R·E

PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS,

CONTRIBUTED BY

OFFICERS OF THE ROYAL ENGINEERS.

NEW SERIES.

VOL. XIII.

PRINTED BY W. P. JACKSON, WOOLWICH.

1864.

PREFACE.

In Papers III and XVII of the present Volume, will be found some interesting particulars connected with Charleston and Fort Pulaski. I much regret that more information connected with the Engineering operations of the American War has not been procurable, and shall feel much obliged to any officers who will forward any authentic memoranda for publication in the next Volume.

Paper XV contains a resumé of the Newhaven experiments with reference to the effect of rifle projectiles on earthen parapets.

The experiments on iron armour plates, up to a late date, are again recorded in Paper XVI.

C. S. HUTCHINSON,
Captain, Royal Engineers,
Editor.

Woolwich Common,
October, 1864.

CONTENTS.

LIST OF PLATES.

MEMOIR

OF THE LATE

MAJOR-GENERAL PORTLOCK,

OF THE ROYAL ENGINEERS, L.L.D., F.R.S., M.R.I.A.

By MAJOR-GENERAL SIR THOMAS A. LARCOM, R.E., K.C.B.,

ETC., ETC., ETC.

The individual is nothing, the aggregate everything, is an apothegm most true indeed in a corporate sense, and it is a source of honest pride to all of us that we may justly feel such to be the case, as year by year honoured names drop from the roll, to be succeeded by new claimants for distinction; but the aggregate is composed of individuals, and it is not only pardonable, but useful, to pause for a moment as the scene closes on another and another, to consider the life of the individual. There was sufficient distinctness in the character of the late Major-General Portlock to render his career both instructive and worthy of study.

He was descended from a family not unknown to the public service. His father, Captain Nathaniel Portlock, of the Royal Navy, was one of the loyal colonists of America, known as the "American Loyalists," who left that country on the close of the War of Independence, and was himself born in Virginia. The family was originally from Hampshire, and there again the Portlocks settled. Nathaniel entered the navy as a midshipman, under the command of Captain Cook, and was with him at his death. He afterwards became himself one of the leaders of that hardy band of circumnavigators whose discoveries distinguished the last century. In 1785-86 and 87, he commanded an expedition of that nature on the western coast of America, the account of which was published in two volumes, "The Voyage of Portlock and Dixon."—London, 1789—and afterwards reprinted in Mavor's Series. They suffered the hardships incident in those days to long voyages and want of medical supplies, such as the occasional appearance among the crews of scurvy, which Portlock ultimately subdued by the use of native plants and herbs discovered by himself, some of which he managed to cultivate on board. On one occasion they encountered a gale of the class we should now call a cyclone, and more than once were dazzled by St. Elmo's fires, "Now in the waist, the berth, the deck, in every place, the yard, and bowsprit."

Of this voyage a curious relic lately remained, thus described by a distinguished naval geographer, Admiral Sir Edward Belcher: "I had completed my observations at a small island which I had selected for a station, but was at a loss for a mark, and had directed a tree near me, which was deprived of bark, to be felled for the purpose. I had hardly time to recall the sacrilegious order on perceiving letters on its sides, and easily traced

PORT ETCHE SHIP KING GEORGE
NATHANIEL PORTLOCK COMM[R] JULY 22 1787"

In these voyages Lieutenant Portlock acquired the intimacy of a young companion, Mr. Banks, afterwards the well-known president of the Royal Society, Sir Joseph Banks, who remained through life his staunch friend.

In 1792 he commanded the "Assistant," in Captain Bligh's second voyage of benevolence, when the bread fruit tree and other useful plants were introduced from Otaheite into our tropical colonies; and in 1793 the following vote of the House of Assembly of Jamaica stands recorded to his special honour: "Friday, 22nd November, 1793—Resolved: That the Receiver General do remit to the agent the sum of five hundred guineas, to be paid by him to the order of Lieut. Nathaniel Portlock, or his representative, for his important service in guiding the ship "Providence" through a very difficult and intricate navigation, whereby that ship was enabled to fulfil the end of her voyage in introducing the bread fruit tree into this island. By the House,

GEORGE FRENCH, Clerk to the Assembly."

These voyages find their place in the "Naval History of George III;" and among the brilliant events even of that stirring period, we may at this time regard, as not the least worthy of admiration, those missions of science and discovery for which we are chiefly indebted to the personal wishes of the King.

The gallant sailor finds excitement, public applause, and immediate reward, in the daring exploits of his noble calling. The explorer of unknown seas and shores requires perhaps yet more the highest qualities of our nature. They have not unfrequently been found combined, and Nathaniel Portlock earned distinction in both. In 1795, having been on the close of these voyages promoted to the rank of commander, he was appointed to the "Arrow," mounting thirty 32-pounder carronades. She was a new ship, and was constructed on principles then novel and not unworthy now of notice, in justice to the inventor, General Bentham, at that time inspector-general of dockyards. She is described as being "fitted with sliding keels, and built without a single knee throughout, her 'tween-ships' were divided with chambers or compartments, the timbers running diagonally down to the keelstone. Her shape was that of a wherry pointed at head and stern, and altogether very slightly timbered for her weight of metal. She was the first ship that ever carried her water in bulk, it being stowed away in huge metal tanks, and being found after the expiration of two years as perfectly sweet as when first started into the tanks. The gold medal was awarded." In this ship, from her light draught of water "when her keels were wound up," Captain Portlock was employed in the Channel and North Sea, scouring the coast of privateers, till 1799, when in the "Arrow," he joined the expedition to the Helder, under Admiral Mitchell and Sir Ralph Abercrombie. During this service Captain Portlock captured a French sloop of war, commanded by Count Conin; and again, from the light draught of water of the

"Arrow," he was sent to attack a large guard-ship, in a narrow circuitous creek, on the coast of Harlingen, thus described by an eye-witness:—"The rain came down in torrents as the vessel gradually neared the Dutch ship, from which a raking fire was kept up with considerable effect for a space of twenty minutes. The main yard arm of the "Arrow" was cut in two, the rigging tumbled about in all directions, and several people were already with the surgeon. On reaching the enemy, Portlock shewed consummate skill: having his anchors ready head and stern, he beautifully laid the ship across her opponent's quarter, rendering all but two or three aftermost guns useless for the moment. The two ships were so close together that a biscuit might have been thrown upon either deck, and as Van Esk, the Dutch captain, was now busily engaged hauling upon his springs to bring his broadside to bear, it became of vital importance the manœuvre should not be effected without interruption. The "Arrow" had not as yet fired a single shot, her guns were doubly charged with round and grape, and at this whispering distance were expected to make a severe example: 'Now my sons,' cried Portlock, addressing himself to the captains of the guns, 'point at the water-line, let no shot miss the hull, are you all ready?' 'Aye, aye, Sir!' Fire! The broadside shook the Dutchman like the leaf of a poplar. A tomb-like silence reigned for some moments, when he again began hauling upon the cable to bring the ship round; but whether from the springs being wounded, or the cordage being unsound, she never obtained a position for bringing more than half her range of guns to bear, and was in consequence so miserably cut up after a forty minutes' action, that it was necessary to sacrifice the prize-money of the gallant crew by burning her at her anchors, after removing the survivors of the crew. Portlock (who was wounded in the action), obtained his post rank, and subsequently was appointed to the command at Port Jackson, of which, however, he was unable to avail himself from a severe affection of the eyes." Captain Portlock died in 1817, at an advanced age, in the honourable retirement of Greenwich; and in its peaceful cemetery—where many years before (though his body was committed to the deep on the scene of his murder), a monument had been erected to Captain Cook—those ancient comrades, in memory at least, now sleep side by side.

Our brother officer was the only son of Captain Nathaniel Portlock. He was born in September, 1794, and left the Royal Military Academy in 1813, served for a short time at Portsmouth and at Chatham, and became first lieutenant in the same year, second captain in June, 1830, captain in September, 1839, brevet-major in November, 1846, lieutenant-colonel in December, 1847, colonel by brevet in November, 1854, colonel in April, 1855, and attained the honorary rank of major-general on retirement in November, 1857.

CANADA.—In April, 1814, Lieutenant Portlock was ordered to Canada, where, though young, he was not undistinguished in the operations on the American frontier. He took part in the siege of Fort Erie, "and when the army retired, was the officer who constructed the lines and tête-de-pont de Chippewa, at which Sir Gordon Drummond made his successful stand, and saved Upper Canada. For this service the officers of Engineers were especially thanked in General Orders." Lieutenant Portlock continued for several years afterwards in Canada. He remained favourably known to the General, and was employed on numerous exploratory expeditions. He found in Sir Gordon Drummond a man of enlarged views, and constantly spoke of him afterwards in terms of admiration and esteem.

SURVEY OF IRELAND.—In 1824, having returned to England, a new career opened upon him. At that time the Ordnance Survey was about to be extended to Ireland, and Lieutenant Portlock was one of the first officers selected by Colonel Colby to be employed on it. The intentions of the legislature in regard to the survey, and the objects to be attained by it, rendered necessary a more extensive organization and a larger department than had been required for the parent work in Great Britain. The survey of Ireland was to serve as a basis for the more equitable adjustment of local taxation (a taxation which already exceeded a million annually and was increasing), which was then levied from the occupiers of lands, according to the ancient terriers of their relative value, long obsolete, never accurate, and at that time flagrantly unequal, and therefore unjust. For this purpose a general valuation of all the lands, buildings, and other fixed property of the country was necessary, and the first requisite was a map on a sufficiently large scale to exhibit the details of the whole taxable area and property. It required also the ascertaining of local boundaries of every description, and these boundaries were frequently, indeed generally, coterminous with private property, and open to dispute and litigation. The survey in Great Britain had, on the contrary, been confined to the construction of a general map, on a scale comparatively small, unequalled indeed at that time in Europe in the perfection it had attained, but furnishing only the roads and features of the country, without boundaries of any kind, except the well known public divisions of counties. The work required in Ireland was in fact no longer a map but a general estate survey, though intended for a public purpose.

The creation of the machinery and arrangements for this new work was the task to be first accomplished, and it was foreseen that it must lead to the formation of a Topographical Department, by which surveys of a similar nature might be afterwards performed in England, and yet more in the colonies. These subjects, now familiar to us, were, it must be remembered, at that time very new and very remote in the prospect of their future application, and so remembered in justice to those who foresaw and provided for them. They were in advance of the day. At that time, leisure from the great struggle for political and national existence which for half a century had engrossed the public mind, and occupied its leading intellect, was beginning to awaken the energies of the country to the importance of science, and the value of its practical applications. The new "Era of Peace" was opening, and we have lived to see, though still very far from its maturity, the great development which material science has already attained. The locomotive had scarcely come to its birth. The great works of engineering to which it has given rise were then unknown, and by the general public wholly unforeseen. The telegraph, the triumphs of electricity and of light, were still in the future, and half the discoveries which have since been made would then have been thought enough for a century. Such was the time at which the new survey began. Its chief foresaw that more than common accuracy and completeness would be demanded. He foresaw too that various difficulties would beset a work such as he hoped to accomplish, but the Duke of Wellington was Master General, and with his support the foundations were laid both deep and strong. Colonel Colby resolved that the department should be military in its organization, because no other was capable of controlling the large numbers who must necessarily be employed, and at the same time so plastic and under control as to enable general or partial changes to be made, from time to time, as circumstances might require. He recommended that the ascertainment and demarcation of local boundaries should be entrusted to the civil government, and the scientific accuracy alone of the survey be undertaken by the Ordnance; that three companies of sappers should be employed; that he should have the selection of his officers and the appointment of all his assistants, and that the officers, while the duty was new, should not be suddenly or frequently removed; in all which the Duke concurred. A careful system of expenditure and account was also framed with the concurrence of the Board. These general arrangements being settled and in progress, it was next necessary to procure instruments of sufficient power and accuracy, and in sufficient number to provide for and equip the several and very various classes of the work.

In all these general arrangements Portlock was the confidential officer and companion of Colonel Colby, and he was retained at head-quarters at the Tower for that purpose, while Drummond and others were occupied with the construction of the new base apparatus, the means of rendering visible the distant stations by the lamp and heliostat, as well as the astronomical and other instruments; and while Captain Streatfield and others were engaged under Colonel Pasley, at Chatham, in the instruction of the sappers. Thus passed Portlock's first year on the survey. Colonel Colby displayed no less skill and prescience in the choice of his officers than in other means of success, and he had the good fortune to obtain, in 1825, the services of Major, afterwards Sir William Reid, who was stationed in Dublin as local superintendent. In 1825 the first detachments were moved to Ireland. The officers and men destined for the interior survey were established in the County of Londonderry, where also the first base was to be measured, and the first trigonometrical station was taken up on the eastern coast, on Divis Mountain, near Belfast, to connect the triangulation of Ireland with the points already fixed in Great Britain. Colonel Colby, then accompanied by Lieutenant Portlock, proceeded himself to Ireland, and having visited all the stations, joined the trigonometrical party on Divis, from which, at the close of the season, the first observations made by the aid of the lamp and heliostat were successfully effected. This was Portlock's first start in Ireland, and all the preliminary arrangements being complete, he remained attached to the trigonometrical branch of the work, of which he soon became the senior and ultimately the sole officer.

In 1826, another principal coast station, Slieve Donard, in the County of Down, was taken up, and again the trigonometrical party was assembled under Colonel Colby, being the last station at which he personally conducted the observations. This was a station of great exposure. In the early winter the whole camp was more than once prostrated by the violence of the wind at the height of 2,800 feet above the sea, and even the instruments were with difficulty preserved. Colonel Colby was seriously wounded by a fall in climbing across the rocks from the observatory to his tent, and it was with difficulty, and sometimes danger, on one occasion indeed with loss of life, that communication was maintained with the country below. Portlock held out to the last. For some weeks he was the only officer remaining, but he struggled on and brought the operations to a successful close.

In the following year, 1827, the bars and instruments being complete, the measurement of the base began on the shore of Lough Foyle, and to that, being now the most important part, Colonel Colby attached himself, leaving the trigonometrical operations thenceforward to Portlock. In that year, with one other officer, he accomplished the observations with the great theodolite at the Vicar's Cairn, Shantaveny, Bessie Bell, Knocklayd, Sawel, Slieve Snacht, and Slieve League, remaining at the latter under canvas, 2,000 feet above the sea, till the middle of January. On this occasion Colonel Colby, even in November, wrote thus :—" You have been carried forward on your journey to the west by a zeal which has, I fear, not been tempered by that due regard to your own health and comfort, which I have more than once enjoined. No services could have been more valuable than those which you and ——— have rendered to the survey this year; and I cannot contemplate the loss of those services without feeling strongly. They can only be continued to me by the preservation of your health, and once more I enjoin you to take care of it. I do so as a friend, and it is my duty to do so as a commanding officer."

In 1828, his old comrade and friend was removed to Dublin, and Portlock, single-handed, year after year, encountered in succession the labour of observing with the great theodolite on all the principal mountains of Ireland, till the network of principal triangles was completed; and by observations across the channel, chiefly effected by the aid of heliostats, the Irish triangulation was laced to that of Great Britain, and formed one with it. But even before this was completed, a want of unity had begun to be felt in the secondary triangulation for the detail survey. This operation was originally performed by the captains of the surveying districts, who being supplied with leading points and distances from the great triangulation, were, with smaller instruments, to carry on the secondary network for the use of the surveying parties. The operations within each district were by them well done, but it soon became obvious that discrepancies would arise at the junction of the separate districts, requiring the combination of a general system. This duty Portlock undertook to direct, though himself still engaged upon the mountains, and when the principal triangulation was completed he was devoted especially to that duty, with a central office in Dublin. Again one, and for a time two, officers were added to his staff, and he thus successfully grappled with and overcame that difficulty also, supplying to the officers in the country a uniform secondary triangulation based on the great network, and directly derived from it, with perfect regularity and sufficient rapidity to meet the great development given by this process to the detail survey, which slow at first, while all was new, reached at last to three millions of acres in a year.

This rapid sketch, the detail of which has been given by Portlock himself in his Memoir of General Colby, was necessary here to furnish some idea of the ceaseless labour imposed on Lieutenant Portlock in observation and calculation of horizontal triangulation alone; but conjointly with this was an elaborate system of vertical observation and calculation for altitudes. The altitudes were deduced at first from the sea, by actual levelling from it to bases of altitude, and from them transferred, by angles of elevation and depression, to the summit of every hill and station, at distances averaging a mile asunder; and on this the minor levelling of the detail survey depended. This also was at first performed in the separate districts, but ultimately generalized into a system by Portlock, and by him furnished regularly and rapidly. With this view he personally carried a line of levelling across the island from the coast of Down to the coast of Donegal, and caused similar lines to be observed in other places. The result was to furnish a more general and homogeneous system of altitudes than had ever before been accomplished. It is true that even the accuracy thus obtained proved insufficient for the increasing wants and improved knowledge which the scientific works of the day soon afterwards required, though far beyond the original requirements and object of the survey as contemplated by Parliament. These wants, however, were immediately met and supplied in Ireland by an elaborate system of spirit levelling, crossing the island in every direction and terminating at stations on the coast, where tidal observations were simultaneously made. These operations were excellently performed by Captain Cameron, who had been trained chiefly by Portlock; and in addition to their immediate and practical object, they furnished the material for the admirable paper on tides, by the Astronomer Royal, published in the transactions of the Royal Society of London in 1845.

THE MEMOIR.—Portlock was not one of those who took the narrow view that a survey was confined to merely topographical operations. He agreed with those who regarded the maps as the preliminary to other inquiries and more extended results in the advancement of Ireland, in its physical, social, and productive aspects. Such to some extent was also the view of the first framer of the work, Colonel Colby, as thus described by Captain Portlock in the preface to his Report on the Geology of Londonderry :—" At the commencement of the Irish survey, Colonel Colby expressed his opinion to Sir Henry Hardinge, then clerk of the Ordnance, that the topographical survey should be considered a foundation for statistical, antiquarian, and geological surveys." But the "foundation" was nevertheless the first step, and it was soon found impracticable to combine fully these desirable results with the original work during its progress, without sacrificing the great rapidity which the Government required in the completion of the maps. When the survey began in 1825, serious attention had begun to be directed to the condition of Ireland. It was known that great changes were likely to take place in that country, and it was known that arrangements for material improvement would be necessary in connexion with those social changes. The maps were urgently demanded for the purpose of the amended valuation; and even in 1833, when considerable advance had been made in the field, and copies furnished to the Government, but only one county had yet been published, Mr. Littleton, Chief Secretary for Ireland, wrote :—" Many measures already effected would have been much better done if the survey had been complete, and many will fail if it be not rapidly completed." Under these circumstances it was impossible to press collateral subjects, and, as Portlock has expressed it in regard to geology, the increasing demand for " more acres " so pressed upon the officers that those only who possessed a taste for the subject could be induced to follow it up.

In 1832, however, another effort was made to accomplish the collateral objects. It was then proposed to compile at the head-quarters, in Dublin, a descriptive memoir, to be carried on in part by separate and special persons, and in part by the co-operation in the field of a new department, at that time formed under

Captain Dawson an accomplished officer, for the execution of the general map, that is, the map on the one-inch scale like the map of England, which was a sequel to the detailed survey from which its outline was to be reduced. In this effort, Portlock having completed the great triangulation was enabled also to co-operate, and undertook the geology and productive economy. He entered into it as usual, with thorough earnestness. In his own words, after describing the original arrangements, and their suspension from the more urgent necessity for the maps, he states: "Geology in fact had been permitted, but not commanded," and even when he was himself appointed to the charge, he "had no power to enjoin a general geological inquiry." In 1834, however, he was enabled to engage "competent assistants in the various branches," and in 1837 formed a geological and statistical office, a museum for geological and zoological specimens, and a laboratory for the examination of soils. It is only from that time that the geological branch of the Irish survey, in its enlarged form, can be said to have begun as an organized work.

The results soon appeared in his sections of the memoir, and would have continued from year to year, increasing in perfection and rapidity, but again the work was suspended. Expense was on this occasion the ground, and there can be no doubt that the extension thus given to the survey was in advance of the original intentions of the Government, though not of the wants of the country or even of public opinion. But the topographical survey—the maps themselves—had in like manner been checked in 1828, only three years after their commencement, on the same ground. The authorities of that day forgot that the first years of a new work are only its infancy, that for the survey men had to be trained, instruments provided, the foundation for future progress to be laid in the base measurement and the great triangulation, the whole establishment in fact created; and that the expenses of these preliminaries belong to the whole work, and spread over the cost of the whole, not of the years only in which they are incurred; mistaking proportion for progression, they took the whole expenditure of those years and the number of "acres" produced in them, and applying the "rule of three," they computed the time and cost for the whole of Ireland, and finding a fabulous amount for both, became exceedingly alarmed. Various retrenchments were suggested. It was at one time proposed to drop the figures of altitude as a needless topographical luxury! The Great Duke was no longer Master General, and the sceptre of the Ordnance had fallen into weaker hands; but due enquiry and proper representations restored that branch to life and progress, a progress which rapidly increased, and when the whole machine was at work, produced two millions and ultimately three millions of acres in the year, at a cost which in the beginning barely produced as many thousands, and which further had created a department able to survey in like manner, at a like rate, anywhere; the greater part of which department was actually removed to England for that purpose, destined probably to become (as under the able management of Sir Henry James it is becoming), the parent of uniform topographical operations in all the colonies.

Those who advocated the yet greater development of the survey into its collateral extension in the memoir, were not without hope that the same success might attend that branch of the work, and that it also might be resumed; but they were too sanguine.

The British Association, the Royal Irish Academy, the Grand Juries of Ireland, men of science and progress in both countries, united in testifying to the competence of the means, the utility of the result, and the importance of seizing an opportunity not likely to occur again, but in vain; the work was stopped. Public opinion, however, was not satisfied, and a commission was appointed in 1843 by Sir Robert Peel, which recommended its resumption and continuance. The valuable moment, however, was by that time gone, or conceived to be so, and the complete memoir was never resumed. Captain Portlock, on the suspension in 1838, had been ordered to draw to a close the work he had already begun, and when the commission was appointed, in 1843, had already done so, and published the volume which bears his name, on the "Geology of Londonderry, Tyrone, and Fermanagh, with portions of the adjacent counties." On the completion of this volume he was restored to the general duties of the corps. The survey in the country was by this time drawing rapidly to a close, and the removal of the parties to England had begun.

The orthography of the names of places for the maps, with the literary, historical, and antiquarian collections connected with them, was also ending, and it was obvious that much of the work of that branch which would have been done in connection with the surveying, must, if resumed, become a separate and new expense. Sir Robert Peel therefore did not think proper to renew the work as a whole, but ordered the resumption of the geology, under Captain James, then, as now, an officer of ardour and ability, devoted to the science; and of the productive economy under Sir Robert Kane, whose remarkable work on the "Industrial resources of Ireland" had awakened men's minds to the importance of that subject. Among the results of the commission it may here also be said in justice to the able men who composed it, and the strong evidence taken before them, that it pressed the advantage of contouring as the best mode of representing elevations of ground on outline maps. This was one of the improvements introduced in the progress of the survey, which, like all its improvements, encountered great opposition, but became ultimately established; and it may not be misplaced here to observe to our brother officers, that every one who is entrusted with the execution of great works—more especially when they are new in their nature, as the Survey of Ireland was—must expect all sorts of lets and hindrances in their efforts to improve; but they ought not on that account to be impatient and fretful, as some of us were, but patient and persevering, trusting, that if the object is in its nature right, it will be attained in good time, though not exactly in the way they would have it. Of this, perhaps, the effort to extend the survey of Ireland by a general memoir, called by Lord Brougham, "a corollary from the survey more valuable than the survey itself," may be taken as an example; for before that work had been found impossible as a whole, public attention had become alive to the subjects it embraced, and the objects of its several sections have been attained by the public, and, perhaps, in a better way. The Industrial Museum was established in Dublin under Sir Robert Kane, combined with Geology under Captain James, and ultimately eventuated in the Geological Survey now in progress under the able directions of Mr. Beete Jukes, as part of Sir Roderick Murchison's great charge—the geological survey and mining instruction of the British Isles. The Industrial Museum in its general objects has had indeed to contend against great difficulties, and narrowly escaped suppression; but its importance has again been recognised by a Committee of the House of Commons during the present session, and it may be hoped that it will yet attain its full development, and realise the hopes of the great minister, Sir Robert Peel, to whom Ireland owes its establishment. The Statistical objects of the memoir have been, to a great extent, obtained by the public, from the development, on the part of the Government, of other public works of a kindred nature, more especially by the great extension given to the census of Ireland in 1841, and the successive decades since; by the statistics of agriculture and emigration published annually since 1847; and by criminal and judicial statistics; and yet more by the results of the professorship of political economy founded by Archbishop Whately in 1833, in Trinity College, which, having led the energy and intelligence of young minds to that eminently important study, may be said to have produced, as one of its earliest results, the Statistical and Social Inquiry Society of Dublin; from all of which, and other kindred movements, Ireland now stands peculiarly high in statistical science. The labours in antiquarian lore of Dr. Petrie, and his assistants O'Donovan, Currie, and others, originally in connexion with the survey, have been recognised as supplying the means of exploring the ancient literature and remains of Ireland, and enabling learned men to prosecute many of the researches published, or in course of publication, in the Archæological transactions, the Brehon laws, and other treasures of Irish literature. One thing indeed for a time appeared to be, and to some extent was, irrevocably lost, the exploration and delineation of numerous monuments and objects of antiquity, many of which, cultivation, railways, and other private and public works, have obliterated, as well as the preservation of much traditional and legendary knowledge which perished with the generation swept away by the famine, and the dying out of the Irish as a spoken language. The appreciation of these subjects, however, is growing in Ireland, and will increase as education extends. They formed always a branch of the pursuits of the Royal Irish Academy, and are becoming now the objects of local and provincial societies also, of which there are already two: one at Belfast, for Ulster; and one at Kilkenny, for the south and east of Ireland; by each of which several volumes have been published. In a recent session of Parliament, the preservation of ancient buildings and monuments was enjoined by law, and penalties affixed to their wanton destruction (24 and 25 Vic., c. 97). The museum of the Royal Irish Academy has grown rapidly since 1843, is already recognised as one of the richest in Europe in Celtic antiquities, and by a recent arrangement of the Treasury, is now made the depository of public treasure-trove.

