. Hutchinson, R.E.