On the discontinuance of the Memoir, the collections of all kinds made on the survey were deposited in public libraries and museums, aiding research, and from time to time recalling the memory of those by whose zeal and ardour they were collected. Thus it is that in letters, as well as in science, art, and industry, the several branches of the Ordnance Survey have in spite of all discouragement left their mark on Ireland, and in connection with them Portlock's name will long be known. It is not to be understood that the writer of these observations assumes for the survey the origination of the subjects adverted to, but wishes merely to show that the individuals connected with that work were alive to the wants of the country, and anxious to seize the opportunities it afforded of meeting them, or furnishing means for their accomplishment. Here also may be mentioned another application of the survey, from the first foreseen, the registry of real property by the aid of maps. On this point public opinion has been gradually maturing. In 1850, an Act of Parliament (13 and 14 Vic., c. 72), was provided for the purpose of enabling it to be adopted by aid of the Ordnance Survey, in connexion with the operations of the Encumbered Estates' Court established in the preceding year. That opportunity was lost, but the subject has been more than once revived, and for the last two sessions has been again under the consideration of Parliament, and that object also will doubtless soon be realised.

Further it is to be added that during the long time Captain Portlock was employed on the Ordnance Survey, from 1824 to 1843, he was no inattentive observer of the scientific advances generally, which in that time were made in Ireland. Before 1831, the only public societies devoted to those pursuits were the Royal Irish Academy and the Royal Dublin Society. They had been incorporated by Royal charters, the former for the advancement of science, literature, and antiquities, the latter for husbandry and other useful arts of a cognate nature. In that year was established the Geological Society, under the presidency, and largely by the exertions, of the venerable Provost of Trinity College, the Rev. Dr. Lloyd, who was already distinguished by the liberal extensions he had given to the studies of the college, who was also president of the Royal Irish Academy, and a strenuous advocate of scientific progress. The Zoological and other Societies rapidly followed, created by the association of men devoted to the several special pursuits.

Portlock joined himself cordially with this movement. He was one of the early presidents both of the Geological and Zoological Societies, and contributed to the former no less than twenty separate papers, including his presidential addresses in 1838 and 1839. The papers are confined for the most part to the announcement and description of facts, while the addresses take the wider range usual in such communications.

In 1835 the British Association met in Dublin, and Captain Portlock as a member of the local committee, and secretary of the section of geology and geography, which at that time were combined in one, displayed his usual activity and usefulness. To the British Association also, in 1837, he contributed a paper on the New Red Sandstone of England and Ireland, and one, in 1838, on the Silurian Rocks in Tyrone. In the proceedings of the Royal Irish Academy for 1837 his name appears in a communication on the occurrence of the Anatifa Vitrea on the Coast of Ireland, and one on Ornithology (*Otus Brachiotus*), both connected with the collections of the Ordnance Survey, and also in a communication relative to the Red Sandstone of Tyrone.

CORFU.—In 1843, Captain Portlock's labours on the survey ceased, and returning to the ordinary duties of the corps, he was stationed at Corfu, Colonel Emmet being the commanding engineer. Here for the time he had the happiness of enjoying comparative leisure, and his letters show how he revelled in the scenery and climate of the Ægean. He took part in the remodelling and erection of the fortresses, (of which the present year has witnessed the demolition!), and Colonel Emmet thus describes his general habits: "What struck me most in him was his untiring perseverance; his spare time in doors was given to the study of military science and the Italian language, the remainder of the day being employed in botanizing and scientific pursuits. Lord Seaton had a great regard for him, and frequently consulted him on matters connected with the College, and on questions connected with the agriculture of the island, placing him I think in charge of an experimental farm, and when he left the island accompanying him to the vessel in which he embarked." The "College," the establishment of which originated with the Earl of Guildford, was so congenial to Portlock's educational propensities that it could not fail to be to him an object of the highest interest. He dwelt on it more than once in writing to the author of this memoir, in connexion with the earlier High Commissioners, Lord Guildford and Lord Nugent, as well as Lord Seaton. At a later time also, in 1859, he looked to it as a means of supplying education to young gentlemen of Corfu for entrance to the British army, an advantage and means of employment which he was very desirous of seeing extended to them. His military studies in the early Italian writers are to be traced in various papers written either in Corfu or subsequently, of which the following have been published. "The Siege of Corfu, in 1716," in the Corps Papers, with notes by Colonel Emmet. "The principles of defence, and use of the various descriptions of arms, in fortresses," in two parts, in the Corps Papers, "A list of Italian authors on military science," communicated by him to the Corps Papers, with prefatory remarks by himself. To this category belong also the practical papers on platforms and on parapets, in the eighth volume of the Corps Papers, first series. Of a less purely professional nature of this date, we find other occasional notices, such as that "On an apparent arched arrangement of the Cyclopean walls of the ancient city of Leucate in Santa Maura." A paragraph in this paper, "Being on duty with Lieut. Hassard at Santa Maura, we stole an evening hour to visit the ruins of ancient Leucate," brings vividly to the recollection of the writer of this memoir many such stealings of evening hours in our numerous journeys of exploration in Ireland, when we wandered, hammer in hand, among the rocks of the Causeway, or the wild coast of Donegal, or examined the ruins and remains of pagan, or ecclesiastical or military antiquities, carrying away fragments in our wallets and sketch books. From Corfu also date several papers and communications to the British Association. At the meeting in Cork in 1843, immediately after he had arrived at Corfu, we find a letter to Professor Phillips on the geology of that island, and in the same year a grant by the council "To Major Portlock, for the exploration of the marine zoology of Corfu," and in the years 1845 and 1846 communications on that subject. Of the same date there are in the fifteenth volume of the Annals of Natural History, notes on papers by former naturalists "On the ova of the Dogfish," and on "Fossil Shells of the genus Cardinia;" also a paper "On the white limestone of Corfu and Vido," in the Quarterly Journal of the London Geological Society, Vol. 1, and "Notices in connexion with the natural history of Corfu and its vicinity," in the 18th volume of the Annals and Magazine of Natural History.

On his leaving Corfu, Colonel Emmet thus expressed himself in General Orders:—"Major Portlock having been ordered to return to England, the Commanding Royal Engineer feels it to be an absolute duty to express his deep regret at the removal of an officer, so valuable to the public service, from this command."

PORTSMOUTH.—From Corfu, Major Portlock passed in 1847 to Portsmouth, and thence in 1849 to Cork, in both which places, amid the ordinary and more or less active duties of the station, he appears by his published papers to have found time for valuable additional labour.

In the transactions of the British Association, we have in 1848 a communication on evidences he had observed at Fort Cumberland and the Block-house Fort, of changes of level on both sides of Portsmouth harbour, contending that as such changes could be traced back to the remotest times, so they had continued up to the present day, and expressing his conviction that a parallel might be found in existing nature to all the phenomena of ancient times. In the same year, is a notice with his name, of sounds emitted by Mollusca, which he had observed in the Helix aspersa, as well as in the Helix aperta, which latter had been described by former naturalists, and of which he had himself for some time kept a specimen in his house at Corfu. Again in 1850, in the same transactions, there occurs a notice by Lieutenant Colonel Portlock of the manner in which igneous rocks intrude into the sandstone and conglomerate near North Berwick; and in 1851, there are discussions on fossils from the Cape Frontier. In that year, 1851, the operations for removing by mines a portion of the cliff on the coast of Sussex, took place under the direction of Colonel Lewis, in which Portlock appears to have borne an active and attentive part; and to the subsequent researches of Captain Ward (by whom the voltaic operations at Seaford were superintended) into voltaic electricity generally, Portlock subsequently bore testimony before the British Association in 1854. To this period also belong several contributions to the Corps Papers: one on the carbonization of wood by steam, and one on the injurious effects of saline solutions on forged iron, both translations from the French, in illustration of subjects then engaging public attention; as well as a note on gun cotton. The professional paper of that date, which to Portlock was doubtless of most interest, was a letter, with some very interesting prefatory remarks by himself, from one of his old followers, Mr. Hemming, formerly a sergeant in the Royal Sappers and Miners, called a "Brief account of some of the survey operations undertaken at the Cape of Good Hope, for the verification of the base measured by Lacaille." Sergeant Hemming was one of the oldest of the survey party on the trigonometrical operations. From the first camp of Divis, in 1825, to the close of that portion of the work, he had been constantly with Lieutenant Colonel Portlock, and he was selected as the non-commissioned officer best fitted to take charge of a party dispatched under Captain Henderson to the Cape in 1848, to be employed in the operations above mentioned, under the direction of the astronomer, Mr. Maclear. In the introductory remarks, Portlock takes occasion to describe the improvement of the men in the duties of the survey, their intelligence, docility, and obedience. By those who witnessed Portlock's mode of life, and the example he set, it can easily be understood how fully the men felt that with him they were in the hands of something superior to themselves in intellect and acquirements. They needed only encouragement, no coercion, and they rapidly acquired knowledge. To all this I can testify, and I am sure it is the experience of the whole corps, more perhaps than any other in the army, that when officers study the characters of their men, and use in governing them the knowledge so acquired, they are amply rewarded by the result, and need no coarser discipline. To his period of service at Portsmouth belong also the articles on "Galvanism," on "Geology and Geognosy," on "Heat," and the Appendix (F) to Dr. Ryan's article on "Gun Cotton" in the second volume of the Aide-Mémoire.

While at Portsmouth, Lieutenant Colonel Portlock also published a treatise on Geology in Weale's rudimentary series, the origin of which he attributes in part to the suggestions of the late Sir William Reid, adding in his preface: "Feeling a warm attachment to my profession, and desiring to see it advance in public estimation, I value and respect any of its members, who, like Lieut. Colonel Reid, R.E., and Lieut. Colonel Sabine, R.A., have endeavoured to combine military eminence with scientific attainments; and I trust it will be acknowledged by every one that a scientific corps like the Royal Engineers, must rest its claims for public support as well on scientific as on military excellence." This just tribute to an officer of the sister corps so eminent as the present President of the Royal Society of London, must be read by all with hearty response and sincere gratification.

Cork.—Lieut. Colonel Portlock, on his return to Ireland, as Commanding Royal Engineer at Cork, was warmly welcomed by the Irish geologists. He was remembered, not only as an ardent votary of the science, but as one of the original members of the Dublin Geological Society, for two years its president; and by the geological volume already mentioned, embracing the principal northern counties of Ireland; as well as by the numerous papers he had formerly contributed to the transactions of the society; and he was again elected to the presidential chair. He contributed a paper "On the variations in depth in the tertiary deposits, as exhibited in a section of borings at Portsmouth," and another "On the schistose condition of the rocks at Bantry Bay;" in addition to the annual address on the 12th February, 1851, and 12th February, 1852, which, like all his annual addresses, are instructive summaries of geological science, while passing in review the proceedings of the society during the preceding years. The excellent article on "Palæontology," in the third volume of the Aide-Mémoire, was at this time furnished by him; this, like "Geognosy and Geology," in the second volume, was in fact a distinct and complete treatise.

It was also during his command at Cork that the employment of convicts on military public works began in Ireland. To this effect Portlock lent his cordial and ready aid, and the unfinished fort on Spike Island was selected for the experiment. This employment of convicts on the works of Spike Island, and on the forts Camden and Carlisle, at the mouth of Cork Harbour, will long be memorable in the history of the social problem, "How to dispose of our convicts," for it was during their employment there that a few years afterwards, in 1853, transportation to the colonies was abolished, and the reformation and absorption of the convicts into society at home engaged more and more attention. There it was that the remarkable changes and improvements rendered necessary in consequence, called now the Irish convict system, were introduced and set in motion by an eminent man, whom we may also regard as a brother officer, Sir Walter Crofton, formerly of the Royal Artillery, and lately the head of the convict department in Ireland. That system has now been fairly and fully tried, opposed, examined, and at length, by public opinion and the decision of Parliament, finally approved and adopted.

Woolwich.—In 1851, Lieut. Colonel Portlock became Inspector of Studies at the Royal Military Academy. He was an ardent advocate for education in the army, and for the pre-eminence in that respect of the scientific corps. It appears to have been from the first his view that Woolwich should be reserved for the advanced stages of professional education, and that the earlier and more general portion should be previously acquired elsewhere. He expected much even from Carshalton in that direction ultimately, and succeeded in giving it a military character by obtaining the appointment of an excellent officer of artillery as superintendent, and in furtherance of the same object, by the adoption of a uniform for the boys. But the years which soon followed his appointment were destined to produce yet greater changes in military education, and entrance to the military colleges, and to the army generally, in all of which his correspondence shows that he took an anxious interest and active part. It is not yet time to review the various projects brought forward, the mistakes made, the success achieved, or even the results obtained. Competitive examination has become the rule of entrance to every branch of the public service, military as well as civil, and being so, the age may be altered, or the standard of qualification extended or restricted, as general education increases, educational establishments improve, or special circumstances from time to time require.

Colonel Portlock felt however that whatever system might be adopted, or whatever arrangements made, by those with whom the decision rested, it was his duty to deal with the state of things as they were, and to that object he sedulously devoted himself, an object in which he had the happiness to possess the full confidence and cordial support of the lieutenant-governor, Major General Lewis; and he was able, not only to extend the mathematical course, and to render more extensive the study of chemistry by obtaining the appointment of a resident instructor and assistant, under whom the senior class, and also a voluntary class, worked in a well arranged laboratory, but also to procure the addition of lectures in geology, in mineralogy, and in natural philosophy, and the increase of the staff of instructors also in other studies. Modifications in the examinations were also introduced, which appear to have been of good effect. Among practical changes, for example, of an apparently minor character, by which time was saved, was the discontinuance of the useless labour of drawing plans of fortification after the construction had once been learnt. It is needless to dwell on matters of mere detail of this description; but to one who left the Academy forty years ago, the course and appliances certainly contrast most favourably with those existing at that time, and we may fairly hope to witness the results in the acquirements and performances of the officers trained under it.

During the time of his connexion with the Royal Military Academy, Colonel Portlock's collateral occupations partook naturally of the military influences around him. He furnished to the eighth edition of the Encyclopædia Britannica the articles on "Cannon," "Fortification," and "Gunnery." In a collection of papers, such as that work consists of, to which the ablest men of the day contributed, it was no slight distinction to be enrolled as a fellow labourer, and the papers above mentioned appear not unworthy of their fellows. They epitomise the subjects both historically and scientifically, and bear the impress of thorough study, both of principles and details. They may indeed perhaps hereafter become valuable, from what at first sight might seem to render them comparatively useless, viz., that they were written precisely at the time when the great changes in artillery and fire-arms were beginning; changes not yet decided or complete, and the effect of which in attack and in defence, as well in the field as in fortified places, is not yet known, but all of which, it is obvious, they must greatly modify. If this be so, while the principles and the history will be the same, these papers will become, as regards detail, the latest repertories of what will soon become the past. He also translated a paper by Augendie, on gunpowder, for the first volume of the Professional Papers (new series), and no doubt foresaw that chemistry would produce changes perhaps no less great in the propelling power than those which improved mechanics were effecting in guns and missiles. Already gun-cotton and explosive mixtures of various kinds were occupying attention, and to all such applications of science he was fully alive.

In 1852, he was President of the geological section of the British Association at Belfast. It was also during his residence at Woolwich that Colonel Portlock furnished to the Professional Papers his excellent memoir of Major General Colby, a paper as honourable to his heart as to his head. The memoir of General Colby indeed, whose whole public life, from its commencement to its close, was devoted exclusively to the Survey, became in fact a history of all the salient points in the Survey itself. It is therefore an addition to the literature of the country, as well as an integral portion of the history of the Corps, recording, as it does, the origin and progress to maturity of its topographical branch.

In 1856, Colonel Portlock withdrew from the duty in which he felt so deep an interest precisely at the time when the result of his labours was beginning to appear. He felt it right in a public sense to do so, and with his usual abnegation of self, he did it promptly and without reluctance. He had the satisfaction to receive from the Secretary of State for War, the following recognition of his services:—"Sir, I have the honour, by direction of the Secretary of State for War, to acknowledge the receipt of your letter of the 5th instant, and to acquaint you that in accepting your resignation therein contained, I am at the same time to convey to you his lordship's cordial approval of the zeal you have evinced during the whole period of your inspectorship, and his congratulations on the success which has attended your efforts; Lord Panmure conceives himself bound to testify his approbation of your conduct in this arduous office by promoting your professional advancement, and has accordingly signified his high opinion and appreciation of your merits to the Inspector General of Fortifications. (Signed) B. HAWES."

Lord Panmure accompanied this official letter with one also from himself:— "I have received and accepted with much regret your resignation of an office, the duties of which you have discharged with so much profit to the rising youth of the scientific corps of the army. I have directed an official letter to be written to you, but I cannot refrain from thanking you for the support which I have received from you at all times. I have desired an official report of your resignation, and of my high opinion of your services, to be written to Sir John Burgoyne, and I have therein signified my wish that your services should be recognised by the first opening in your professional line, and more especially should the command in Ireland to which you point become vacant. Your scientific attainments will do honour to yourself and the distinguished corps to which you belong, wherever they may be exercised. I hope that in any case where my assistance may be necessary, and my testimony worth having, either in civil or military employment, you will have no hesitation in addressing me as a friend ready to promote your interests.—(Signed) PANMURE." Not less gratifying to his feelings were the esteem and regard expressed for him by his colleagues in the government of the Academy, as well as by the eminent professors and masters whose talents adorned it, who can rarely hope to find in a military officer the extent and variety of attainments which were combined in Colonel Portlock, with the zest for education and knowledge by which he was distinguished. Regarding him indeed as a public man in an important position, at a peculiar moment, remarkable for qualities which it is desirable to encourage, it is to be regretted that some mark of public appreciation was not conferred upon him, for though honours would neither have increased nor diminished his own exertions, they might have proved a valuable incentive to others.

DOVER.—On leaving the Royal Military Academy in 1856, the Irish command not having become vacant as was expected, he was anxious to have retired from the corps with the rank of major general, but there was no vacancy for his retirement at that time, and he held the command at Dover from November, 1856, to May, 1857.

COUNCIL OF MILITARY EDUCATION.—Among the changes which resulted from the long and angry discussions in the press and elsewhere on military education, when in 1855 and 1856 public opinion had become aroused to its importance, there was none more practically useful than the establishment of a council of military education, as recommended by the commissioners who had been appointed to inquire into and report upon the subject. By this council all examinations for the military colleges, whether for entrance or exit of the Artillery, Engineers, Staff, or general army, were to be conducted. The commander-in-chief of the army was most appropriately the president, with a council composed of men eminent for military and scientific acquirements; and if it be not presumption to express an opinion, no better selection could have been made than was made. Colonel Portlock, from his antecedent duties, was, it may perhaps be said—naturally—one of those selected for the first council, and there can be no higher tribute to the collective body than the success which has attended its labours, and the general satisfaction, which, on the whole, so novel and difficult a task has given.

In the first, and as yet only printed report of the council, its progress is clearly told, and the views and intentions of the government of the day are clearly shown. The instructions to the council on its establishment, in 1857, were :—First, to direct its attention to the formation of a staff college; secondly, to revise the whole system of examination for direct appointments to the army, and establish the standard to be attained for admission to the service; thirdly, to suggest a mode in which Woolwich might be amalgamated with Sandhurst for primary instruction in common, and how cadets could be passed out of the primary college to the practical classes, at Chatham for the Engineers, and Woolwich for the Artillery; fourthly, the council was to extend its consideration beyond entrance to the army, to the professional examination of the younger officers for promotion in the junior ranks, and for staff appointments.

In the next report it will probably be shown why it became necessary to drop the primary education of the several branches of the army in common, and it will doubtless be seen that in this point, as well as in so many others in English affairs, the advantages of the course which is theoretically the best, are met by countervailing difficulties and consequences, which render it more prudent, and, on the whole, the best course, in the first instance at least, to modify rather than reconstruct the system.

As by the instructions to the council, the views of the military government are seen, and the degree to which they have been effected learned from the report of the commissioners; so the qualifications, which the military authorities have from time to time considered necessary for the British officer on entrance to the army, may be seen by the programmes of the examinations enjoined; and the extent to which they have succeeded, measured by the result of the examinations in the number of successful candidates. The application of this test, as shown by the first report of the council, is creditable to the military authorities, and effectually answers the often repeated complaint that they were indifferent to the education of the army, for even the subjects demanded at first by the Duke of Wellington and Lord Hardinge were found too extensive. In truth the examinations were a test of the education of the country, in the class from which the officers were drawn, and reduction in the qualification became for a time indispensable in order to obtain officers with sufficient rapidity; but the report also shows, and doubtless future reports will yet further show, that the supply responds to the demand; and thus the examinations for the army, like those for the civil service, at home, in India, and elsewhere, will have helped to produce, as not the least valuable of their results, a general elevation of standard in education, more especially in the classes where the stimulus was formerly the least.

It may well be supposed by those who knew Major General Portlock, and those more especially who had witnessed his labours at Woolwich, that no employment could be more congenial than this which now opened upon him, and I am permitted to use a memorandum which has been kindly furnished by one of the original members of the council:—"It is difficult to give the career of any particular member of the council of military education, as it must necessarily be, to a very considerable extent, that of the council itself. In nearly all cases the council are, after full discussion, unanimous as to the line of action they should take, and though any member of it may wish more should be done than is done, still up to that point his opinion is the opinion of the council, and this may very well be without any derogation to the usefulness of the man, as the most advanced opinions are not always practicable at the moment, and it is often enough that the right direction be taken, though the end in view be not yet attainable. General Portlock's opinions on the questions presented to him as a member of the council were in all cases those of the most forward advocates of education. He looked upon competition, and especially open competition, as the great principle upon which public appointments should be made, nor did he shrink from the inevitable social results which such a change would involve. Education, combined with good morals, he regarded as constituting a paramount claim to the rank of gentleman. He was therefore a warm advocate of the system of open competition as applied to the elections to the Royal Military Academy of Woolwich, nor did he share the apprehension, which has been very frequently expressed, of a consequent lowering of the social position of the officers of the two great scientific corps. General Portlock was, as might be expected, a warm advocate of the claims of science upon the education of youth. Not only were chemistry and geology introduced as voluntary subjects in the examinations for admission to the army, but professorships were also founded in those subjects at the Royal Military College of Sandhurst, and in the Staff College, upon the recommendation of the council of military education. It is a significant fact that while the number of candidates who took up those sciences at the examinations held by the council at Chelsea, was a few years ago, ordinarily, about ten or twelve, it is now seldom less than thirty out of about one hundred and fifty, and the progress made in them by the cadets at the Military College shows that the General's efforts in this direction were not in vain, so far as respects a fair introduction to the elementary principles of modern science. On the subject of classical education, General Portlock's views were by no means warped by his natural predilection for the scientific ; on the contrary, he received it as most valuable in itself, provided really sound instruction was imparted. But he considered the many instances of failure in classics at the army examinations as discreditable to the state of education in this country. Upon the whole, the General's opinions on the subject of education may be said to have been chiefly that it should take a wider field, that it should embrace science as well as mathematics and the modern languages, and that classical literature should not be neglected but rather better cultivated. Hence he cordially concurred in giving classics the high place it takes in the army examinations, and in encouraging science as a subject of the education of military aspirants."

While a member of the council of military education, as during his connexion with Woolwich, Portlock's thoughts became impressed with the subject of his current duty, and they found occupation in matters connected with it. In 1858 he translated from the Italian a work on strategy, by Sponzilli, and in the same year published a pamphlet called "Reform or no Reform for the Army." In 1860 he revised the article "War" for the eighth edition of the Encyclopædia Britannica. This article, written twenty years after that in the former edition, when the new powers of steam had come into full operation, and the improvement of projectiles of all kinds had begun, is of considerable interest. The opening of the article introduces a notice of the changes then in progress in our military establishments, both personal and material, and infers the changes which may be expected in military strategy from the improvement of both. The closing pages show how the movement of ships by steam, making the manœuvres of a fleet independent of the wind, would have to a great extent rendered impracticable the daring tactics of Nelson, such as those of the Nile and Trafalgar, depending, as they did, on the almost total immobility of a portion of the enemy's fleet. From this the author infers that naval tactics will become more and more assimilated to military, in order still to accomplish by the new means at the disposal of both fleets, what Nelson did with those of his time, the same great principle of concentrating the greatest mass of force on the decisive point, with which, whether on sea or land, in the words of Jomini, "Toutes combinaisons sont bonnes et sans lequel elles sont toutes vicieuses." The author, in another part of the paper, gives reasons for supposing that the modern improvements in projectiles, and other means of war, will prove on the whole more favourable to the defence than the attack, and applies these principles to the defensive position of these islands, a point of view from which the subject is worthy of the most serious consideration.

The relative authorship of the article, as now published, combined with that in the earlier editions, is described in the work itself in a foot note to the edition of 1842 (the seventh) :—" The foregoing part (the military) was written for the supplement to the former edition by Lieutenant-Colonel Hamilton Smith. The part that follows (on naval tactics), was written by one of the contributors to the fourth edition, of whose name we are not accurately informed." In a foot note to Portlock's article (in the eighth edition), is the following :—" As to the military part, the able article in the last edition, by Lieutenant-Colonel Hamilton Smith, has been freely used in the present ; " and to the naval part :— " This is adapted from the article in the former edition."

But Portlock, however actively engaged, whether by general or special duty, cried ever for more and more. It is not to be wondered at, therefore, that in the midst of the mental excitement and activity of London, his devotion to general science suffered no abatement. In 1857 and 1858 he was elected President of the Geological Society of London. In this honour he may well have felt the culmination of his long labours in his favourite science, of which that distinguished society may be justly considered the general head. The writer of these pages remembers Lieutenant Portlock reading his first paper before it in 1826, when the society met in its modest rooms in Bedford Street, and to which, though for many years after he was seldom in London, he always looked up as the parent of the many Geological Societies which have since been formed ; his own principal connection having been with that of Dublin. In each of the years 1857 and 1858, he delivered the annual address ; of each of which (and without entering upon their merits, which in common with his other contributions to geological science, it is the province of geologists to review) it may be said that they are remarkable for the copious information and minute research by which the addresses annually made to that society, by the eminent men who have in succession filled its chair, are year by year distinguished. In the address of 1858, in paying due compliment to Dr. Bigsby, he incidentally records his own early attention to geology during his explorations on military duty in Canada, when in one of his tours, " Strontian Island " derived its name from the discovery in it of that mineral by Dr. Bigsby, and he might have added, when " Portlock Harbour," in Lake Huron, was so named by Sir Gordon Drummond after himself. During his presidency of the Geological Society of London, in 1857, he attended the meeting of the British Association in Dublin, as a member of the council of the association. On this occasion he received in Trinity College the honorary degree of Doctor of Laws ; thus at the same time couronné in London and Dublin. He was also a fellow of the Royal Society, the Royal Astronomical Society, and of the Royal Geographical and Geological Societies of London ; a member of the Royal Irish Academy, of the Geological and Zoological Societies of Dublin, and of various others.

CONCLUSION.—It only remains very briefly to summarize the numerous duties and pursuits of our lost friend and brother officer. He began his career in active war, in the scientific branch of it, and it has been seen that even in that brief portion of his early days, he was not wholly undistinguished.

The war ceased, and in a long peace the scien ific element of his profession and character became developed in his life. That element found ample field for exercise during twenty years in the national Survey, rendering him one of the most prominent of those to whose energies and exertions the country and our corps owe its present Topographical Department. He joined in the effort to extend that work into a yet wider field; and his comprehensive mind led him to amplify his own peculiar and favourite branch, the geology, into the cognate subjects of natural history, on which Sir Roderick Murchison remarks that it is not unworthy of notice that "His energy and powers of critical research enabled him, as he worked, to enter with success the field of professed naturalists." His labours in the field and in the closet were alike conspicuous. He was twice President of the Royal Geological Society of London, and four times President of the Geological Society of Dublin. As a geologist no greater tribute can be paid than the emphatic words of Sir Roderick Murchison: "He was a geologist after my own heart."

In later years his life again assumed its military phase at Corfu, Portsmouth, Cork, Woolwich, Dover, and ultimately London; whether in military work or in military education, the life and duty of the "soldier" was his leading thought. In working he did what he had to do with all his heart. In education his life was one great lesson to all of us.

The last page in this "Life Book of a Labourer" opened in 1862, when sudden illness warned him to withdraw from active and public duty. After his partial recovery he expressed to the writer of this memoir his intention of settling near Dublin, and his hope that he should still be able to join usefully in its scientific society. This hope was not destined to be fulfilled. His illness continued and increased, and now the bare and genuine texture of his mind displayed itself in all its purity. From his earliest days he had strong religious feelings, which are indeed apparent in many of his writings; in his habits, life, and actions, they were always conspicuous, and as he gradually but slowly sank, and outer things faded from around him, that noble groundwork—the warp and woof of Christian character—grew more and more distinct, till on a peaceful Sabbath morning (the 14th February, 1864), soothed by domestic and family endearment and affection, he calmly breathed his last.

T. A. L.

PROFESSIONAL PAPERS.

PAPER I.

NOTES UPON THE WORKS IN AFRICA EXECUTED BY THE SPANISH PONTOONERS.

Extracts from a Paper by Don Mariano Garcia y Garcia, Captain of Engineers and Colonel, published in the Spanish "Memorial de Ingenieros," for 1862.

Translated by MAJOR GENERAL SANDHAM Royal Engineers.

The Engineers attached to the expeditionary army of Africa in 1860-1, consisted of 14 companies, each having a nominal effective of 1 first sergeant, 6 second sergeants, 9 first corporals, 9 second corporals, 2 buglers and drummers, 18 artificers, 40 first class and 59 second class sappers, in all 144 men. From various causes however the total number amounted only to 1,400 instead of 2,000, yielding no more than 1,000 men for daily work.

According to the organization of the corps, each company, in addition to its clothing, equipment, and arms, is provided with the proportion of tools and implements necessary for the work of the sappers, carpenters, blacksmiths, sawyers, &c. The sappers, like the German pioneers, are able to act either as pontooners, sappers, or miners, and consequently the train of each company is similar. It is divided into two parts; the first consists of heavy tools, such as are necessary for cutting down trees, making platforms, and for executing the general works of a campaign; the second part is composed of four chests, containing the necessary tools for the 18 artificers. For transport on the backs of horses or mules, the heavy tools are divided into six loads, the four tool chests form two loads, the provisions and materiel of the company two loads, and the forage one load; each company consequently requires eleven baggage animals to transport its train.

On the 1st January, 1861, the army commenced its march towards Tetuan, and after crossing several small rivers, it debouched, at daybreak on the 16th, on the plain before Tetuan, passing the formidable positions and passes of Cabo Negro with all its artillery; that evening the first and second companies of Pontooners began the construction of a bridge across the River El Lil, which was swollen by the discharge of the waters from the large lake of Torre Martin;

the latter was nearly empty, the water being very shallow; there was however instead such a mass of mire, that the horses sunk in up to their bellies.

Having made a reconnoissance, the most convenient point for passing was selected; and a good ford was discovered by which the artillery, the cavalry, and the mules could cross.

At 3 P.M. cutting brushwood was begun, and large stones and heaps of sand were collected; with these materials a dike 110 yards long and $5\frac{1}{2}$ yards broad was commenced, the height varying with the depth of the water. In the middle of the current an opening of $4\frac{1}{2}$ yards was left for the passage of the water; this opening was covered with planks 2 inches thick, placed double to sustain the passage of infantry and some horses. At 6 P.M. the companies were withdrawn, having constructed 66 yards of the dike.

The following morning the 2nd and 3rd Companies were employed on the work, which they completed at mid-day; when all the Infantry of the army crossed over, notwithstanding the bad and weak construction of the bridge.

On the evening of the 17th of January, the army took possession of the fort called Torre Martin, and the Custom House at Tetuan, and established its camp on the sandy plain between them; from that day till the eve of the battle of Tetuan, the companies were employed in the construction of three forts, called respectively, the Powder Magazine, the Custom House, and the Star Forts; they were also employed on the entrenchments that were to connect the two last, which were not completed for want of time.

Bridges over the River Alcantara.

Immediately on the occupation of the Custom House, reconnoissances and soundings of the River Alcantara had been made, and the construction of three bridges had been decided on: these bridges, with the stone bridge that existed upon the causeway, and which the Moors had not destroyed, would allow the army to cross to the opposite side of the river at four points simultaneously; for reasons to which it is not necessary to refer, these dispositions were not then carried out. The River Alcantara is only the outlet of the lakes of the plain into the mouth of the River of Tetuan, consequently in rainy weather it carries much water, but is quite dry in summer.

At the time referred to, it was in its worst state for making the passage of the river, for although its greatest breadth was only $15\frac{1}{2}$ yards, and depth of water 3 ft. 4 in., it had 13 feet of mud before reaching the solid bottom.

On the morning of the 3rd February, the 2nd Company was ordered to make the three bridges just alluded to, one of which was to serve for artillery, the other two for cavalry and infantry; they were to be ready by daybreak the next morning.

In the park established at the Custom House of Tetuan there were planks $2\frac{3}{4}$ inches thick, 14 feet long, and 11 inches wide, as well as nails and cordage.

The reconnoissances were repeated and the points for the establishment of the bridges fixed; the first for the passage of artillery at 55 yards below the bridge over the causeway, the river at this point being 10 yards broad, and $3\frac{1}{3}$ feet deep, with $8\frac{1}{4}$ feet of mud; the 2nd and 3rd for the passage of infantry and cavalry were, the one 88 yards above the stone bridge, the river at this point being $9\frac{1}{2}$ yards wide, $2\frac{1}{3}$ feet deep, and $6\frac{1}{4}$ feet of mud; the other 77 yards higher up, the breadth of the river being 9 yards, depth of water $2\frac{3}{4}$ feet, depth of mud $6\frac{1}{2}$ feet; the near bank was sloping, and the opposite bank somewhat scarped, but both of earth and open.

At 9 A.M. the construction of three 4-legged trestles was begun; the top of the first, $16\frac{1}{2}$ feet long, was formed by three planks united by screws; the legs were made of two planks screwed together in the same manner, 15 feet long; the stays, the cross-timbers, and the braces were each formed by two planks united. The top and legs of the second were formed of two planks united, the former being $13\frac{1}{2}$ feet long, and the latter $10\frac{3}{4}$ feet each; the 3rd was formed in the same manner, but the legs were $11\frac{1}{2}$ feet long. The baulks of the bridge were formed of two planks screwed together; the floor was of planks nailed to the baulks.

In consequence of having to make part of the nails, the trestle, sills, and baulks of the first bridge were not ready until 3 P.M., at which hour the company began to transport the material with such activity that by half-past 4 the bridge was constructed. They then transported the material for the second, which was finished at 6 P.M., and subsequently that for the third, which was constructed by nightfall. The artificers of the park, who were under our orders, did us signal service, or it would have been impossible to construct what was necessary, and to establish the bridge in so short a time, with only the artificers of the company. As the bridges had to be guarded during the night, a small intrenchment was made in front to protect the guard.

We found some difficulty in placing the trestles, for no amount of driving caused the feet to reach a firm bottom; the middle of the bridge was in consequence somewhat arched; however next day it sunk by the passage of the troops, and the floor remained perfectly horizontal.

In the bridge for the artillery, seven baulks were placed per bay, and only five in those destined for the infantry; these baulks were lashed to the top with thin cord, and although the planks were nailed to the baulks, it was not because we thought it most convenient, but because want of time did not admit of making the slots necessary for the lashings.

Heavy rain fell in the early morning of 4th February, and this retarded the movements of the army; at 8 A.M. it left off a little, and the different corps began to advance.

The artillery and cavalry were divided into two columns, the one to pass the Alcantara by the stone bridge, the other by the bridge made for them the evening before; the company was told off in three parties, each under an officer, to take care of the bridges, and to repair any damage that might occur, so that the passage of the troops might not be retarded, and to warn them to keep the weights equally distributed, that the trestles might settle uniformly.

The rise of the stone bridge was very considerable and overfatigued the cattle of the artillery, for which reason all that could, and the waggons, passed by the wooden bridge; the passage was effected without difficulty, until a gun of position having come on the bridge, badly overloaded the upper side, and the mud giving way on that side, the legs of the trestle sunk unequally until the upper one reached the solid ground; the gun was however drawn on without any other precaution than to incline it to the opposite side, by which the level was re-established in such a way, that when the infantry began to pass the top of the trestle was quite horizontal.

Nothing occurred in the other bridges, the infantry passing with a front of four, without intervals; and the cavalry two and two. When the troops had passed over, the floor of the first bridge was taken up and the bridge examined carefully, and finding that the trestle had suffered some damage, it was taken up, repaired, and replaced.

The three bridges remained without any alteration until the army left Africa, in the month of April, having served for the constant passage of troops, of artillery, and of commissariat waggons; the stone bridge of the Moors was useless, it being only intended for foot passengers and horses, for they have no carriages.

As soon as the army had passed, and the first bridge was repaired, as above described, the company marched to the vanguard of the army, taking part in the battle which was fought in the afternoon.

Bridge over the Mouth of the River of Tetuan.

To the left of the causeway leading from Tetuan past the head-quarters, runs the mouth of the river Guad-el-Gelu, and with the object of occupying both banks, a bridge was ordered to be constructed near the ford, for the passage of infantry and artillery.

For the preliminary operations, one of the boats of the bridge train (which was at the Custom House), was employed to take soundings, to measure the velocity of the current, and to examine the nature of the banks; it was found that the smallest breadth of the river was 64 yards, the greatest depth 5 feet, and the least $4\frac{1}{2}$ inches, the velocity of the current $3\frac{1}{2}$ feet per second, the banks scarped, of earth, and 13 feet high, owing to which latter circumstance it was necessary to make large ramps to get on and off the bridge.

Although it would have been more convenient to form the bridge of floating bodies, on account of the rapid rise the mouth of the river was subject to, arrangements were made to use trestles, formed of the resources at hand; these consisted of 200 poles which supported the arbours of the magnificent gardens of the beautiful plain of Tetuan, and of over 80 planks of different sizes; the engineer park furnished the hand railings, each 74 yards long, about 31 yards of thin cord, and about 44 lbs. of nails of all sorts.

The trestles were constructed, as just stated, of the poles collected from the gardens, whose dimensions were—length $9\frac{1}{4}$ feet, diameter $4\frac{1}{2}$ inches; the largest poles were used for the top, and the longest and straightest for the legs.

Four carpenters were told off from the company who began to work at 8 A.M. on the 15th February. The upper face of the top piece was slightly smoothed, leaving the rest rough; in the side faces four slots were cut, in order to receive the heads of the legs, these slots were narrow at the top, so that when weighted, the legs were wedged to the top piece. The poles intended for the legs were, as has been said, the straightest; their heads were squared that they might enter well into the slots in the top piece, the union being secured by two good sized nails; and to keep the legs at equal distances apart, four braces were nailed to the top piece and to the legs, and for the same purpose short transverse braces were nailed to the legs at about the centre of their height; the length of the legs varied according to the depth of the water.

Two carpenters with four assistants made a trestle in half-an-hour, so that in $3\frac{1}{2}$ hours the fourteen trestles, necessary for a bridge of fifteen bays, were made.

The floor of the bridge was formed of planks reaching from trestle to trestle. To prevent their springing up their ends were halved into each other and fixed to the top piece by two nails in each joint.

Whilst the carpenters were making the first trestles, and adjusting the boards for the floor, one section of the company was employed in cutting the ramp to the bridge, another in making a small raft, by means of which, and by the usual proceedings as laid down in the manual for this class of bridge, the trestles were placed in the water 13 feet apart, the length of the boards.

Near the banks, where for want of depth of water the raft could not float, the trestles were placed by means of manœuvring baulks.

To fix the trestles in their positions when placed, the top pieces were driven near their ends, with mauls of wood, until they rebounded; for greater security two large piles were driven at the ends of the trestles; these stood $3\frac{1}{4}$ feet above the floor of the bridge, and served also to support the side railing. The heads of the top pieces were strongly lashed to the piles. To the head of the piles the side rails were fixed, and nailed to posts on the banks of the river.

As soon as the last bay but one was constructed, a section of the company passed to the other side on the raft, to form the ramp at the other end of the bridge.

The whole operation, including the preparation of materials and making the bridge, was completed in seven hours.

This bridge perfectly resisted three floods, in one of which the current brought down a sort of boat which beat against two trestles all night without displacing them; when the advanced guard reached the bridge on the 5th of March, they found that the Moors had unlashed almost the whole bridge, carrying off the lashings; this damage was immediately repaired, but the following day they repeated the operation, taking also the railing. Soon after the flood increased in so extraordinary a manner that the water rose $1\frac{2}{3}$ feet above the floor of the bridge, which then gave way, and was carried off by the current.

The Pontoon Company of the 2nd Battalion, as soon as they had fortified the White House, were told off to open the road to Tangiers; before reaching the plain they constructed eight bridges of different dimensions, some with piers of dry stones, and others with trunks of trees; to all they gave width and strength enough for the passage of artillery.

Just as the road enters the plain, it is crossed by the stream Samsa, which runs into the Guad-el-Gelu; two bridges were established over this stream, one in the narrowest part, $7\frac{1}{2}$ yards long, and the other, a little above the first, 9 yards long.

The first was a bridge of two bays, with a trestle 10 feet high, constructed of planks joined together; the floor was constructed of five small baulks (formed of two half-planks united) covered by planks lashed to the top pieces and the baulks.

The second was also of planks, on the system of Captain Pirain, of the French Artillery.

Captain Pirain's bridges are constructed of ordinary planks about 13 ft. long by 10 in. broad by $2\frac{3}{4}$ in. thick. Each trestle is composed of two legs and a top piece. Each leg consists of two parallel planks separated from each other from 2 to 3 inches by means of cleats fixed at each end by bolts passing through them and the planks of the legs. In the space between the two planks of the legs the top piece is enclosed, composed of two or three planks attached to each other by screws, and having at each end cleats bolted to it at the proper inclination with respect to the legs so that the cleats may lie along them; the legs are pierced at different heights with holes, through which iron bolts to support the top pieces are passed. (See Figs. 1, 2, and 3).

The baulks of the roadway are replaced by frames 13 feet long, fastened to the top pieces or transoms by spikes; each frame consists of a certain number of half-planks placed on edge; these planks are placed lengthways of the bridge, and are united to one another by horizontal cross pieces, nailed one above and the other below, at both ends of the frame. The number of half-planks in a frame varied according to the width and strength that it is desirable to give the bridge.

The frames are covered by planks, and are fastened one to the other by chains attached to their ends.

The bridge constructed on this system was 26 feet long by $9\frac{1}{4}$ feet broad, and intended for the passage of artillery if necessary; the frames were made of fifteen planks 6 inches high, and the top piece or transom was made of three planks: each bay of 13 feet weighed about 11 cwt.

This system offers great lightness and much facility for construction and dismantling; four carpenters constructed one bay in four hours, and formed the bridge in half-an-hour. This bridge sustained the passage of infantry four deep, and the mules of the army on the 23rd, 24th, and 25th of March.

Bridge-Train to be Carried on the Backs of Camels.

Object of this Train—Its Organization—Description of Materiel—Method of Managing and Loading the Camels.

At the beginning of March, the prospect of negociating a peace disappeared, and among the preparations that were made for the continuation of the war, one was the means necessary for passing the swamps at the mouth of the river of Tetuan (Guad-el-Gelu), at the point which was considered the most convenient and best for commencing operations.

For this operation the bridge-train à la Birago had arrived at the custom-house of Tetuan, with iron pontoons and double superstructure; this was due to the zeal and activity of the chief engineer, who had it prepared at Aranjuez before the commencement of the campaign.

The train was obliged to be left at this point for want of open roads and the necessary teams; when the army arrived at Tangiers and the roads had been opened, it was enabled to march in the track of the artillery.

On the 5th of March the following communication was received from the Brigadier Commanding the Engineer Force:—

"His Excellency, the Chief of the Staff, having ordered that materiel for bridges, easy of transport, be immediately prepared, you will arrange that the

Commandant Don Mariano Garcia, Captain of the Company of Pontooners of the 2nd Battalion, shall immediately proceed with his Company to where the Birago bridge train and the materiel belonging to the Engineer park are stored, in order to take charge of the said train, and see that it is in a state for use, the Company of Pontooners of the 1st Battalion, encamped near the Custom House, rendering him every assistance. As the materiel of the bridges ordered is to be carried on pack-saddles, the above-named officer will ascertain whether it be possible to carry some rafts or bays of the Birago train on camels, and if not, he will proceed to construct pieces of portable trestles and roadway capable of passing field artillery, and sufficient for the passage of the mouth of the river of Tetuan. From the known zeal and intelligence of the officer entrusted with this duty, it is left to him to carry out the details which he may think most likely to conduce to the completion of the commission entrusted to him. Lastly, he will report immediately that he has ascertained whether or not it is possible to transport the train on camels, and if so, the number of them, and of mules necessary to carry it into effect."

In consequence of this order, the 2nd Company of Pontooners was removed to the custom-house of Tetuan and joined the 1st Company who were already there. They proceeded to look over the materiel of the Birago train, to report on its state, and propose means for repairing damages sustained in its embarkation and disembarkation.

A plan was immediately proposed for forming a bridge train that would fulfil the required conditions, viz., to be easily manageable, to be carried on the backs of camels, to have a sufficient width of roadway, to be firm enough for the passage of field artillery, and long enough to cross any rivers that might be met with.

As no floating body could be transported on the backs of camels, and as the trestles of Birago's system require some auxiliary pontoons or rafts to establish them in the water, the idea of utilizing them in this train was given up.

Trestles of four legs being those which are managed and placed in the water most easily, without the help of a raft or other floating bodies, it was decided to adopt them; considerable difficulties arose however as to their transport and construction. In fact to transport a trestle put together was little less than impossible, on account of its weight and above all of its size; to obviate this great inconvenience it was proposed to construct all the pieces of the trestles separately, and to make their fittings and mortices, disposing them in such a manner as to be able to carry them in separate pieces so as to be put together wherever the bridge was to be formed.

The construction of this sort of trestle was difficult for want of any wood at our disposal except planks; this was quickly overcome, by screwing planks together, by screw-bolts made on the spot at the forge of the company.

A trial trestle was made of the smallest practicable dimensions in length and thickness; this was put together and taken to pieces repeatedly, always giving satisfactory results, and its adoption was finally decided upon.

One difficulty still remained, viz., to know what length of bridge it would be necessary to transport to fulfil the object proposed; the scarcity of information respecting the country we should have to traverse did not allow us to determine this point, but being aware that it abounded in timber, and that with such skilful carpenters as were in the park we could construct a trestle of unsquared timber in 20 minutes by two carpenters and four labourers; and that the operation of establishing one bay of the bridge in the water required approximately a quarter of an hour, it was decided that to carry six bays of bridge of 13 ft. each, or what is the same thing 25 to 28½ yds. of roadway, would be enough for the necessities of the moment, and if a greater extension of bridge at any point was necessary, the extra materials for completing the bridge could be prepared without interrupting in any way the establishment of the bridge with the materials carried.

With this object cordage and spikes enough for the establishment of three more trestles were carried.

The form and dimensions of the baulks of the floor were also the object of lengthened considerations. The baulks of Cavalli's system are the best for carrying on backs, because they fold by a strong hinge in the middle of their length, and are thus less embarrassing to transport; but the impossibility of making these hinges for want of iron at hand, made us give up this idea, and we had to adopt baulks on Thierry's principle, reducing the length to 13 feet for the facility of transport.

Lastly it was decided, instead of nailing the baulks to the top pieces of the trestles, to fix them by lashings in the ordinary manner; and also instead of nailing the floor planks to the baulks, to lash them after Birago's method, it being the most simple. By thus getting rid of the nailing, the bridge could be constructed more quickly, the wood would not be destroyed, and greater facility would be afforded for dismantling and remaking the bridge.

Keeping in view the above considerations, the train was organized in the following manner and with the following materials:—

8 Boat-hooks.		2 Manœuvring baulks.
5 Trestles of 4 legs.	Cordage	2 Guy ropes.
2 Ground sills (for the banks).	Cordage	18 Cables.
8 Mauls.	Cordage	200 Rope lashings.
20 Pickets.	Nails ...	200 Large nails.
80 Flooring planks.	Nails ...	160 8-inch bolts.
24 Half-planks.	Nails ...	20 lbs. of assorted nails.
30 Baulks.		

A Company of Pontooners, and a section of carpenters from the park, consisting of at least six workmen, were to march with this train; the tool-chests of the companies were sufficient to supply the tools necessary for the work to be performed.

Description of the Materiel.

Trestle (Figs. 4 and 5).—This consists of a top piece or transom and four legs, the legs being fitted to the transom two and two, and fastened by bolts; to secure them in their proper position, four stays or props are carried from the legs to the top piece, to which they are fitted; to keep the legs properly apart, braces are fitted and nailed to them; lastly, two cleats are fixed to the legs close under the top pieces, and thus is insured the stability of the trestle.

Top piece or Transom.—This is formed of two planks, 2¾ inches thick, 10⅛ inches broad, and 10 feet long, united by six bolts, thus making a piece 5½ inches thick, of the length and breadth above named; at $2\frac{1}{4}$ feet from the ends of these planks slots are cut to receive the legs. On the upper side of the transom are marked the positions for the ten baulks of the two bays, and in the sides are cut the holes for the lashings that secure the baulks to the transom.

The weight of the transom is 76 lbs.

Legs of the Trestle.—Each leg is composed of two planks $2\frac{3}{4}$ inches thick by 9 inches wide, and 10 feet long, united by five bolts; the figures shew the connection of the legs with the struts, braces, and transom.

In the upper part of the legs are four holes for the bolts that fix the cross-beam or transom.

The weight of each leg is 76 lbs.

Stays.—Each stay is formed of one plank 2 inches thick, $4\frac{3}{8}$ inches wide, and 8 feet long, the ends are fitted as shewn in Fig. 4; it is fixed to the transom and the legs of the trestle by bolts.

The weight of each stay is 7 lbs.

Braces.—Each brace is formed of one plank $5\frac{1}{4}$ feet long, $4\frac{3}{8}$ inches thick, and 9 inches wide, the ends are halved into the legs and bolted to them.

The weight of each brace is 6 lbs.

Cross-pieces or Cleats are each formed of one batten, of the form shewn in Figs. 4 and 5, and are $1\frac{3}{8}$ foot long, 3 inches thick, by 9 inches wide, with bolts to fix them to the trestle.

The weight of each cross-piece or cleat is 5 lbs.

The total weight of the trestle is about 430 lbs.

Ground-sills.—Each ground-sill is formed of two planks $2\frac{3}{4}$ inches thick by 9 inches wide and 10 feet long, united by six bolts; on its upper face is marked the position of the five baulks which support the floor of the first bay, and on the sides are cut holes for the baulk lashings.

The weight of each ground-sill is 76 lbs.

Boat-hooks.—These were of the common shape and weighed 29·3 lbs. each.

Cordage.—This term applies to all the rope of the bridge train—the cables, anchor lashings, small lashings, and cordage, weighing together 481 lbs.

Maul.—Usual form, not hooped or shod, weight 11·5 lbs.

Pickets.—Usual form, without hooks or rings, which could not be made for want of time: 4 feet long; 4 inches diameter; weight 12·2 lbs.

Planks and Half-Planks.—The planks are $8\frac{3}{4}$ feet long, 11 inches wide, and $1\frac{5}{8}$ inches thick; the notches are 11 inches long. The half-planks have only one notch, their width is $5\frac{1}{2}$ inches.

The weight of one plank is 29·4 lbs.

Ditto of one half-plank is 15·2 lbs.

Floor Baulks.—Each baulk is formed of two planks 13 feet long, $2\frac{3}{4}$ inches thick, and $6\frac{3}{4}$ inches wide, united by four bolts, with the necessary holes $4\frac{3}{8}$ inches from each end, to lash them to the transoms of the trestles.

Weight of each baulk, 76 lbs.

Manœuvring Baulks.—Each of these baulks is formed by bolting together two planks and two half-planks, so as to make one long baulk 21 feet long, 5 inches thick, and $7\frac{1}{2}$ inches wide.

Weight of each, 138·7 lbs.

To Form the Bridge.

To construct this bridge a trestle must be made to slide upon the two manœuvring baulks placed at a slope, one end of each being at the bottom of the river, at the point the trestle is to occupy, and the other ends resting on the ground-sill or on the transom of the trestle last placed. The trestle is then raised by pushing the baulks forward and assisting with boat-hooks.

The smallest detachment necessary for forming bridge is 26 men, in addition to the workmen and their assistants; they are detailed as follows:—

1st Section—12 men in two ranks, numbered from 1 to 6, to place the trestle, baulks, and planks	12
2nd Section—4 men in two ranks, numbered 1 and 2, to lash	4
3rd Section—10 men told off as carriers to bring up the trestles, the baulks, and planks; if the bridge is long, this section may be doubled or tripled...	10
Total... ...	26

These three sections are commanded by an officer and two sergeants.

When a company can be spared the detachment is increased and divided into sections, as follows:—

1st Section	—Trestle carriers,	1 sergeant and 12 men	13
2nd -	—Baulk carriers,	1 sergeant or corporal and 10 men ...	11
3rd -	—Plank carriers,	1 do. do. and 8 men... ...	9
4th -	—Lashers,	1 corporal and 8 men	9
5th -	—Plank layers,	4 men...	4
6th Reserve,		1 sergeant and 16 men	17
		Total... ...	63

Also one officer and two sergeants to direct the operation. The detachment of workmen consists of 6 carpenters and 24 assistants.

A brief account of the employment of each section will now be given, in order that the operations may be fully understood.

The preliminary reconnoissance having been made, and the position of the bridge having been determined upon, the materials are unloaded, and parked up stream, leaving sufficient space between the park and the river bank, so as not to interfere with the operations. The camels, always frightened at horses, should be collected as far as possible to the rear and away from the road.

The workmen and their assistants commence at once to put the trestles and the manœuvring baulks together; the detachment for forming bridge is told off into sections, and by word of command, the following operations will be executed:—the 1st Section forms the ramp of the bridge, fixes the ground-sill, lifts the trestles and places them in the water in their proper places; the 2nd Section divides itself into pairs, each pair carrying a baulk and placing it; the 3rd Section is divided in the same manner, each pair bringing up three planks; the 4th brings up the necessary small stores, such as half-planks and lashings to lash down the floor as the bays are covered; the 5th collects the planks for the floor; the 6th or reserve maintains the direction of the bridge with boat-hooks, makes a small raft by which to sound the river, measures its breadth, lays down the ground-sill on the other bank of the river, and assists the other sections.

If the breadth of the river is greater than the length of the materials for forming bridge, the necessary number of trees must be cut down, to make the trestles, baulks, and planks required. One sergeant with the carpenters and the necessary assistants is charged with this operation.

To Dismantle the Bridge.

The detachment is told off in the same order and the same number of sections as in the formation of the bridge. At the word "Dismantle the Bridge," the section of lashers first goes on the bridge and unlashes the first bay and the others in succession, Nos. 3, 4, 7, and 8 carrying the materials to the park; the plank layers and carriers follow this section; as soon as the first bay is unlashed, the layers lift the planks and hand them to the men, who carry them to the park. Behind the plank carriers, the reserve section advances and passes to the other bank of the river to unlash the baulks from the ground-sill; having done this, it places the five baulks together side by side in the middle of the bay, and on them the section, carrying all the materials, passes back. At the word "Baulk carriers March," the section advance and unlash the heads of the baulks attached to the transom of the first trestle, collect them, and after placing them on the floor of the bridge, take them up and carry them to the park.

The second and remainder of the bays are dismantled in the same manner, the trestles being removed by drawing them in succession up the manœuvring baulks, whence they are passed to the rear.

Distribution of the Materiel in Loads and the Manner of Loading and Unloading the Camels.

The materiel put together, which, as before stated, consists of six bays of bridge, gives a length of way of nearly $28\frac{1}{2}$ yards, the weight of which is about $80\frac{1}{3}$ cwt., according to the following table:—

Weight of the Materiel of Bridge constructed for transport on the Backs of Camels.

	Weight.	cwt.	lbs.
	5 Trestles	19	22
	2 Ground sills	1	40
	8 Mauls...	0	92
	8 Boat-hooks	2	10
	20 Pickets	2	20
	80 Floor planks	21	0
	24 Half-planks	3	29
	30 Floor baulks	20	40
	2 Manœuvring baulks...	2	53
Cordage	18 Cables	1	32
Cordage	2 Guys	4	73
Cordage	200 Small lashings	0	100
	Assorted Nails and Spikes	0	85
	Total	80	36

The materiel is divided into two parts; the first formed of that necessary to form and dismantle the bridge, reserve articles, and the first bay; the second, of the remaining bays complete.

1st Part.

	cwt.	lbs.
2 Ground-sills	1	40
3 Boat-hooks	0	88
8 Mauls	0	92
20 Pickets	2	20
10 Floor planks	2	70
4 Half do.	0	61
5 Floor baulks	3	44
2 Manœuvring baulks...	2	53
Cordage	5	25
Total	19	45

Divided into 4 loads of about 4 cwt. 96 lbs. each, classified as follows :—

		cwt.	lbs.	
1st Load...	2 Ground-sills	1	40	4 cwt. 96 lbs.
	4 Floor baulks	2	80	
	3 Boat-hooks	0	88	
2nd Load...	2 Manœuvring baulks	2	53	4 cwt. 96 lbs.
	20 Pickets...	2	20	
	2 Mauls	0	23	
3rd Load...	10 Planks...	2	70	4 cwt. 92 lbs.
	4 Half-planks	0	61	
	1 Baulk	0	76	
	5 Cables	0	40	
	6 Mauls	0	69	
4th Load...	2 Guys	4	73	4 cwt. 97 lbs.
	3 Cables...	0	24	
	Total... ...	19	45	

The weight of each intermediate bay is 12 cwt. 22 lbs., and consists of the following materiel :—

	cwt.	lbs.		cwt.	lbs.
1 Trestle complete	3	94	5 Baulks...	3	44
1 Boat-hook	0	29	Cordage: 2 Cables ...	0	16
14 Planks	3	76	Cordage: 40 Lashings...	0	20
4 Half-planks	0	61	Large nails	0	17
			Total... ...	12	21

TRESTLE.

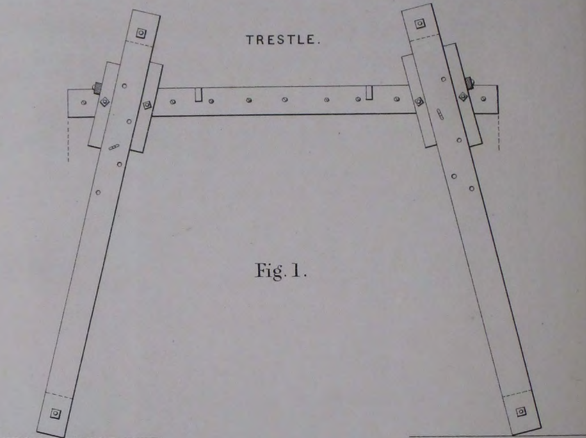
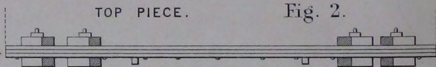


Fig. 1.

TOP PIECE. Fig. 2.



LEG. Fig. 3.

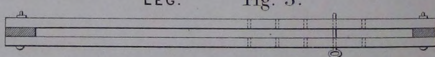


Fig. 4. TRESTLE.

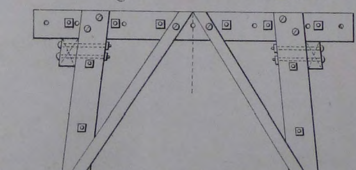
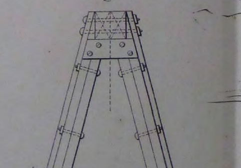


Fig. 5.



Scale of English Ft. $\frac{1}{50}$

Inches 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet

Fig. 7.

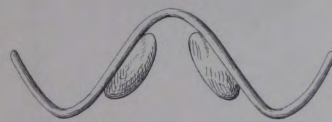
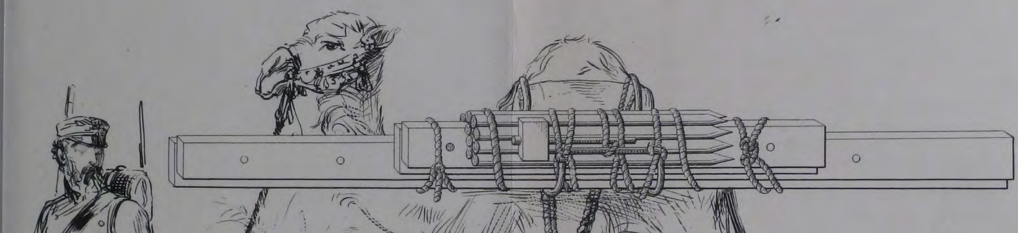


Fig. 6.



Kell Bros Litho. Castle

For facility of transport each bay is divided into two loads.

		cwt.	lbs.	
1st Load...	1 Trestle	3	94	6 cwt. 11 lbs.
	3 Baulks	2	4	
	1 Cable	0	8	
	1 Coil of lashings	0	17	
2nd Load..	2 Baulks	1	40	6 cwt. 10 lbs.
	14 Planks	3	76	
	4 Half ditto	0	61	
	1 Boat-hook	0	29	
	1 Cable	0	8	
	1 Coil of lashings	0	3	
	Large nails	0	17	
	Total...	12	21	

Thus, to carry all the materiel, 14 camels were necessary (reckoning on the contingencies that might occur); and to carry forage for a march of six days, 22 in all were demanded. Each load was naturally divided into two parts to balance the weight and bulk; the load for each side was lashed with strong cords, and the camels kneeling down to be loaded, made the loading easy. The load being adjusted on each side, a top load was added between them.

The pack-saddle is shewn in Figs. 6 and 7. This arrangement may not be the most advantageous, yet, without doubt, it gave sufficiently good results. Fig. 6 shews a loaded camel led by one pontooner, as we marched on the 23rd, 24th, and 25th of March, last year.

Camels eat and drink once in 10 or 12 days, during which time they sleep and rest without disturbing their loads; this much facilitates the transport, and for our object promised to be of great advantage. The age and weakness of the camels provided for us was, however, such that they could scarcely carry their loads for as many hours, which obliged us to unload and feed them every evening, as being better for their digestion; in consequence, it was determined to pack the loads in the same manner as the trains of the companies.

The company was divided into sections, each of one corporal and four pontooners, in charge of one camel; four sections were under the command of a sergeant, and eleven of an officer. At the order to strike tents, the sections formed, and each section loaded its camel, and was distributed as follows:— The corporal, at the camel's head, holding it by the halter; Nos. 1 and 2, on the right; Nos. 3 and 4, on the left. The camel laid down with his feet tied; when fully loaded, the feet were untied, and all was ready for the march at the word of command.

By the middle of March, all the materiel was constructed, the loads adjusted, and the second company of pontooners drilled to manage them, to form, and to dismantle the bridge; to load and unload the camels was repeatedly practised, and everything was ready for the march.

On the evening of the 22nd of March, this company left the Custom House with the train, to encamp at the head-quarters of the army. At day-break on the 23rd, the army marched, this train marching in rear of the first corps, to be in readiness at any moment; but the river of Tetuan and that of Buceja had so little water in them, that the troops forded them and the train was not used.

Two camels were killed and one wounded by the enemy's fire on that eventful day; their loads were distributed amongst the camels that carried the forage, and the forage was divided amongst the whole.

The campaign ended, the train returned to the custom house, from whence it was transported to Aranjuez, where it still remains.

PAPER II.

DESIGN FOR A ROLLING BRIDGE.

By C. T. GUTHRIE,

Temporary Draughtsman, War Department.

(Communicated by Capt. W. Crossman, Royal Engineers.)

To guide in the formation of this design it has been thought advisable that a rolling bridge should fulfil the following conditions :—

1st—It should not be greater in length than the opening intended to be spanned.

2nd—It should not involve any alteration in the construction of the roadway at either side of the opening.

3rd—When spanning the opening it should be flush with the roadway.

4th—The force necessary to move it should be so slight that any assistance from machinery should be unnecessary.

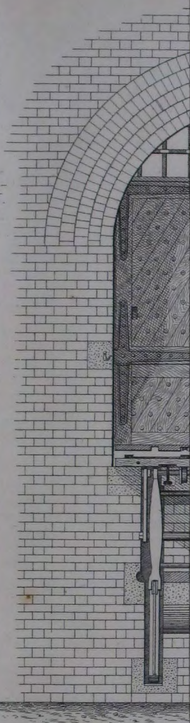
5th—One action should be sufficient to move it.

6th—When rolled back no part of it should be exposed to damage by the fire from the flanks.

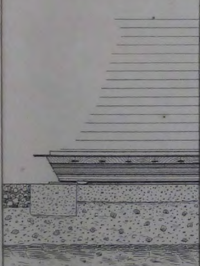
7th—Where gates are used in connection with it, it should be capable of being rolled in either direction while they remain closed.

8th—When the bridge is rolled in and the gates closed, no ledge should be left which might assist the enemy in bridging the opening.

The above conditions have been fulfilled in this design, and simplicity and cheapness of construction have been constantly kept in view.

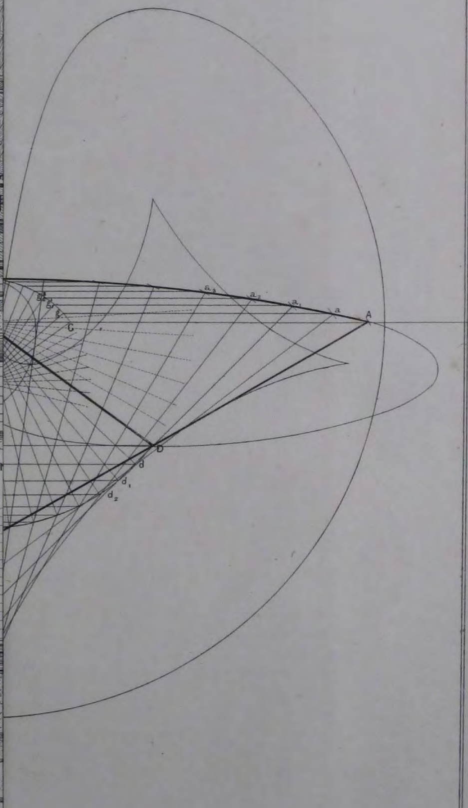


TRAN



SECTION SHOWING THE

ROLLED IN.



Construction of Bridge. The bridge is formed of two rolled or built wrought iron girders, covered with planking and supported at their centres by cast-iron struts; these are suspended by links in such a manner that while the upper ends of the struts accompany the bridge in its motion, their lower ends travel nearly vertically against the escarp wall. Thus their centres of suspension, which are also their centres of gravity, descend in circular arcs, whilst their upper ends which support the bridge ascend in arcs of a certain curve. The weight of the struts is thus opposed to the weight of the bridge, and the position of their points of suspension, their angle of inclination, and weight, and the form of the racers against which their lower ends travel, are such that they balance the weight of the bridge in every possible position, without any waste of material. It follows from this that the force required to move the bridge is exceedingly small, being due only to the friction on the axles.

The diagram (Fig. 5), is to illustrate the method of finding the proper curve to give the racers, in order that the bridge should be balanced in every position; it also shews the path of the centre of gravity of the bridge. It is unnecessary for any practical purpose to find the equations to these curves, suffice it to say that the first is compounded of the equation of a circle and its diameter, and the second of the equation of an ellipse and its diameter, and that while one centre is moving diametrically, the other is moving perimetrically.

The constructive method of finding the proper curve for the racers is as follows:—

While the centre of the bridge ascends in the arc AB, the centres of the struts descend through the arc DE. Now as the struts are to balance the bridge in every position the relative vertical rate of motion of their centres must be inversely as their respective weights. Draw the horizontal lines AC, DK, then the weight of the bridge is to the weight of the struts as KE is to CB, and the centre of the bridge must pass vertically from C to B at the same relative rate at which the centre of the struts passes from K to E. Draw the sector BGC_1, similar to the sector CDE, and divide the arcs BG and DE into the same number of equal parts and draw the horizontal lines ga, g_1a_1, g_2a_2, &c., dk, d_1k_1, &c. Then it is evident that if the centre of the bridge rises successively to the levels g, g_1, g_2, &c., while the centre of the struts falls to the levels d, d_1, d_2, &c., respectively, the conditions of equilibrium will be fulfilled. So from the point d, with a radius DA, describe an arc cutting the line ga in a, join ad, and from d, with a radius DF, strike an arc cutting ad produced in f, then f is a point in the required curve. Similarly f_1, f_2, f_3, &c., may be found. The part of the curve taken for the racers deviates very slightly from a straight line.

The most convenient proportion to make the several parts of a bridge of this description, which may vary in length from 10 to 40 feet, is perhaps to give the struts an inclination of 30°; to make them half the weight of the bridge, and to cause their centre of gravity to descend, as the bridge is rolled back, twice the space the bridge itself has to ascend.

The estimated cost of bridges of this description is about £4 for every foot in length.

C. T. GUTHRIE.

PAPER III.

NOTES ON THE DEFENCES OF CHARLESTON, SOUTH CAROLINA.

BY LIEUTENANT INNES, R.E.

The accompanying notes and extracts were made during a recent visit to Charleston, S. C. The notes are necessarily rather meagre, partly because I was unable to take anything bulky in the way of drawings, &c. with me when on my return, but chiefly because the publication of more detailed plans or descriptions would be obviously unjustifiable under the circumstances; for the above reasons the sketches of batteries are not exact representations of any particular work, but are only intended to show the types generally used.

The extracts from the official report of the first naval attack were made with General Ripley's sanction, and as it has not been published before, I think they will be interesting.

NOTES ON THE DEFENCES OF CHARLESTON, S. C., TAKEN JANUARY, 1864.

General description of Earthen Sea Batteries.

The general profile of these works was that of heavy siege batteries, the guns having a command of from fifteen to twenty feet over the water. Even this small command involved an immense deal of work, the natural level of the ground not being more than six feet above high water mark: the earth was taken from both within and without as in half-sunken batteries.

Spacing of Guns, &c.

The guns were all on dwarf platforms, with the centre pivot arrangement, firing over a parapet about five feet high: there was a traverse and bonnette to every gun, and that portion of the terreplein in rear of the traverses was from four to eight feet below the level on which the guns were mounted. Wooden steps to give access from the lower terreplein were provided in rear of each gun. The principle of isolating the guns one from another, was carried still further in the batteries at the City and Fort Johnson, where each gun was placed in a small circular nest, (which only just offered sufficient room for traversing), in the middle of a sixty-foot parapet; the communication between the guns and the interior of the battery being by deep narrow trenches, or sometimes by covered galleries: the guns were placed at central intervals of from 50 to 70 feet.

The arrangements described above are shown in the accompanying sketches. (See Pl. II). No. 1 is the construction most used at Sullivan's Island; No. 2 at the City and Fort Johnson.

Revetments, &c. The parapets, traverses, &c., are constructed of very fine sand, revetted with sods, cut in the neighbouring marshes; these latter are of a most excellent quality, the soil being a fine black mould without the vestige of a stone, and where there has been time and opportunity to finish up, they make beautifully neat work. Where space was an object, as in interior revetments, the sod-work had a slope of four or five to one in slopes under ten feet high. In a few situations where sods could not be conveniently procured, sand-bags were employed; they were made of a coarse cotton stuff which did not appear to last well. At the long ranges at which the batteries have been hitherto engaged, the penetration of the heaviest missiles has been quite insignificant, not more than six or eight feet; even shells do but little damage, owing to the wide spacing of the guns and the heavy traverses.

Magazines. The magazines were ordinary timber bomb-proofs; by giving the roofs a slight pitch, shingling or clap-boarding was said to keep them sufficiently dry; but I doubt whether it would have done so, had they been covered with anything but sand. Besides the magazines there were large numbers of small bomb-proofs in all the batteries for the use of the garrison not actually at the guns.

Platforms, &c. The platforms were of the dwarf pattern, but fired over a parapet somewhat higher than ours, (5 feet or a little more), owing to the racers being raised about a foot off the ground on an octagonal wooden framework of 12-inch timbers; the heavier guns had two racers, giving the platform three bearings in its length, the centre piece of the frame-work just mentioned contained the pivot and inner racer, and was connected with the circumference by a spoke at each angle. The racers were both complete circles, the front and hind tracks running on the outer one, as in our centre pivot. The platforms were much shorter than ours, being only about 12 feet long, and the whole affair worked within a circle of 15 or 16 feet diameter; most of them were fitted with pieces of wood, hanging from the tail almost to the ground, to prevent tipping in case of excessive recoil; but with the small charges commonly used the recoil was mostly very slight.

Arrangements for traversing and laying the Guns. A good many platforms were fitted with a rack and pinion arrangement for traversing, nearly similar to one proposed by Captain Beaumont, R.E., about two years ago; it was said to be found particularly useful in firing at moving objects. I enquired particularly as to whether the necessity for stepping down off the dwarf platform was found to interfere with this last, and was informed that it did not; No. 1 laying the gun slightly ahead of the object, and giving the command to fire as he stepped down. The arrangements for giving the elevation were as follows: a vertical line with the degrees marked on it, was painted on the breech of the gun, just beside the cascable; a vertical slip of wood was attached to the carriage close behind the breech, the top of which was against the zero of the scale when the gun was laid point blank; the required elevation or depression was given by bringing the proper numbers on the scale opposite the top of the stick; this could be attended to by one man, whilst another gave line, by which means the gun was laid very quickly. It was found particularly advantageous for night firing, because the light used can be concealed behind the gun and carriage, instead of being exposed as in adjusting a tangent scale, besides the difficulty of laying a gun in the dark, is very much increased by having to lay it exactly on the object, instead of merely giving the line.

Bombardment. Since the Federals occupied Morris' Island, they have thrown shell into the city more or less nearly every day. The range is from four to four and a half miles, and the ordnance used are 6-in. and 8-in. rifled guns; a few shell were thrown from a 10-in. rifled gun at one time, but this had been apparently given up. The shells are fitted with percussion fuzes, and a large proportion fall blind, owing, I suppose, to the rear end striking first. The majority of the inhabitants left the city when the bombardment commenced, but otherwise the effect had been perfectly insignificant. A few houses had been struck, (the shell making a good sized hole in the wall, and blowing out the window glass if it burst), and four persons killed (an old man and three women). Up to the beginning of January, when I left, not a soldier had been struck, and only two or three fires caused, which were got under without much difficulty. No shells had reached within a quarter of a mile of the Arsenal, and as there are but few troops quartered in the city, it is hard to see what good end the bombardment serves.

Fort Sumpter. Fort Sumpter is a comparatively modern work, having been built about the year 1840. It was intended for three tiers of guns, two in casemates, and one en barbette; the upper tier of casemates, however, was never quite completed, and at the commencement of the present war only the lower and barbette tiers were armed. It was constructed for 140 guns; the number actually mounted at the time of the first naval attack was between 80 and 90. The piers and front wall are built of concrete, faced with brick, and having tie courses of brickwork run through it at intervals; both the concrete and mortar have attained a respectable but not extraordinary degree of hardness, they appeared to be made of a mixture of lime and cement, but about this I am not sure. The front wall immediately on each side of the embrasures is five feet thick, the general thickness being eight feet. The embrasures are of the hour-glass form, with flaring cheeks, but a very small exterior opening. The guns pivot about their own muzzles, by means of a pivot in the thickness of the wall under the throat of the embrasure. The piers carrying the bombproof arches are five feet thick, and the main arches are about two feet three inches thick, with three feet of concrete over; the lower tier of arches are only one foot two inches thick; and are covered only by the stone pavement of the upper tier of casemates.

During the naval attack Fort Sumpter suffered no injury of any consequence. The gorge and right flank have since however been breached by batteries on Morris' Island at ranges varying from 1,500 to nearly 4,000 yards. The guns used were 6-inch, 8-inch, and 10-inch rifles; and their fire was said to be quite effective at the longest of the above two ranges. The projectiles most used were shell, and at a range of between 2,000 and 3,000 yards the 8-inch shell had a penetration of more than four feet. Wherever the wall was only five feet thick, it invariably came through. As soon as it became apparent that the gorge would be breached, the casemates on that side were filled up solid with layers of sand and cotton, the cotton serving to retain the sand at a much steeper slope than it otherwise would admit of. As the debris accumulated outside immense numbers of sandbags were thrown over amongst it, so as to form a screen for what remained of the gorge, and now there is scarcely any of the original outer wall left visible, the upper part having been shot away, and the lower part buried. It being an object to keep the gorge as high as possible, the foot of the breach was never cleared. Had the gorge been much lowered, the breaching batteries would have completely searched out the interior of the work. Although there is almost no wall, the breach is nevertheless very difficult and steep; the bottom, being composed of the débris of the masonry and fine sand, gives a very bad footing, and at the top the sand and cotton, supported by the piers and arches, stand so steep as to be almost impracticable. Add to this, that the stormers have to go straight up the breach out of their boats, there being scarcely any space available for forming, and that the approaches are within range of Fort Moultrie and Battery Bee, and it will not be surprising that the attempts to storm it have hitherto been failures.

The interior has suffered much from plunging fire; the upper tier of casemates are no longer tenable, and the lower ones, in which the garrison live, have to be completely covered up in rear with enormous blindages of timber and sandbags. It was observed that the piers were much weakened by containing flues, &c., those thus circumstanced giving way much more readily than solid ones. I was shown one instance in which a 10-inch rifle bolt, striking a pier 8 ft. x 7 ft. (on plan) diagonally, carried away the whole of it excepting about eighteen inches of one corner. Yet this pier was a foot thicker than those of many recent works.

To prevent the garrison from repairing the breach at night, the Federals successfully employed a lime light at Cummins' Point, about 1,000 yards off. By its means the working parties were almost invariably discovered.

Official Report of the first Naval Attack made by the Federals on Charleston, S.C.

Head-Quarters, 1st Military District,
Department of S.C., Ga., and Fla.
Charleston, April 13th, 1863.

General,

Upon the 1st instant, the increase of the enemy's force in the Stono, and information from Edisto, gave warning that the long threatened combined movement on Charleston was about to take place.

Brigadier General S. R. Gist, Commanding the 1st Sub-division of the district, James' Island and St. Andrews', took prompt measures for the observation and repulse of any attack in that direction. Colonel R. F. Graham, Commanding 3rd Sub-division, occupied the shore of Morris Island, on Light House Inlet, to control the passage from Folly Island, and a strict watch has been kept up to the present time on the land movements of the enemy.

On the 5th, the iron-clad fleet, consisting of seven monitors and one double-turretted vessel, hove in sight from Fort Sumpter, and came to an anchor outside in the vicinity of the "Ironsides" frigate, then a part of the blockading squadron. The 6th was apparently spent by the enemy in preparation, and by our artillerists in verifying the condition of their material. On the morning of the 7th the enemy was inside the bar with all his iron-clads, including the frigate, but from his proximity to the shoals and the haze of the atmosphere his position could not be determined.

The various works of preparation were progressed with, both on the exterior and interior line of defence, until about 2 o'clock, when the enemy steamed directly up the channel; the Weehawken, with a false prow for removing torpedoes attached, leading, followed by three monitors, the Ironsides flag-ship, three monitors, the Keokuk (double-turret), bringing up the rear.

At each fort and battery the officers and men made preparations for immediate action, while the enemy came slowly and steadily on. At 3 P.M. Fort Moultrie opened fire. At five minutes past 3 the leading vessel having arrived at 1,400 yards off Fort Sumpter, opened upon it with two guns; the eastern battery of Fort Sumpter replied. Batteries Bee, Beauregard, Wagner, and at Cummin's Point opened about this time, and the action became general, the four leading monitors closing up on the Weehawken, and taking position at an average distance from the forts and batteries of 1,500 yards. In accordance with the instructions, the fire from the different points was concentrated upon the leading vessels, and the result was soon apparent from the withdrawal of the leading monitor from action, her false prow having been detached, and she otherwise apparently injured. The remaining monitors in advance of the flag-ship held their positions, directing their fire principally at Fort Sumpter, but giving occasional shots at Fort Moultrie, of which the flag-staff was shot away. The Ironsides meantime opened fire and drew the attention of Forts Moultrie and Sumpter, and of the Cummin's Point battery; a few heavy and concentrated discharges caused her to withdraw out of range, where she was followed by two other monitors.

At five minutes past 4 the Keokuk left her consorts and came to the front approaching to within 900 yards of Fort Sumpter, 1,200 yards of Battery Bee, and 1,000 yards of Fort Moultrie; her advance was characterized by more boldness than had hitherto been shewn by any of the enemy's fleet, but receiving full attention from the powerful batteries opposed to her the effect was soon apparent: the 10-in. shot and 7-in. rifle bolts crashed through her armour, her hull and turrets were riddled and stove in, her boats were shot away, and in less than forty minutes she retired with such speed as her disabled condition would allow.

The remaining monitors kept their position for a time, but soon one by one dropped down the channel and came to anchor off range, after an action of two hours and twenty-five minutes, at ranges varying from 900 to 1,900 yards.

The full effect of our batteries upon the enemy could not be fully ascertained, and as our strength had not been entirely put forth, it was believed that the action would soon be renewed; the monitor which had led into action, however, proceeded south on the outside of the bar on the same evening.

Before the commencement of the affair I was proceeding in a boat to Battery Bee, and watched the progress of the cannonade from that point; the guns were worked with as much precision as the range would admit; there were no damages or casualties.

Visiting Fort Moultrie, the damaged flag-staff was being replaced and everything prepared for the renewal of the fire, should the enemy approach again; one man had been mortally wounded by the falling of the staff. Crossing the channel to Fort Sumpter, the effect of impact of the heavy shot sent by the enemy against the fort which they are so anxious to re-possess—greater in calibre and supposed destructive force than any hitherto used in war—was found to have been much less than had been anticipated; five men had been injured by splinters from the traverses, one 8-in. columbiad had burst, one 10-in. carriage had its rear transom shot away, and two rifled 42-pdrs. had been temporarily disabled from the effect of recoil on defective carriages.

The garrison was immediately set to work to repair damages, and the strength of the enemy's projectiles having been ascertained, to guard such points as would have been exposed to their effect should the attack be renewed.

Cummin's Point Battery and Fort Wagner were uninjured, except from the accidental explosion of an ammunition chest at Fort Wagner. * *

* * * * * * * * * * *

When day dawned on the morning of the 8th, the enemy's fleet was discovered in the same position as noticed on the previous evening. About 9 A.M. the Keokuk, which had been evidently the most damaged in the action, went down about three and-a-half miles from Fort Sumpter and three quarters of a mile from Morris Island. * * * * * * * *

* * * * * * * * * * *

On the 11th there were indications that the attacking fleet were about to withdraw, and on the 12th, at high water, the Ironsides crossed the bar and took up her position with the blockading fleet, and the monitors steamed and were towed to the southward, leaving only the sunken Keokuk as a monument of their attack and discomfiture. * * * * * *

* * * * * * * * * * *

The action however was purely of artillery: forts and batteries against the iron-clad vessels of the enemy; other means of defence, obstructions and torpedoes, not having come into play. * * * * * *

* * * * * * * * * * *

I have the honour to transmit herewith a sketch* of the position of the enemy's fleet at 4.15 P.M. on the 7th, a return of the guns engaged, a return of the ammunition expended, and a numerical return of casualties; to the last I beg respectfully to refer for such information as is not included in this report.

I have also to transmit herewith two Federal ensigns obtained from the Keokuk, as she lies off Morris Island, by Lieutenant Glassell, C.S.N., one of which is evidently the ensign under which she fought and was worsted. None of the iron-clads flew large flags, the object having doubtless been to avoid presenting a mark to our artillerists.

I have the honour to be very respectfully
Your obedient servant,
(Signed) R. S. RIPLEY,
Brig. Gen. Commanding.

Brigadier General Thomas Jordan,
Chief of the Staff,
Dep. of S.C., Ga., and Fla.

RETURN OF CASUALTIES.

	Killed.	Wounded.
Fort Sumpter	...	5
Fort Moultrie	...	1
Fort Wagner	3	5
Total	3	11

* See Pl. I.

Return of Guns and Mortars engaged on the 7th April, 1863, at Forts and Batteries in Charleston Harbour.

Fort or Battery.	Nature of Ordnance.								Totals.
	10-in. Columbiad.	9-in. Dahlgren.	7-in. Brooke Rifle.	8-in. Columbiad.	42-pdr. Rifled.	32-pdr. Rifled.	32-pdr. Smooth.	10-in. Mortars.	
Fort Sumpter*	4	2	2	8	7	1	13	7	44
Fort Moultrie	...	...	...	9	...	5	5	2	21
Battery Bee	5	...	...	1	...	...	...	...	6
Battery Beauregard	...	...	...	1	...	1	...	...	2
Battery Wagner	...	...	...	...	...	1	...	...	1
Battery at Cummin's Point	1	1	...	...	...	...	...	...	2
Totals	10	3	2	19	7	8	18	9	76

* The Columbiads and Dahlgren guns occupied the barbette tier at Sumpter, which had a command of 40 feet over the water; the upper tier of casemates was unfurnished, and the two Brooke guns were the only ones mounted in it, the remaining guns were in the lower tier.—W. I.

Return of Ammunition Expended in the Forts and Batteries in Charleston Harbour on 7th April, 1863.

Fort or Battery.	Round Shot.				Spherical Shell.		Rifle Shot.				Rifle Bolt.	Friction Tubes.	Gun-powder.
	10-in. Columbiad.	8-in. Columbiad.	9-in. Dahlgren.	32-pdrs.	10-in. Mortars.	8-in Columbiad.	7-in Brooke.	42-pdrs.	32-pdrs.	32-pdr. shell.	32-pdrs.		lbs.
Fort Sumpter	120	270	54	100	40	..	86	140	21	..	..	1,047	7,620
Fort Moultrie	..	339	..	243	51	5	..	..	..	38	192	1,200	7,375
Battery Bee	225	58	..	..	..	..	..	..	..	..	..	350	3,940
Battery Wagner	..	..	..	..	..	..	..	..	22	..	..	27	132
Battery Beauregard	..	64	..	..	..	..	..	..	45	7	41	157	1,155
Cummin's Point Batt.	40	..	26	..	..	..	..	..	..	..	..	73	860
Fort Johnson	..	..	..	..	2	..	..	..	..	..	..	2	11
Totals	385	731	80	343	93	5	86	140	88	45	233	2,856	21,093

Notes on the Foregoing.

The Federal monitors, or single-turret vessels, carried one 15-inch and one 11-inch gun each. The Keokuk carried two 11-inch guns, and the Ironsides twelve 11-inch guns and two 8-inch rifles. The projectile most fired from the 15-inch gun, was what is called the battering shell; it has walls 5 inches thick, and weighs 450 lbs.; it was fired with a charge of 45 lbs. of powder, and the average penetration in the walls of Sumpter, which are of good sound concrete faced with brickwork, was 3 feet 6 inches—very little more than that of the 11 inch.

According to the Northern newspapers, the leading monitor had her turret stove in so that it would not revolve, and two others had their decks seriously torn up and injured by rifle shot, but none were penetrated except the Keokuk, which was of weaker construction than the rest.

The Confederate officers state that the 8-in. columbiad is comparatively ineffectual at the long ranges in Charleston harbour, and all lighter guns almost worthless; the damage to the enemy's vessels was done principally by the 10-in. columbiads and 7-in. rifles. They have since rifled a number of 8-in. and two or three 10-in. columbiads, and strengthened them by banding at the breech; they are found much more effectual thus than as smooth bores, although fired with very low charges; some were rifled with shallow ratchet grooves, others with broad shallow rectangular grooves, the first being the Brooke and the second the Parrot pattern; in both kinds the grooves occupy about half the surface of the bore. The projectiles are all on the expansion principle, the body being made of cast or wrought iron, with a disc or cup of gun metal in rear, which expands into the grooving. Some solid shot for the Brooke gun formed an exception to this; except the head, which is of steel, they are of wrought iron throughout, there is a hollow in the base, the edges of which being very thin expand and take the grooving, this action being no doubt much promoted by the shallow grooves and heavy charge. I made particular enquiries as to whether it was found to injure the bore (cast-iron), and was assured it did not.

Subjoined is a table shewing the charges employed and the weights of the different projectiles :—

Calibre	Weight of Shot. lbs.		Charge. lbs.
	Round.	Elongated.	
10-in.	130	220 to 240	12 to 16
8-in.	64	120 to 140	8 to 10
7-in. Brooke......	..	120	10 to 25
42-pdr.	..	90	8 to 10
32-pdr.	..	50 to 92	5 to 7

The same charges were used for round and elongated shot; one of the Brooke guns had burst with the 25-lb. charge, and the full charge is now seldom used.

The Brooke gun is made of cast-iron, strengthened by wrought iron bands shrunk over it, sometimes two and sometimes three layers being applied according to the charge it is expected to stand; it is manufactured in Richmond, as also are considerable numbers of columbiads and smaller rifles on the Parrot pattern.

The Brooke guns and columbiads were served by seven men each, the smaller calibres by five men each.

There have been several other naval attacks since the foregoing, of which that on the 8th September was the most considerable, but the vessels have never come so near as in the first attack; in the former, however, the casualties were much heavier, owing to the blowing up of an expense magazine in Fort Moultrie, which killed and wounded nearly thirty men.

W. INNES, Lieut. R.E.

Halifax, N. S., 3rd March, 1864.

PAPER IV.

THE THICKNESS AND MATERIAL OF WALLS AND ROOFS OF BUILDINGS,

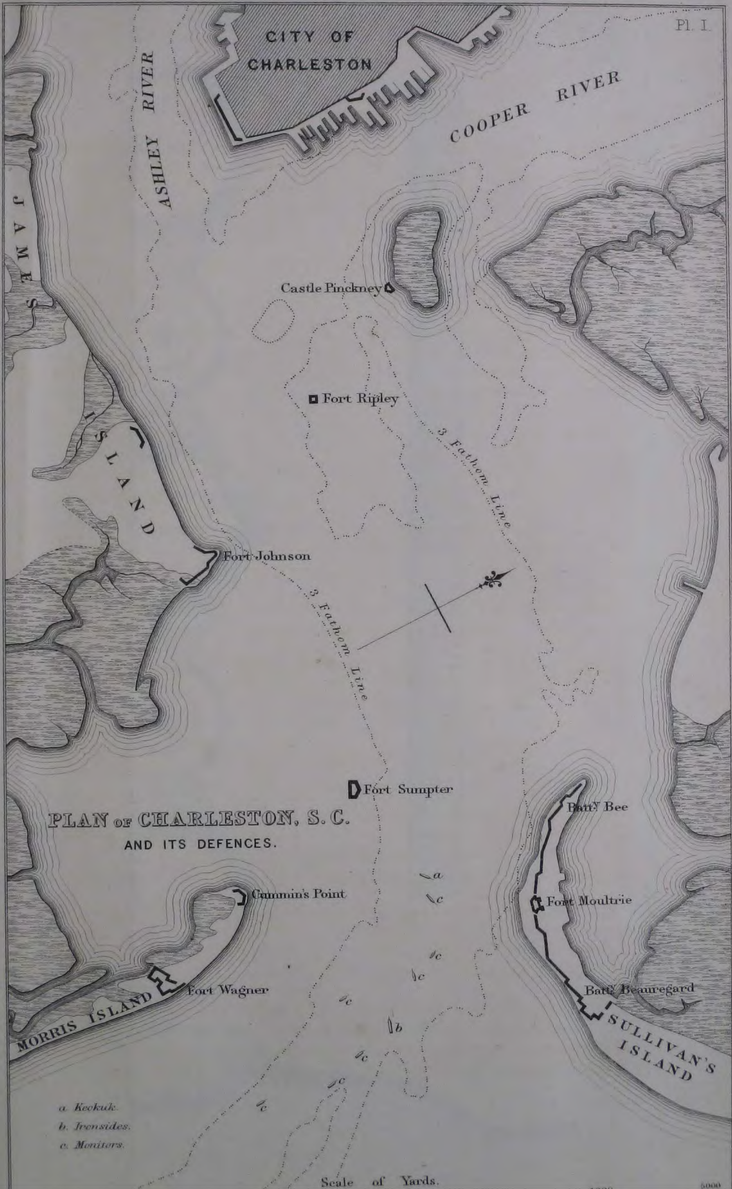
CONSIDERED IN RESPECT OF COOLNESS IN TROPICAL CLIMATES.

BY LIEUT. COLONEL FIFE, R.E.

There is probably no more common fallacy in the East than that buildings with very thick walls are much cooler than those with walls of moderate thickness, and there is no doubt that much labour and capital are thrown away in the construction of ordinary buildings, in consequence of the unsound view of the subject which is prevalent.

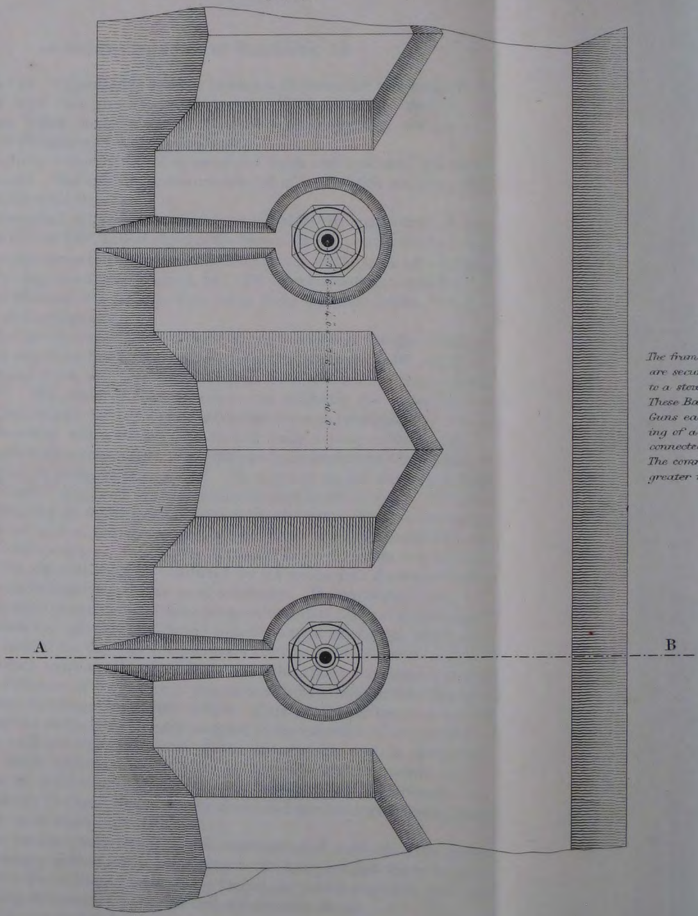
It was so firmly insisted upon by some of the civil officers in Sind a few years back, that thick walls of sun-dried brick were much cooler than thin walls of a more permanent construction, that before the construction of some large civil buildings was decided upon, I was authorized to make an experiment to decide the question.

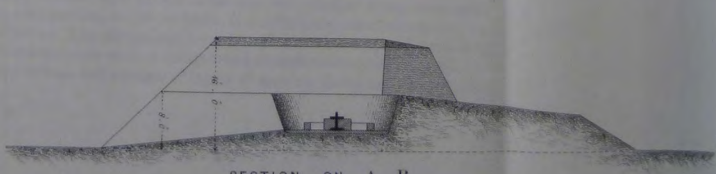
Two small buildings were constructed; they might be called ovens. They were 4 feet in interior diameter. The walls were 8 feet high and 1½ feet thick, and they were covered in with domes also 1½ feet thick. With the exception of a small window 8 inches square on the north side of each oven, they were


Pl. I.
CITY OF CHARLESTON
ASHLEY RIVER
COOPER RIVER
JAMES ISLAND
Castle Pinckney
Fort Ripley
3 Fathom Line
Fort Johnson
3 Fathom Line
Fort Sumpter
PLAN OF CHARLESTON, S.C.
AND ITS DEFENCES.
Batty Bee
Cummin's Point
Fort Moultrie
Fort Wagner
Batty Beauregard
MORRIS ISLAND
SULLIVAN'S ISLAND
a
c
c
c
c
b
c
c
c
a. Keokuk.
b. Ironsides.
c. Monitors.
Scale of Yards.
5000

COAST BATTERIES.

No. 2





SECTION ON A. B.

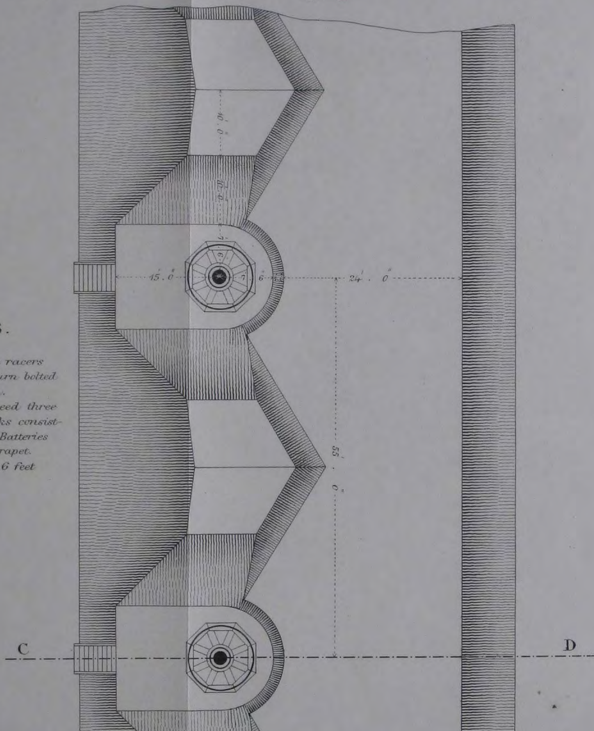
RE

The framewo
are secured
to a stout
These Batter
Guns each,
ing of a nu
connected b
The comman
greater tha

CHARLESTON, S. C.

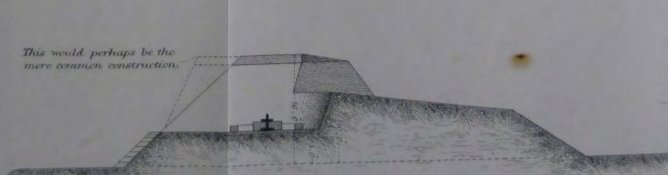
PLATE II.

N° 1



ERENCES.

…which the racers
… in their turn bolted
…d Platform.
…seldom exceed three
…larger Works consist-
…of small Batteries
…squetry Parapet.
…often 5 or 6 feet
…t shown.



SECTION ON C. D.

entirely closed in. Opposite the window in each a thermometer was suspended. The windows were then glazed and the recesses filled up with a packing of folded carpets, which could be easily removed when necessary, and closely fitting wooden shutters were added outside all.

One of the ovens was constructed of sun-dried brick and mud, and plastered outside with mud. The other oven was constructed of burnt brick and lime, and plastered outside with lime.

They were exposed all day to the burning sun, when the temperature of the air rose daily to over 100°, and at night to the breeze which towards the morning lowered the temperature to about 80°. The temperature of the sun's rays during the heat of the day was not ascertained, but 130° is not uncommon, and during the six weeks when the observations were taken there was clear settled weather with an almost cloudless sky.

Shortly after the observations commenced it was found that the thermometer in the oven of sun dried brick, or temporary construction, rose to 96°, while in the oven of burnt brick and lime, or permanent construction, the temperature was only 91°. The cause of this difference was evidently the colour of the material, the lime plaster having a great advantage over the mud plaster. Both ovens were therefore white-washed outside and made exactly alike in colour. The thermometers then read alike. The readings were registered three times a day: at sun-rise, at noon, and at sun-set. They never varied more than one degree in 24 hours: they were *highest at sun-rise* and *lowest at noon.* If there was any general change in the weather outside, the mean temperature becoming sensibly lower or higher, the ovens took several days to adjust themselves to this new mean temperature. One degree of change in the 24 hours was all that took place. The observations were continued for six weeks with the same result.

The result of this experiment was most conclusive. It was evident from the difference between the sun-rise and noon temperature, that the cool of the night did not penetrate through the walls to any material extent till the day following, and that the heat of the day did not penetrate till the night, and even then to but a very small amount. If with such small buildings unprotected with verandas the difference of temperature was so small, how insignificant must it become in large buildings where the volume of air contained bears so much higher ratio to the surface of the walls exposed to the extremes of temperature.

It is quite evident, from the result of the experiment, that in designing buildings for warm climates the thickness of the walls and the nature of the material may be decided irrespective of any consideration of coolness. In ordinary buildings the heat enters by the doors and windows when open, and passes through them when they are closed.

It is further evident, with respect to the construction of roofs, that the vault or dome of masonry cannot cause a building to be hot, provided there is any ventilation near the ceiling to permit any heated air, which may find its way into the building by means of the doors and windows, to escape.

It may also be inferred that the flat or terrace roof, whether of the permanent or temporary construction, in use in India, is a sufficient protection against the heat of the climate. The permanent terrace roof consists either of brick and lime, or of about 4 inches or more of concrete and lime plaster supported by timber. The temporary terrace roof consists of layers of matting, grass, and mud plaster, giving a total thickness of about 6 inches for the covering. These constructions are generally admitted to be cool, even by those who insist upon the advantage of thick walls.

The result of the experiment leads to the further conclusion that a better description of roof than the tiled one, in general use in India, might be adopted. The double tiled roof is heavy, troublesome to maintain, and most unsightly. It moreover cannot be a cool roof, unless, as is practised in Sind, a layer of plaster be laid on the roof underneath the tiles, and this, though securing coolness, adds still further to the weight, and facilitates the attack of the white ant upon the wood-work.

A much lighter roof of more durable construction might be introduced, and would probably prove, in the present state of prices in India, actually more economical and satisfactory in every way than the clumsy double tiled roof. A covering of corrugated or flat plate zinc or iron painted white would be light and durable. If a ceiling of thin planking, or three or four thicknesses of bamboo or date matting, were nailed to the underside of the principal rafters or to some light framing, so as to leave a space of about 6 inches below the metal covering, such a roof might be rendered an excellent protection against the heat of the climate. It would evidently be a much cooler roof than the ordinary double tiled one in which there is commonly nothing but a single ceiling cloth between the matting carrying the heated tiles and the interior of the building. It is not always indeed that there is even a ceiling cloth.

J. G. FIFE, Lieut. Colonel,
Royal Engineers.

PAPER V.

ON THE MOUTHS OF THE DANUBE,

AND THE

IMPROVEMENT OF THE MOUTHS OF RIVERS IN NON-TIDAL SEAS.

By MAJOR STOKES, R.E.

A Paper read at Chatham, October 16th, 1863.

The object of this paper is to bring before the officers of the corps the different methods that have been used for removing the bars of rivers discharging into non-tidal seas, with which the author has become acquainted whilst employed on a special duty.

He purposes first to treat of the general causes which lead to the formation of bars, and of the means to be employed for their removal.

Secondly, to mention generally the special treatment to which the bars of different rivers have been subjected.

Thirdly, to give a more detailed account of the works that have been successfully applied at the mouth of the Danube.

Round the mouths of most rivers are found shoals formed of the deposits of the river, and modified by the batter of the waves during rough weather; through these shoals the river forces a channel, which has greater or less depth, according to the state of the river and the sea. As this channel rises as a ridge between the deep waters of the river and the sea within and without it, and connects the higher shoals lying right and left of it, it resembles the neck connecting two hills in the same range; and, though really a channel, is called the bar.

The height of the bar, or depth of the channel, varies, as has just been said, under different conditions of the river and sea. When the flood waters of the river come down loaded with mud and sand they meet with a check at this ridge, but their impetus being greater than in ordinary times, the ridge itself is generally pushed farther out to sea, and the river waters being still further retarded by the opposing stationary mass into which they issue, the particles hitherto hurried along begin to fall to the bottom as the force of the current grows less and less, thus, on the new ridge, pushed out as above described, falls the coarse sand, making it grow up to larger dimensions than the original bar;

further out will be the fine sand; and in the depths far out to sea will invariably be found mud and fine silt if the river flows through an alluvial soil. Should these flood waters be accompanied by a land wind, it is evident that the effect on the entry will be less injurious, the current being increased will carry the opposing ridge or bar further out into deeper water, where the new ridge will require a larger base, and, consequently, take a longer time to grow; and the strength of the current will also carry the deposits further out to sea, and the shoals formed by them will be less dangerous to navigators.

If the floods occur at a time when gales are blowing into the mouth, the force of the current is checked, the bar is pushed out comparatively but a short distance, the deposits of the checked river are more immediately thrown down, and there is a greater danger of the formation of new and extensive shoals beyond and round the entry. After the subsidence of these floods the action of the waves generally drives the bar back to its original position after a struggle of weeks or months, according as the wind may prevail most from seaward or landward, and the fresh shoals are in the same manner driven in and piled upon the coast line, causing it to advance seaward. The case hitherto considered is that of a river issuing into a sea without littoral currents under different conditions of the wind; should, however, the sea have a constant current in one direction, a very important element is introduced, and the formation of shoals and growth of the bar may be brought under control.

As most rivers date from the remotest times, it is, of course, difficult to show their *first* effects, or to prove any theory of the formation of their bars; the author, however, calls attention to the following example which may tend to throw light upon the subject.

The river Vistula discharges into the Baltic by several branches, of which the western and most important formerly debouched into the Gulf of Dantzic, below the fortress of that name; the course of this branch was singular, it approached the coast in a direct line to the sea, to a point A, within 700 yards of it, when it took a sudden bend away from the coast, and finally found its way into the gulf, at a point B, more than five miles further along the coast to the west. In the spring of 1840, however, the break up of the ice on the Vistula began from above, and immense blocks of ice were piled up in the bend above mentioned, until they formed a high dam which held back the flood-waters of the river, and threw their weight upon a line of sand hills about 50 to 70 feet in height, which separated the river from the sea. Thirty-six hours of this pressure sufficed to the raging waters to break through this barrier, and ever since the western branch of the Vistula has debouched into the Baltic at this point; the channel which it broke through was, at first, 16 to 17 feet deep, but as the river current decreased, its deposits were thrown down and a bar formed so that only a channel of 6 to 7 feet remained.

General Plan, No. 3.

The existence of bars may then be briefly resumed as due to two causes:—

1. The deposit of matter from the flood-waters of the river.

2. The effort of the sea to maintain the coast line by throwing up and packing together the sand and shells at its bottom.

The variety and amount of effect produced by these causes depend upon the action of the winds and currents, and on their changing force, duration, and direction, from which we may deduce the following axioms:—

1. That the mouth of every river has its own local peculiarities on which the successful treatment of it must depend.

2. That in studying to apply general principles to the improvement of any river, its local conditions must alone be allowed to guide such application.

3. That the fact of works having proved successful, or having failed at any river mouth, by no means ensures that the same kind of works will succeed or fail at any other river mouth, unless the very same conditions exist.

We now proceed to consider the different remedies proposed for the removal of bars, or, more properly speaking, for the attainment of a deep navigable channel into rivers whose entrance are obstructed by bars.

These remedies may be briefly stated thus :—

1. By cutting a channel and maintaining it by dredging, assisted by the use of a rake towed over the channel.

2. By confining the river waters between piers which lead them across the bar and into deep water.

3. By cutting a canal to connect the sea with the river above its mouth, the river waters to be excluded from the canal to prevent its being silted up, the canal to lead into deep sea between piers, and kept clear by dredging.

The first of these methods may be practised with advantage, only where the channel to be dredged lies in a bay or gulf sheltered from the action of the waves. On an open coast, exposed to the swell produced by every breeze, a dredger cannot produce any perceptible effect. The least swell prevents her working, and for one day's perfect calm she will have two days of swell, even in summer, so that the work of one day is liable to be filled up the next; if, by the end of autumn, some little effect is produced, the long cessation of work during the winter months will certainly leave the waves at liberty to fill up the deepened channel.

A thorough trial was given to this system at the Sulina mouth of the Danube, in the summer of 1857, when three months constant dredging, relaxed only when there was too much swell on for work, gave no more than six inches additional depth, which was soon lost in the following months, although there were then no floods to throw down deposit. The beating of the waves did the work, for the coast at Sulina is entirely exposed to all of the prevailing winds.

It is to be remarked that this dredging did not aim at the removal of the stuff in barges. In the narrow channel where the dredger worked there was not room for barges to lie alongside of her; even the dredger herself was frequently run into by vessels passing in and out. The stuff dredged was allowed to fall on a grating, and being thus broken up was carried away by the river current into which it fell.

At the canal entry to the Vistula, of which mention will be made further on, a dredger works successfully every day from May to October or November, but the ground on which she works is entirely protected from the prevailing winds.

In the channel at the mouth of the Oder, a dredger is also kept at work with good effect to prevent the growth of the sand bank by which it is sheltered while working.

Both at Sulina and off the Vistula the presence of the dredger has been found to be a great inconvenience to the navigation. At Sulina there was no advantage gained to counterbalance the annoyance and expense of the dredger; at the Dantzic canal entrance the maintenance of a channel of 17 feet compensates the navigation for both.

Examples of the second method, namely, that of parallel piers, are to be found at the mouths of the Oder, Rhone, Danube, and Vistula. In the first and third instances they have been successfully applied, in the second and fourth unsuccessfully. The reasons for these various results will now be traced.

General Plan, No. 1. Oder Plans. Nos. 1 to 12.

The Oder, not long before reaching the Baltic, passes through a lake called the Haff, in which it deposits any of the matter that it may hold in suspension, and whence it continues its remaining short course to the sea in a clear and limpid stream. The bar, or rather the menacing sand bank at its mouth, is formed by the littoral current which attacks the line of high dunes extending westward for a distance of 12 miles, and brings in the sand which accumulates so fast to the west of the entrance, thereby necessitating the employment of a powerful dredger to keep this bank from growing inwards.

An examination of the charts of this mouth, which have been kept for the last 120 years, shows that in 1739 there was only six to seven feet in the entry. From that time till 1776, efforts were made to render the banks at the mouth more solid, and to bring them closer together by groins of fascine work, which collected the sands travelling along the coast, and a survey of that year shows that this system had led to a considerable advance of the coast, and to but a slight improvement in the depth, which seems to have been its condition in the year 1816. At this time it was determined to have recourse to piers, and the works of that nature then commenced were steadily carried forward for nine years with an ever-increasing depth in the navigable channel, until in the year 1825, when the piers were completed, there was a channel of $17\frac{1}{2}$ feet, which went on improving, till in 1845 we find a fair channel of 24 to 27 feet to the north-east, and a very broad channel of 18 feet to the north. It will be seen, however, that although this channel was cut through the old bar by the river current concentrated and directed by the piers, a part of that bar always remained in the shape of a sand bank running out beyond the west pier; it must be clearly understood that this bank, on which great stress has been laid by those who pretend that the piers have failed, is *not* a new formation; its growth has, from time to time, tended to render the navigable entrance narrower, but, as has been observed above, it has ever been removed by the action of the current aided by dredging, so that in 1858, 33 years after the completion of the piers, the 18-ft. channel had always been maintained without any prolongation of them, and there was still a fair 24-ft. channel for steamers. It was then in contemplation to prolong the western pier in a direction converging on the eastern pier, so as to increase the scour, and check the travel of the sands along the coast from west to east.

It will now be useful to explain the causes of the bar forming at the mouth of the Oder, and of the great success of the piers.

The bar was formed, and the west pier sand bank is increased, by the travelling sand carried eastwards from the western head-land of the bay (into which the Oder discharges), by the littoral current. Some of the dunes attacked by the current are 200 feet high, and several of these big sand hills have been degraded at the rate of 12 feet a year. This littoral current circulates round the Baltic, from Denmark along the north coast of Prussia by Russia and Finland, returning down the coast of Sweden. It is urged forward by the prevailing westerly winds, but is at times held back by north-easterly gales, which, by banking up the waters, cause the sea-level to rise and the sea-water to pour into the haffs shown on the map. When the gales abate and the prevailing winds and currents cause the sea-level to fall again suddenly, the waters of the Haff pour rapidly out through the Oder mouth, at the rate, generally, of some five miles an hour for some three or four days; this great scour, which recurs at not very long intervals, has served to maintain the channel, and to cut down the bank growing under the influence of the travelling sands. It is unaccompanied by any deposit on the bar, as the waters are quite clear, being, in fact, sea-water escaping back from the Haff. These peculiar conditions of the Oder mouth deprive the results gained by the piers of some of their value, as experience gained for the general question; but these results are, on the other hand, conclusive against the assertion that the works have failed of their object. The substitution of a channel 18 to 24 feet deep, maintained for 33 years, for one from 8 to 12 feet deep, must be allowed to be a success. The prolongation of the piers from time to time will, of course, be necessary; but, if only required once in thirty years, the expense will be fully compensated by the results obtained.

General Plan, No. 1.

At the mouth of the Rhone, piers have been projected, but the plan never advanced beyond the embankment of the river. It will be well to examine the causes that led to the abandonment of the scheme.

General Plan, No. 2.

The Rhone discharges through several mouths into the gulf of Lyons; the deepest natural outlet, and that by which the greatest body of water passes, is the easterly mouth. This mouth discharges in a direction exactly opposed to the prevailing winds, so that when the floods descend they find themselves immediately arrested, and the matter held in suspension is at once thrown down close to the mouth. At the same time, it must be observed, that the usual force of the current is very feeble, being less than a mile an hour, so that it has no chance of forcing a way through the banks formed during the floods; and, on the other hand, the winter gales breaking directly on these banks pack and consolidate them, so that they advance, in their natural state, 40 to 50 yards a year. So feeble is the current, that the river, for $2\frac{1}{2}$ miles above the point where it joins the sea, does not maintain the depth of 26 to 30 feet that it has higher up, and which here falls to 14 or 15 feet.

So much for the natural conditions of the river mouth, conditions the most adverse to the pier system. If one, however, considers the works that were executed there from 1852 to 1857, one can hardly admit that the pier system failed at the mouth of the Rhone; for piers, in the sense understood, at the mouths of the Danube and Oder, were never carried out.

By the works executed, the engineers employed seem only to have sought to quicken the current whilst in the river; the works consist of dykes and causeways by which the outlets of six other branches have been closed, and the river has been confined to one channel. Beyond the increase of power thus gained to the current, no step has been made towards removing the bar.

This method of proceeding has had the effect that might have been foreseen:

the increased mass of river water has thrown an increased deposit; and the banks, instead of advancing at the rate of 40 to 50 yards a year, made in the year 1857 an advance of 300 yards forward.

In that year, the first after the complete embankment of the stream, the summer floods produced an increase of depth to $13\frac{1}{2}$ feet, the former depth having been from 5 to 8 feet. This improvement lasted only four or five months, when the depth went gradually down to 7 feet. What the effect would be, of rapidly carrying out piers across the bar, as has been done at the Sulina mouth of the Danube, it is difficult to predict. The most violent winds blow directly into the mouth; and, for as much as 70 days out of 120, drive a heavy surf on to the bar. Still, the carrying of the river into the littoral current, which does cross the mouths from east to west, might have a beneficial effect. It is certain, however, that the Rhone offers but little chance of success to piers; it is also certain that they have never been really tried there. They cannot, therefore, be said to have failed at the mouth of the Rhone, though their failure *there* would constitute no argument against their employment elsewhere.

A project exists for entering the Rhone by a lateral canal from the Gulf of Foz, which, from its sheltered position, offers peculiar facilities for the execution of that class of works; the "Baie de Repos," into which the canal would debouch, being so calm at all times as not to interfere with dredging operations, and the bay itself having sufficient depth and a good bottom for anchorage.

The next example of the application of piers, which it is proposed to mention, is the Sulina mouth of the Danube; but, as the description of the works executed at this embouchure will form the subject of the concluding part of this paper, the author will here speak only of the results obtained by them, and of the general conditions of the locality which seem to him to have conduced to those results.

The Sulina is the least important of the three principal branches of the Danube, but it is that which has usually had the deepest navigable channel into the sea; its channel, from the point where it leaves the main river, 50 miles from the mouth, is the worst of the three branches, being everywhere narrow and in very many places encumbered by shoals which entail many delays and heavy expenses on vessels navigating from the principal ports of loading, namely, Galatz and Ibraila, whereas the other branches are broad and deep everywhere except at their mouths.

Without at this point referring to the circumstances which led to the improvement of the Sulina mouth, it will suffice to say here, that the depth, on the Sulina bar before the improvements, was very variable, being sometimes as great as 12 feet, at others as low as $7\frac{1}{2}$ feet; that the ordinary depth was from $9\frac{1}{2}$ to 11 feet, and that it was more rarely above $10\frac{1}{2}$ than below $9\frac{1}{2}$ feet, and more frequently below $8\frac{1}{2}$ than above 11 feet; that since the construction of piers the depth has never been less than 16 feet, and is usually 17 feet, there having been at times a good channel of $17\frac{1}{2}$ feet.

The works commenced in April, 1858, were completed in August, 1861. The spring floods of that year had formed a menacing bank on the continuation of the south pier, and about 2,500 feet to seaward of it, but this bank was speedily broken down by the spring gales and carried away by the littoral current. In 1862, the floods threw down a similar bank, but without obstructing the navigation, and that bank was again removed by the action of storms and currents. The supposition that a bar would form again outside the piers has not been in any way confirmed. The banks just mentioned have been the nearest approach to such a formation; but the rapidity with which they were removed seems to favour the supposition that the bar will only creep across the front of the piers when the general advance of the Delta shall have pushed the littoral current further away from them, and thus caused a double effect dangerous to the channel.

In the first place, the river current would then not be turned southward, and would throw down its deposits immediately in front of the piers instead of to the south, as in 1861-62; and secondly, the banks thus formed, instead of being broken down by the gales and carried southwards, would be driven back on the channel, which they would still more choke. In the present year there have been no floods worthy of the name, and the current of the river has, consequently, been so feeble that the bank has formed between the heads of the piers, narrowing the entrance but not *barring* it. This bank is not disquieting, because being almost in the position of the old bar, and being distinctly traceable to the weakness of the current, there is not the slightest reason to doubt that the first strong flood will at once carry it away; the deep water being no farther off than in 1860, the littoral current is still there, so that the same causes for removing the bank existing, no one can doubt but that the same result will ensue. In fact, the entry at Sulina may be pronounced to be well in hand, for should any summer's survey show a decided advance of the coast line, it will always be in the power of the authorities charged to keep open the river, to extend the piers, and again reach the littoral current. No such prolongation seems at the present moment called for, and a comparison of this year's (1863) survey with that of 1857, shows that the 15 feet line is about where it then was, whilst the 18 feet line is now much nearer to the entry than in 1857.

There is then every reason to suppose that these works will continue to produce their effect for the time that they were originally intended to last, namely, for 5 or 6 years.

The fourth river alluded to as an example of the effect of piers, and the first that will be cited to throw light on the application of the canal system, is the Vistula, a river which indeed gives instruction on every kind of river-works, whether in the channel or at the mouth.

Vistula Plans, No. 1. Attempts were made to improve this river as long ago as 1594, when, as seen on Plan No. 1 of the Vistula series, rough piers were carried out, but it would seem without producing much effect, as the plan does not show more than $5\frac{1}{2}$ feet.

No. 2. Plan No. 2 bears no date, but shows the piers of 1594 already absorbed in the advancing coast line.

No. 3. Plan No. 3, of 1682, shows the Western Pier extended seaward and banks again forming behind it. A breach in the root of this pier through which the river cut itself a lateral communication with the gulf, 10 to 12 feet deep, suggested the idea of obtaining a permanent channel independent of the mouth. The engineers of that day set to work to dredge the channel, throwing the stuff on to the bank at the back of the pier, and thus aiding the natural deposit to form an island which became the right bank of a lateral canal leading from the river to the gulf.

No. 4. Plan No. 4, of 1691, shows that this canal was then led into the gulf under a pier projected from this dredged island.

No. 5. Plan No. 5, of 1697, shows the canal shut off from the river by lock-gates, but shows, also, the difficulty of keeping open the canal, which was then only 7 ft. deep at one part and had a passage of 9 ft. only into the gulf.

No. 6. No. 6 shows that in 1717, a further attempt was made to keep open the proper mouth by piers, which seems to have been abandoned, for Plan
No. 7. No. 7 shows that in 1724 a second pier was carried out at the entrance of the canal, the old pier prolonged, and the banks of the canal revetted; and as the canal itself was narrowed, its depth was doubtless increased, though no soundings are given.

No. 8. Plan No. 8 shows that in 1745 the Eastern Canal Pier had been much extended into the gulf, but a depth of only 10 feet obtained. An extension of the pier at the mouth of the river had, at the same time, produced only 6 feet.

No. 9. No. 9 records the apparent abandonment of all further attempt to open the mouth, and shows the successive prolongations of the canal piers, the western in 1775, 1796-97, 1802-03, the eastern in 1797, 1801, 1802, and 1802-5, which resulted in a depth of 13 feet in 1805.

No. 10. No. 10, in 1815, shows no extension of piers, but, as it gives no soundings, is of no value, except in showing the growth of buildings along the canal banks, and that the lock was solidly constructed in masonry.

The author was informed by the engineer who, in 1858, had charge of all the Prussian Harbour Works, that no efforts were available to keep open a greater depth than 10 feet into the canal before the year 1840. Each successive prolongation of the piers gave an additional depth up to 13 feet, but it was always immediately lost, and fell back to 10 feet. It was not till after the breaking through of another mouth several miles to the east, in 1840, as before mentioned, that the Prussian Engineers could congratulate themselves on having obtained a good entrance to the Port of Dantzic. As soon as that unlooked for, but fortunate, event took place, they commenced with praiseworthy activity to take advantage of a circumstance which had removed from the neighbourhood of the canal the continual deposit of sand which choked it. The river was at
General Plan, No. 3. once shut off from its old course at the point A (General Plan, No. 3) by a dam through which vessels of small tonnage and rafts pass by means of lock-gates, on the sill of which there is a depth of 8 feet.
Vistula Plans, Nos. 11 and 12. The old mouth was cut off from the sea by a solid dam built across its channel; the old lock-gates, at the entrance to the lateral canal were removed, being no longer necessary, and the piers at the mouth of the canal were greatly extended.

By these means an excellent channel of 17 feet was obtained, and has since been maintained by constant dredging at the head of the east pier.

As already mentioned, the dredging is carried on under peculiarly favourable circumstances, as the Gulf of Dantzic is land-locked, and gives no rule for what could be done in the open sea.

The author has adduced the case of the Vistula as his last example of the effects of piers, and his first of the application of the canal system; but it is now time to examine why and how piers have failed—and how, if at all, the canal can be said to have succeeded.

In the Gulf of Dantzic there can hardly be said to exist a littoral current. The littoral current of the Baltic, from west to east, passes along the Helas—the long low natural breakwater forming the Gulf of Dantzic—and strikes against the coast which then immediately tends to the north; the main force of the current is then carried northward, but a portion of it sets into the Gulf of Dantzic, from east to west from the point of contact, whilst a second current passing round the head of the Helas sweeps along the shore of the gulf, and travelling from west to east, meets the main current somewhere opposite the old mouth.

No more unfavourable circumstance for the opening of the river could be imagined.

The river issuing into slack water at the meeting of the two currents threw down its deposits at once. The easterly current being, if anything, the stronger, these deposits were slightly carried to the west, just sufficiently to fill up the canal entrance. One cannot be surprised, therefore, at the failure of the Vistula piers.

As to the canal, it is not an example of the cutting a channel through a delta such as has been done at the mouth of the Ebro, and has been proposed for the Danube; a better channel having, by an accident, made its appearance behind one of the piers, advantage was taken of it, and an island formed outside of it.

Nevertheless, adroitly as this was done, persevering as were the efforts of the Dantzigers, for more than 150 years, to keep this channel open to sea-going vessels, it was not till the event of 1840, which removed the mouth so many miles to the eastward, that anything like success was obtained, and then only by the employment of piers and by dredging.

Who shall say then, decidedly, that one system has failed and the other succeeded? Rather let it be said that engineers, taking advantage of nature's help, have used one system and the other, each in its measure, according as local circumstances directed, and that any attempt to lay down any one system, dogmatically, without reference to the locality, would assuredly fail.

The only instance in Europe of a river opened into a tideless sea, by means of a lateral canal, is the Ebro in Spain; but, here again, the experience gained does not allow the author to say that a decided success has been achieved, nor does the example bear on the general question, for the canal opened is so small that it will not admit sea-going vessels; and although nominally completed in the autumn of 1861, it had not been opened to general navigation in March, 1863.

General Plan, No. 4. A glance at the chart, No. 4, will show that this canal connects the Ebro with the Port of Alfaques, a small gulf formed by the delta of the Ebro to the south of the embouchure.

The length of the canal is 10,334 metres, its depth 2·70 metres, and its width 10 metres.

It leaves the Ebro at Amposta and passes through two locks before arriving at the sea; at the first of these there is a fall of 1·50 metres, and at the second, which is in the Port of San Carlos, there is a fall of 2·20 metres. The canal is nourished by a smaller one, led out at Cherta, 29 kilometres above Amposta. This second canal also irrigates the Delta of the Ebro; its level, in the basin of Amposta, is 4 metres above the sea canal.

Ample means thus exist for flushing the channel and keeping the locks clear of deposit, which, nevertheless, forms to a considerable extent.

The sea entrance is led into the gulf by dykes which direct the flushing, and thus increase its effect. From what has just been stated, it will be evident that this kind of canal would be applicable only where there is so rapid a fall in the river near its outfall as to give the required head of water within a reasonable distance. On the Danube, for instance, even if the canal would admit vessels frequenting that river, which it would not, no means exist for forming an alimentary canal furnishing the means of flushing.

When the river is low, and that generally happens when the navigation is most active, there is a difference of barely 3 feet in the level on a length of 50 miles; and the ground to be traversed by an alimentary canal is a swampy marsh intersected by lakes, through which a canal could only be led at a great expense. Again, then, let it be said, that local conditions must decide the choice of works; and though a canal, of dimensions sufficient for river craft, and fed by a canal at a high level, may have been opened on the Ebro, it affords no argument in favour of a similar work elsewhere, where the same conditions do not exist.

There can be no empiric cure for river bars; the remedy for the evil must be sought by patient study and examination of the locality where it exists, and founded on a consideration of all the disturbing causes, winds, currents, and quality of water, so different on different coasts and even at different points of the same coast.

Having now considered generally the causes that lead to the formation of bars across the mouths of rivers discharging their waters into tideless seas, and the systems of improvement that have been applied to certain rivers in Europe, the author will next proceed to give a detailed account of the works which have been carried out at the Sulina mouth of the Danube. It will, however, be necessary first to give a short sketch of the considerations other than technical, which are involved in the improvement of this river, which alone will account for works having been carried out in that branch of it which has been generally admitted to be the least suitable for navigation, and for the temporary character of those works.

Prior to the year 1829, the mouths of the Danube were held by the Turks, and it is said that under their direction every vessel leaving the river was obliged to tow a heavy rake to sea over the bar, so as to raise the sand, and let it be carried by the current away from the channel. It is even said that, in consequence of this treatment, there used to be a depth of 14 feet on the bar. These assertions are not worthy of much belief; no written record is in existence establishing their accuracy, and a strong reason exists for disbelieving them, which will be presently mentioned.

From 1829 till 1854 the Russians had possession of the Delta of the Danube, and in 1840, the navigable channel having become very shallow, the Austrian Government called upon Russia to take steps for improving it. A convention was signed, by which Russia engaged to keep a steam dredger employed in removing the sand which had encumbered the channel. This dredger worked but at rare intervals, and constant complaints were made against Russia for not keeping open the channel, which went so far as to accuse her of not only not trying to remove the obstacles, but of adding to them by sinking vessels in the channel. It was at this time that the condition of the river under the Turks was held up in contrast to its state under the Russians, and the power of the rake was so much insisted upon.

After the Crimean War, the free navigation of the Danube having formed one of the principal preliminaries of peace, a special arrangement for its proper administration was stipulated for in the Treaty of Paris, and the improvement of the mouths of the river was confided to a Commission, in which the Seven Powers who signed the treaty were represented, each by a delegate.

This commission, of which the author of this paper is the British member, entered upon its duties in November, 1856, and has ever since remained in office. Its principal duties were to free the mouths of the Danube from the obstacles that hindered their navigation. It may be mentioned here, that before the Russian occupation of the Danube, in 1829, the trade of that river was very insignificant. By the Treaty of Adrianople, the Russians secured to the principalities a right which they had accorded to them during their occupation, of freely exporting their grain, which was previously a Turkish monopoly.

From this time the Danube trade went on gradually increasing, until the abolition of the English Corn Laws gave it a great impulse, as shown by the exports of 1847, which bounded up to more than 1,800,000 quarters from 1,200,000 quarters in 1846, and from 230,000 quarters only in 1837. Since 1847 the trade has steadily increased, excepting in the years affected by the Hungarian Rebellion and the Russian War.

One of the first cares of the Danube Commission was to seek for means of temporary improvement, whilst a proper study of the river was being made to ensure the proper application of permanent works. In the spring and summer of 1857, a full trial was given to the dredging and raking systems during a strong current, when, if ever, they should be successful.

A heavy iron harrow was towed over the bar from 50 to 80 times a day for two months, on as many days as the weather, which was generally fine, permitted; at the same time, a powerful steam dredger was at work in the channel, but their united efforts did not do more than increase the depth by about 6 inches, and when the flood current became weak even this much was lost, and the raking and dredging discontinued.

The rake only scratches up the bottom, but does not raise the mud and sand into the current. Near the bottom the current is feeble, and sometimes even running inwards, if, then, a rake passing 50 to 80 times in the day produced no effect, how could the vessels going to sea, which before 1829 did not number as many per month, deepen the channel 4 or 5 feet? One practical question, moreover, has never been answered, how did the rake get back again? For there were no tugs in those days, and the rake was too heavy for a boat to take on board or tow back. The intermittent working of a dredger in the open sea may be also set aside as unequal to the task of deepening a channel over a bar exposed to all the prevailing winds, for the channel dredged to-day is filled up by the swell of to-morrow, as the experience of 1857, at the mouth of the Sulina, fully proved. In the course of 1857, surveys of the different branches of the Danube, forming its Delta, were made, and reports received by the commission from their own engineer, Mr. Hartley, an English civil engineer, and an engineer sent by the Russian Government, to aid their commissioner.

A strongly pronounced division of opinion ensued, the majority of the commission desiring to improve the southern channel called the St. George, according to the project of Mr. Hartley, the minority aiming at the improvement of the Sulina, the central and smallest branch, upon the recommendation of the Prussian engineer, M. Nobiling.

The researches of Mr. Hartley had established that of the three branches traversing the upper part of the Delta, the northern or Kiliah branch contains $\frac{17}{27}$ths of the volume of the river, the St. George's, or southern branch, contains $\frac{8}{27}$ths, and the Sulina $\frac{2}{27}$ths of it. The current of the river varies from one knot to three knots an hour; it has been known to be as high as four knots an hour, but that was for a very short time; the usual current is from one-and-a-half to two knots.

On two points unanimity of opinion existed, namely, in the rejection of the Kiliah branch, which, discharging by five different mouths forming a minor delta, offered no hope of success; and in the adoption of the parallel pier system, as best adapted to the local conditions of the coast.

As unanimity of opinion was necessary, the points in dispute, after a discussion of five months, were referred to the governments, and by a portion of them submitted to the examination of another commission.

During the delay that seemed inevitable, the Danube Commission considered it advisable to give a temporary relief to the navigation by opening a passage through the bar at the mouth of the Sulina.

With this object it called upon Mr. Hartley to give a project for works to obtain an additional depth of two feet for a space of five or six years, that could be rapidly constructed at a cost repayable by the navigation in the interval likely to elapse before the permanent works should be open to trade.

This sum was estimated at about £40,000, and a project for that amount was submitted by the engineer and approved, the engineer stating, however, that he did not think it likely any appreciable improvement would be obtained with the limited extension given to the piers which he recommended, but that with an expenditure of £80,000, he believed that success would be almost certain.

He proposed to construct his piers of cribs filled with stones, and connected with strong piling. In the absence of any experience of works on the coast, and in view of the frequent bad weather, Mr. Hartley thought that this system could be carried out with more rapidity, with fewer obstructions from bad weather, and at less cost than any other.

Experience did not justify his predictions, but his skill speedily turned that experience to account, and produced a work that has more than answered the original intention. It was decided to construct the north pier first, as the prevailing winds blowing from the north, the south pier could then be carried out under the lee of the other. In April, 1858, the first piles were driven, and no difficulty was experienced in advancing rapidly in the shallow water. At the end of May the first crib was sunk in seven feet of water, at 900 feet from the root of the pier. This crib was formed of beams laid horizontally, and dovetailed into one another at the angles, the cohesion of the structure being ensured by iron bolts and oak trenails passing through the beams and holding them together. The floor was fixed at two feet above the bottom of the sides, that these might settle down into the sands. The crib was successfully sunk, and filled and surrounded with stones; the following day as it was found to be sinking unequally, timbers were added to bring the upper surface above the water, and more stone thrown in, till it seemed firmly bedded in its proper position. On the 6th June a heavy gale came on, and a heavy sea beat on to the crib which was exposed at some distance in advance of the piling; on the 8th the crib was seen to be slowly rising, and at length fairly floated away. As soon as the storm ceased it was recovered, and examination showed that the workmen had neglected to bolt the timbers together as directed, the sides only having risen, leaving the floor weighted down by the mass of stone. This, the only failure in the whole course of the works, is mentioned here as it led to the construction of cribs of a more solid description, as shown on Sulina Detailed Drawings No 1, where it will be observed that the horizontal beams are tied and bolted together by bolts through them, and straps round them, whilst the frame is still further strengthened by cross beams through every second layer projecting beyond the sides, and again bolted and strapped together. On the 4th October, a crib of this description, 30 feet long by 15 feet wide, and $14\frac{1}{2}$ feet high, was sunk in $8\frac{1}{2}$ feet of water, at 1,710 feet from the root of the pier, and up to this crib the skeleton piling was carried before the winter. This crib was successfully floated into position, and rapidly filled with stones and sunk; it was surrounded on the same day by 100 tons of large stones to protect it against the scour of the river current. During the four following days the weather was too stormy to admit of more stone being deposited, and in this interval the scour caused it to sink unequally at the four angles from 2 ft. 9 in. to 5 ft., or on an average 4 ft. On the fifth day a further 150 tons of stone was thrown down, and the crib was built up to the intended level of the pier. After finding its bed it never changed or sunk further, and most successfully resisted all the storms of the winter, acting as a buttress against which the waves broke, and thus so well protecting the unfinished skeleton piling, that no injury was sustained by the latter during the many months that elapsed before work could be resumed.

Sulina Detailed Drawings, No. 1.

The piling was carried out as follows:—

Stage piles were driven from a light flat bottomed barge on which a ringing engine with a 5-cwt. monkey was fixed. On every available fine day the stage piles were driven on the line of the pier, keeping 100 feet or so ahead of the work; these stage piles were connected by cross planks on which rested the staging, whence the guage piles were driven by a crab engine and 15-cwt. monkey. The guage piles, in three parallel rows, of which the two outer were 14 feet apart, were driven at intervals of $7\frac{1}{2}$ feet from centre to centre, and were tied together at their heads longitudinally by oak walings, 12 in. × 6 in., inside and out, bolted through and through, and transversely by cross stays 15 ft. × 12 in. × 4 in.; upon these transverse beams rested a roadway of pine planks, and an iron tramway for transport of materials. The guage piles were of pine, obtained from the Carpathian mountains, in fine masts 80 feet long, and $2\frac{1}{2}$ feet diameter at the butt end. The sheet piles were at first of hornbeam, but subsequently of oak, as the hornbeam proved a very indifferent wood for water-works. The outer ends of the pier were constructed entirely of oak, of which fine straight piles 35 ft. × 1 ft. × 1 ft., were obtained from the forests of the Save.

Sulina Detailed Drawings, No. 2.

The original project was to fill in the outer and inner line of guage piles with sheet piling, and to fill the intervening space with stone, throwing down stone outside of each line of sheet piling at the angle it might take from the water line, to protect the foot of the piling from scour by the river current on the inside, and by the beat of the waves on the outside.

In the countries bordering the Danube, great difficulties were encountered in executing works, from the fact that no great works had been carried on there by the present generation, there were, therefore, no good artizans or even common labourers worth the name. Such contractors as were to be found based all their calculations on making enormous profits and fraudulent deliveries. Workmen unaccustomed to regular and fair payment, demanded a higher rate of wages than their labour was worth; the commonest was not to be had under half-a-crown a day, for less than half the work a good English workman would do. The Sulina works have produced quite a revolution in this respect, instead of having to bring workmen from Hungary and Transylvania, as in 1858, the Commission Works are now sought by more men than can be employed, who are ready to do a fair day's work for fair wages, because they have learnt that they are regularly paid to the day, and to the last penny due to them, and that to remain in employment they *must* do the work. The author has no hesitation in saying that the superintendence of English engineers and foremen has brought about this satisfactory state of things.

At first, however, great delay and many difficulties arose from the failures of the stone contractors to deliver stone of the size and quality required in the time stipulated; it thus frequently happened that the piling was far in advance of the stonework, and great scour consequently took place, leading to a far greater consumption of stone than was intended. Only the outer or seaward line of guage piles was therefore sheeted at first, and stone thrown in to protect it.

During the first winter, which gave the structure a severe testing, the works stood thus: 1,390 feet of the pier were sheeted and protected by stone within and without to the level of the water, from thence to the crib the guage piling was unprotected for 320 feet. The heavy break of the sea was in a great measure warded off by the crib but nevertheless there was a considerable attack upon the remainder of the pier; this stood the assault so well that it was resolved to modify the original plan of the piling, and to sheet only the outer line, leaving the stone to take its slope from the water level on that line. The feet of the inner row of guage piles were thus protected from all injurious scour from the river current, and it has been found that, although near the end of the pier, the stone goes down every winter, it is only packed closer down upon the sheet piling by the beat of the waves, and thus each successive filling in, in the spring, is adding to the strength of the pier at but small expense.

The year 1858 gave a further experience, namely, that to give the cribs the necessary strength, their price became much enhanced, whilst the expected rapidity of construction to be obtained from them was not realised, on account of the difficulty of getting them safely into position, and filled with stone, before rough weather came on. The irregularity of the stone supply naturally contributed to increase this difficulty, but even had stone been abundant cribs could not have been sunk with the rapidity anticipated, nor could workmen have been found to build them; moreover, it was found that the piling proceeded with a rapidity beyond the most sanguine expectations, and was limited only by the insufficient supply of stone; it was only when the weather was very bad indeed that the pile engines could not go on with their work. It must be borne in mind that the absence of tides was an important advantage to this system. The cribs proved highly successful as bulwarks against winter storms, but as they were neither economical nor expeditious, their use was given up after the sinking of a second crib in the spring of 1859, and every effort was bestowed on getting forward the piling as quickly as possible. To this end great efforts were made to increase the supply of stone, every block thrown in was brought 50 miles in barges from the Toultcha quarries, which were of hard blue limestone "grauwacke," and a quickly pulverizing schist. It was found necessary to forbid altogether the supply of this latter, as it was not able to resist the roll of the sea, but the contractors naturally preferred to work it, as the most easy.

In the course of 1859, the frequent failure of the contractors enabled the commission to withdraw the supply of stone from them, and the quarrying was then carried on under the direction of their own *employés*, with the double advantage of obtaining the stone at a far less price, and in the quantities required. No serious difficulties were encountered from want of stone after the spring of 1860, by which time the working of the quarries was put on a proper footing. In the autumn of 1859, the north pier had been nearly carried to the extent of the project adopted. As no solution of the St. George's question then seemed probable for some time, and the possibility of finishing the second project without prejudice to the permanent works became apparent, it was resolved to continue the works to the extent of the second project, and the north pier was, therefore, continued without doing more to the south pier than to run out a portion of its guage piles, and to protect them with four feet of stone, in the hope that the slack water to the east would silt up, and thus a large outlay on sheet piling and stone would be saved; a hope that was fully realised.

In the spring of 1860, the good effect of the north pier became apparent in an increase of 4 feet to the depth of the channel. By the month of July, that pier was finished to its full length of 4,380 feet; but the want of the south pier to maintain the increased depth became manifest, and this pier was pushed forward with great rapidity. The weather was generally fine, and as the works were under the lee of the north pier, the swell from the more frequent northerly breezes was not felt, and the very great advance of 1,020 feet was made during the months of August and September—of which 830 feet were carried forward in the month of August—so that by the end of the year the effect of the south pier was already perceptible in an increased depth, which in the spring of 1861 reached 16 feet, on a good broad channel from which it has never gone back, though at times it has been as much as $17\frac{1}{2}$ feet.

In the spring of 1859, an Italian vessel, new, and built of oak, was wrecked in mid-channel of the intended direction of the piers. After several fruitless efforts, by native divers, to get a charge below her keel, a diving dress of Heinke's pattern was purchased, which has been found most useful; by means of it, successive charges were lodged under this wreck, during the years 1860-61, and she was thus completely destroyed to a depth of 18 feet.

In the autumn of 1860, it was decided to extend the piers beyond the length projected, and they were completed to the lengths, respectively, of 4,640 feet in the north pier, and 3,000 feet in the south pier, during the spring and summer of 1861. The north pier has been sheeted (both inside and outside) on lines of guage piles for 40 feet, and the interior filled in with stone. The stone footing, seaward, has been formed of the largest blocks of stone that could be obtained, and every year its base widens by the subsidence of the stone which is constantly thrown in to keep it at the level of the water.

Taking the whole length of the pier, this subsidence is very inconsiderable. After the storms of last winter, 1,600 cubic yards of stone sufficed to make good the sinking. At certain points in the length of the north pier, the sea was observed to break with more violence than at others; these portions were, therefore, strengthened by enclosing a solid block of 30 or 40 feet of pier with sheet piling and filling it in with stone. At certain intervals, too, the space between the inner and outer piles was sheeted to check the enfilading roll of the heavy seas as they curled round the pier-head, and the displacement of the inner pile of stones was thus prevented.

At the head of the north pier a small timber light-house was built on piles driven through, and forming part of the "musoir," in which a light is kept during all but the winter months, when the pier becomes a solid mass of ice, which cuts off the light-house from assured communication.

The immense weight of ice thus heaped upon the pier has, up to the present time, never seriously damaged it. The head of the south pier is formed of a large crib which presents a solid mass on which the waves break harmlessly; it is, of course, well protected with stone.

The mode of construction and the changes introduced from time to time both in it, and in the extent of the piers, having been now explained, a general idea will be given of their direction, and of the gradual growth of the channel produced by them.

The north pier is a continuation of the left bank of the river. It is 4,640 feet in length, and is carried out to what was the 16-ft. line before the works were begun in 1858. The pier runs east for 2,250 feet; thence it curves slightly to the north for 1,550 feet, on a radius of 6,000 feet; and the remaining 840 feet of its length runs E. by N. ½ N.

The south pier springs from the lip, forming the right bank of the river, at a point due south of the 1,900th foot of the north pier, which it approaches on a curve of 2,400 feet radius, for 2,400 feet, when it arrives at a point 600 feet from the north pier, to which it then runs parallel for 600 feet, leaving the latter to project 650 feet beyond it.

By the autumn of 1859, the north pier had attained a length of 2,700 feet protected by stone, the timber work being some 300 feet further out.

The south pier had, by that time, been carried out only in frame work without sheet piling or stone for 1,300 feet, and, therefore, exercised no effect on the current. At this stage of the works, the theory of an Austrian engineer, Mr. Wex, that only one pier was needed to remove the bar, seemed about to receive confirmation; for, in the spring of 1860, there was a narrow channel of 15 feet, and a good broad channel of 14 feet deep.

The spring and summer floods of 1860, however, quickly dispelled any illusion on this subject; for although the north pier had become 4,500 feet long by the beginning of August in that year, and the south pier, in skeleton, had reached the deep water, the old bar had speedily reformed in its old position, and there was a channel of barely $8\frac{1}{2}$ feet. The object of carrying out the north pier first had been to gain shelter for the works on the south pier against the swell raised by the prevailing wind. As the north pier was now nearly at its full length it was decided to fill in and extend the south pier energetically; and, by the end of 1860, this had been so well done that the timber frame-work had a length of 2,700 feet, of which 2,350 feet were solid, with the exception of 450 feet near the root, left open as above stated for the escape of flood waters.

The effect of the south pier became apparent as soon as it reached the channel; at the end of September, 1860, when it began to take a direction parallel to the north pier, the depth had increased to $9\frac{1}{2}$ feet, in November to $11\frac{1}{2}$ feet, and by the end of the year to 13 feet.

The early spring floods, which were in 1861 of unusual violence, gave a channel of 16 feet, which reached $17\frac{1}{2}$ feet when the piers attained completion in the month of August, 1861.

The detailed drawing, No. 2, shows piles outside both the inner and outer guage piles; these are oak piles which have been driven since the completion of the piers to increase their strength and durability, and to prevent any ill effects that might arise from the guage piles of pine perishing.

The advantages possessed by these works may be stated as:—

1. Their fitness for the object sought, as proved by their success.

2. The rapidity with which they can be extended to remove any serious shallowing of the channel.

3. Their cheapness; their section having been found to be amply sufficient to resist, not only the shocks of the sea, but very heavy collisions with vessels which have been driven upon them, and yet their first cost has only been £10 a foot forward in 16 feet of water.

It may be interesting to those who have accompanied the author thus far in this subject, to know what works have been proposed for the permanent improvement of this fine river.

The narrow and shoal channel of the Sulina above the lower 18 miles of its course, and the broad deep channel of the St. George throughout its whole length, together with the greater depth and more rapid slope of the sea bottom in front of its embouchure, have not allowed engineers and sailors to hesitate between the two rivers; they have declared unanimously in favour of the St. George, which would long ago have been opened but for the political considerations which were involved in it at first, and which, always resting professedly on engineering and financial reasons, have of late been strengthened by a division of opinion upon the system of works to be carried out.

The Commission of Engineers appointed to examine the technical question, whilst entirely in favour of opening the St. George, pronounced in favour of a lateral canal, leading from a point above its mouth into the sea to the north of the embouchure.

The opinion of those acquainted with the localities founded upon the examples, cited in the first part of this paper, is entirely opposed to the formation of the canal, and a long suspension of the permanent works has, consequently, taken place. It is probable, however, that a decision will before long be arrived at upon this subject.

APPENDIX.

TABLE SHOWING THE WEATHER AT SULINA.

Year.	Total of Days.	Fine Days.	Moderate Days.	Stormy Days.	Period.
1858	234	$60\frac{1}{2}$	$104\frac{1}{2}$	69	From 21st April to 31st Dec.
1859	365	$74\frac{3}{4}$	$183\frac{1}{2}$	$106\frac{3}{4}$	— Jan. — Dec.
1860	366	$143\frac{3}{4}$	$127\frac{1}{4}$	95	— Jan. — Dec.

ADDENDA.

With reference to the concluding remarks on the effect of piers at the Sulina entry in the former part of the preceding paper, the author is desirous to give the experience gained during the last nine months, which is instructive.

In his paper (concluded and revised in September, 1863), he mentioned the absence of floods in 1863, and the consequent feebleness of the current, which had given rise to the formation of a bank in a position where it was not expected, but whence it would be easily removed by the first floods.

The correctness of this anticipation has been proved this spring. As 1863 advanced, the river became lower and lower, the current ever feebler, till it barely reached a quarter of a knot per hour. The bank between the pier heads grew up to within 14 feet of the zero level, except in a very narrow channel; but to sea-ward of the north pier, there was no filling up. In March of this year the river began to rise, and the current to increase.

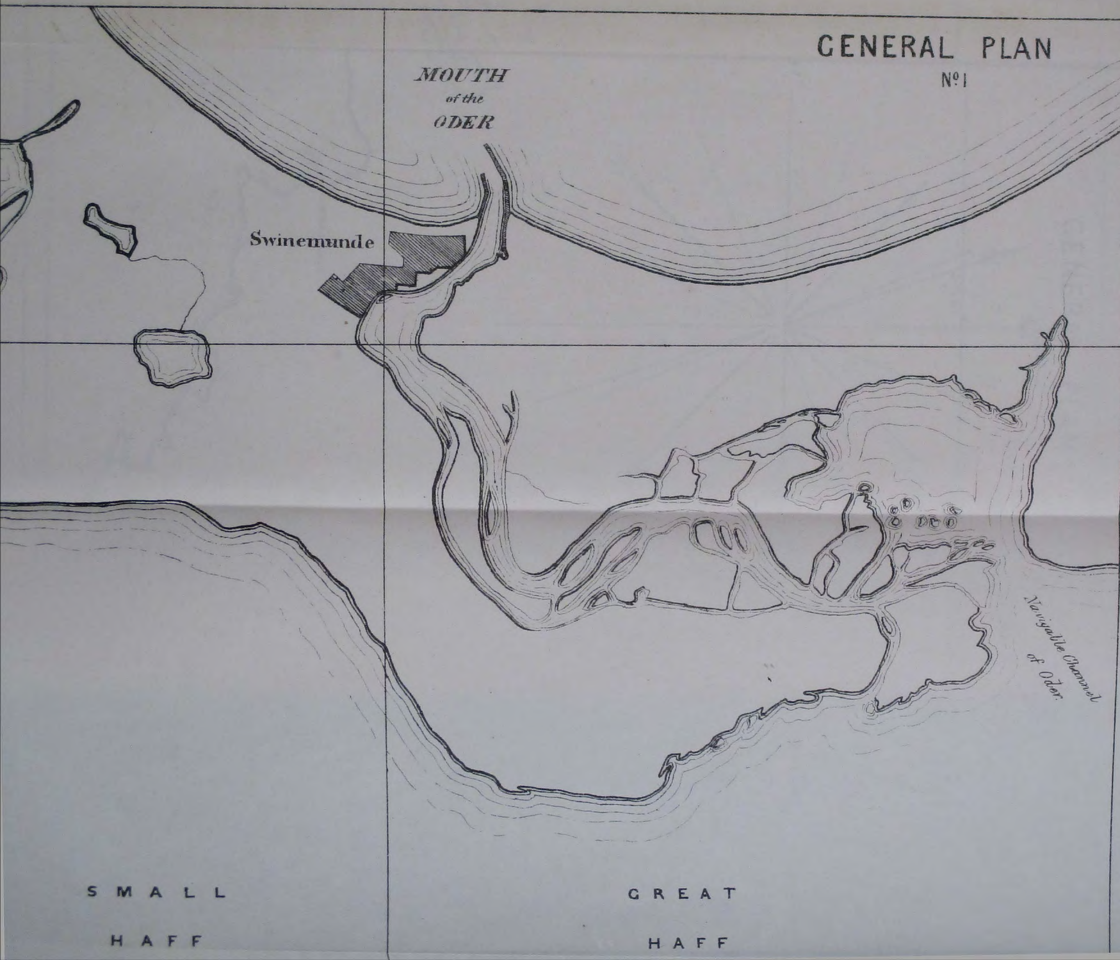
The effect on the entry was immediate, and in less than a month there was again a navigable channel of 15 feet deep, which by the first week in May was increased to $15\frac{1}{2}$ on a width of 150 feet, and the shoal of 13 feet, on a length of 700 feet, reduced to one of 14 ft. on a length of 150 feet.

This large slice of shoal was not taken off to be deposited again in front of the piers, for the 15 and 18 feet lines are still where they were. The surveys of 15th February, 1st April, and 6th May,* shew the improvement due to the current, and how little deposit has formed outside, although the waters have for the last two months been thick with alluvial matter.

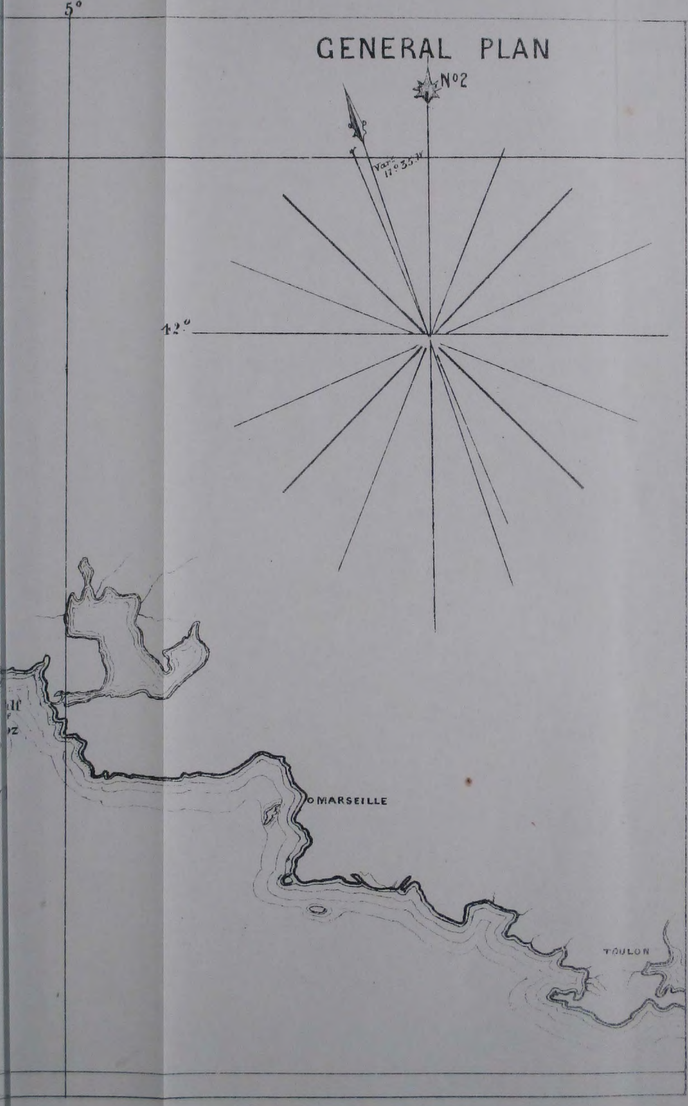
The floods, although considerable, have not exceeded an average height, and therefore the current has rarely exceeded, and not often reached, two knots an hour at the mouth; otherwise a greater depth would doubtless have been obtained.

The experience of the last three years has shewn, that any bank formed outside is speedily broken down by the waves in the frequent gales from the N.E., and their substance carried away southwards by the littoral current; whereas, a shoal arising from the feebleness of the current at the point where the parallel-

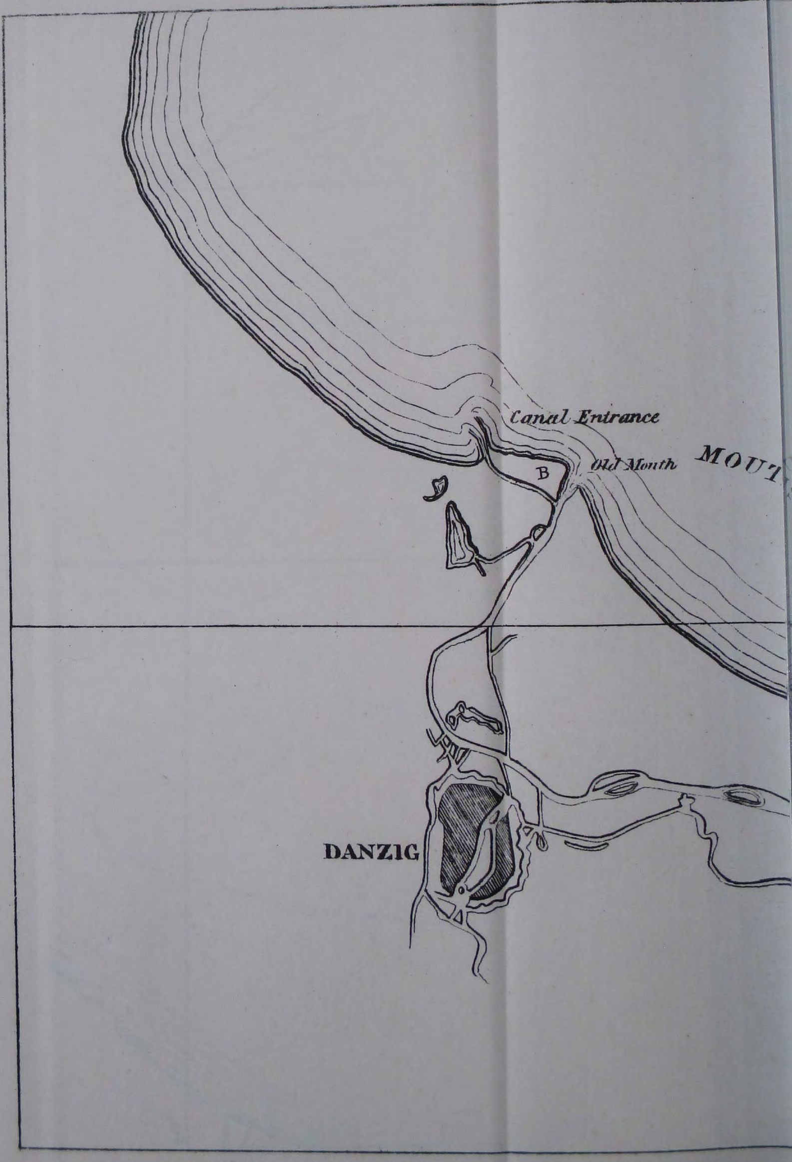
* See last three plans.

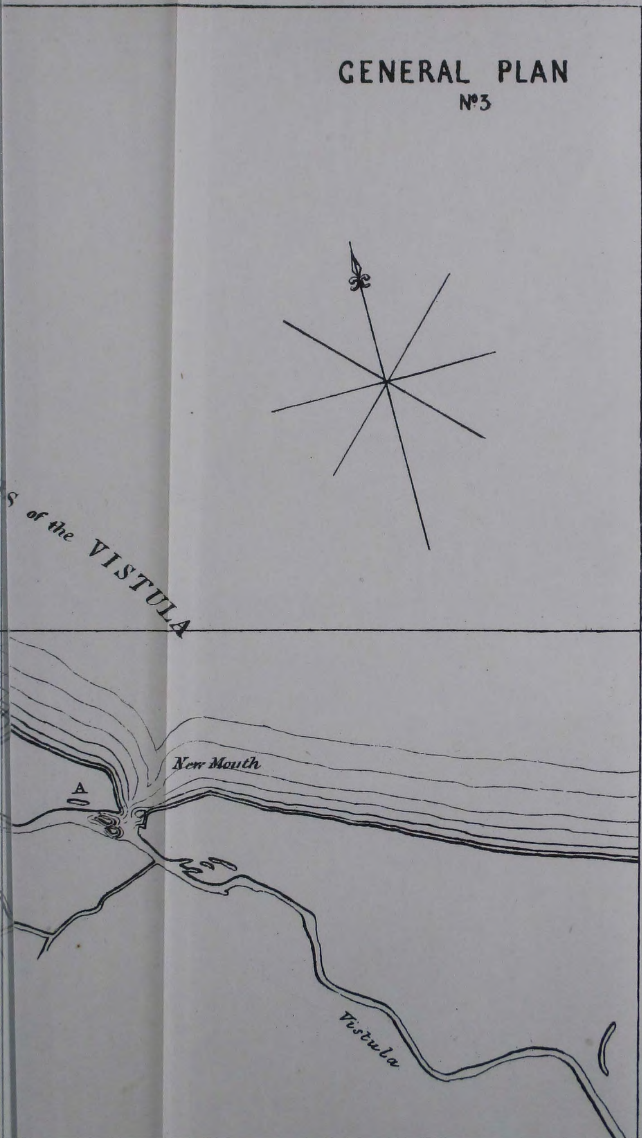

GENERAL PLAN
No. 1
MOUTH
of the
ODER
Swinemunde
Navigable Channel
of Oder.
SMALL
HAFF
GREAT
HAFF

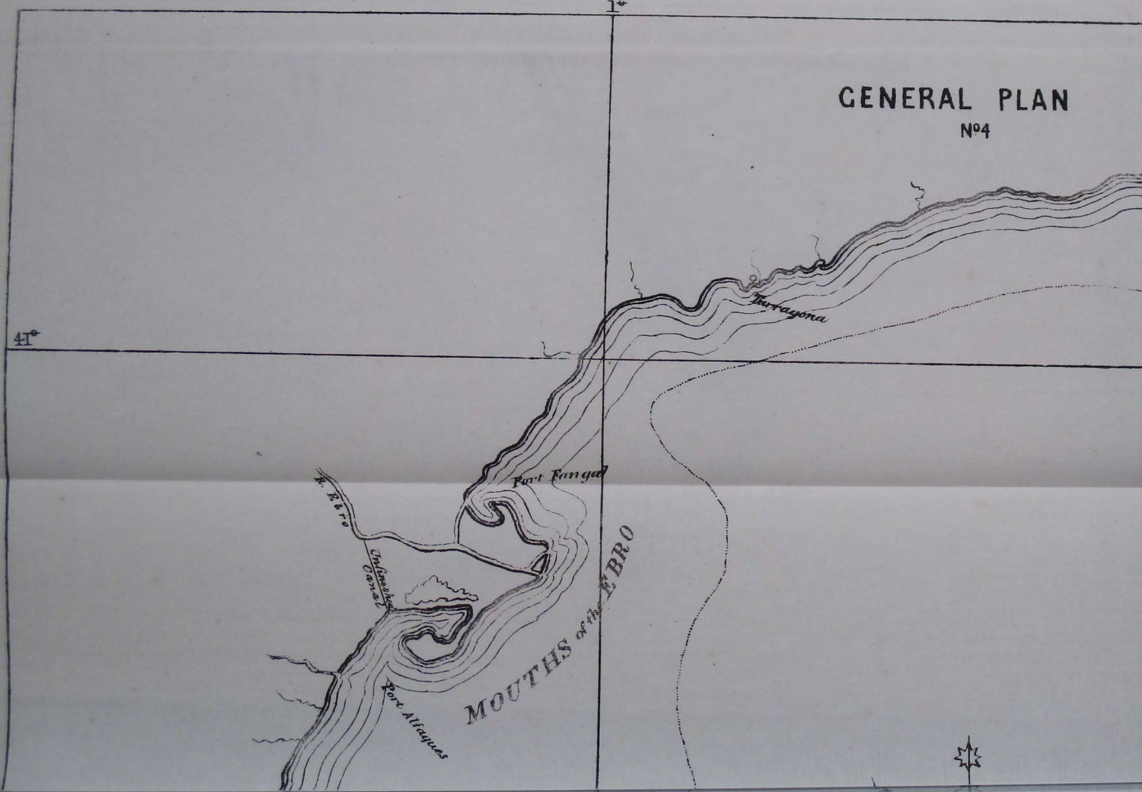

4°
44°
43°
CETTE
Petit Rhone
R. Rhone
MOUTHS, of the
GULF of LYON



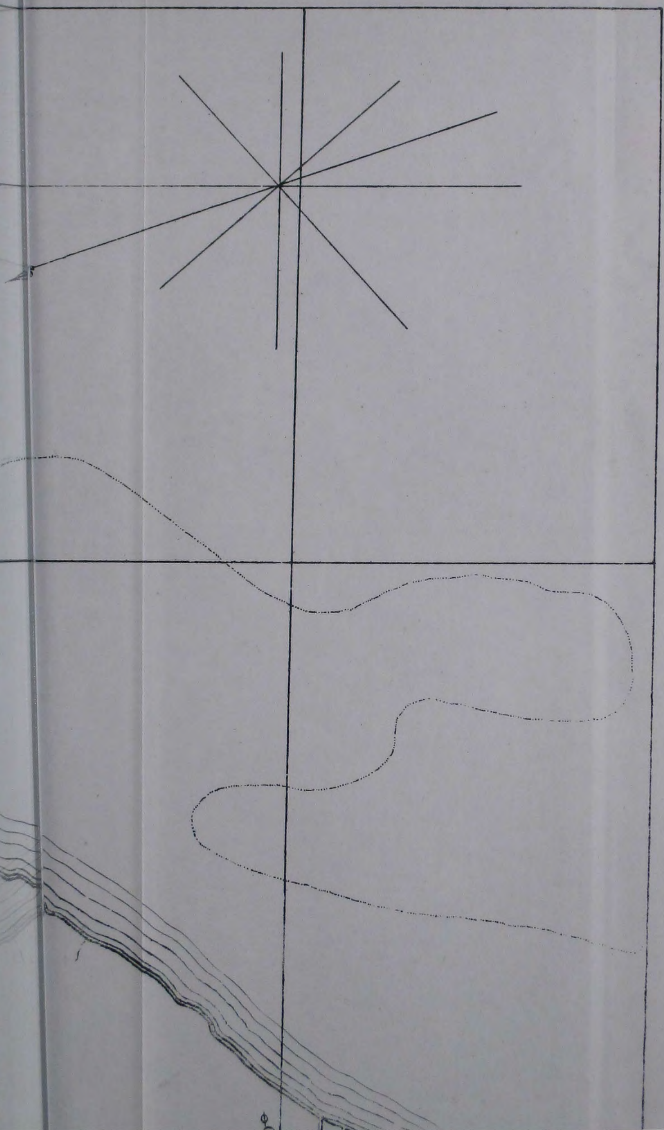
GENERAL PLAN
No2
Varn 17° 35' W
5°
42°
MARSEILLE
TOULON

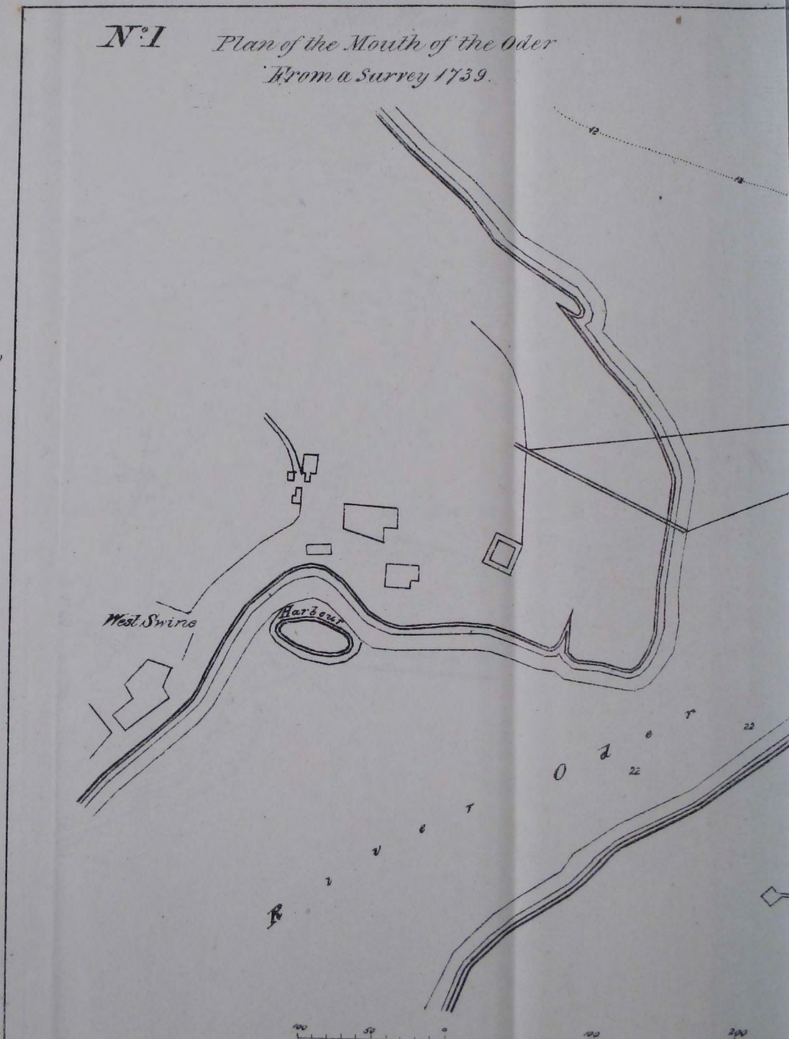

Canal Entrance
Old Mouth
MOUT
B
DANZIG


GENERAL PLAN
Nº3
S of the VISTULA
New Mouth
A
Vistula

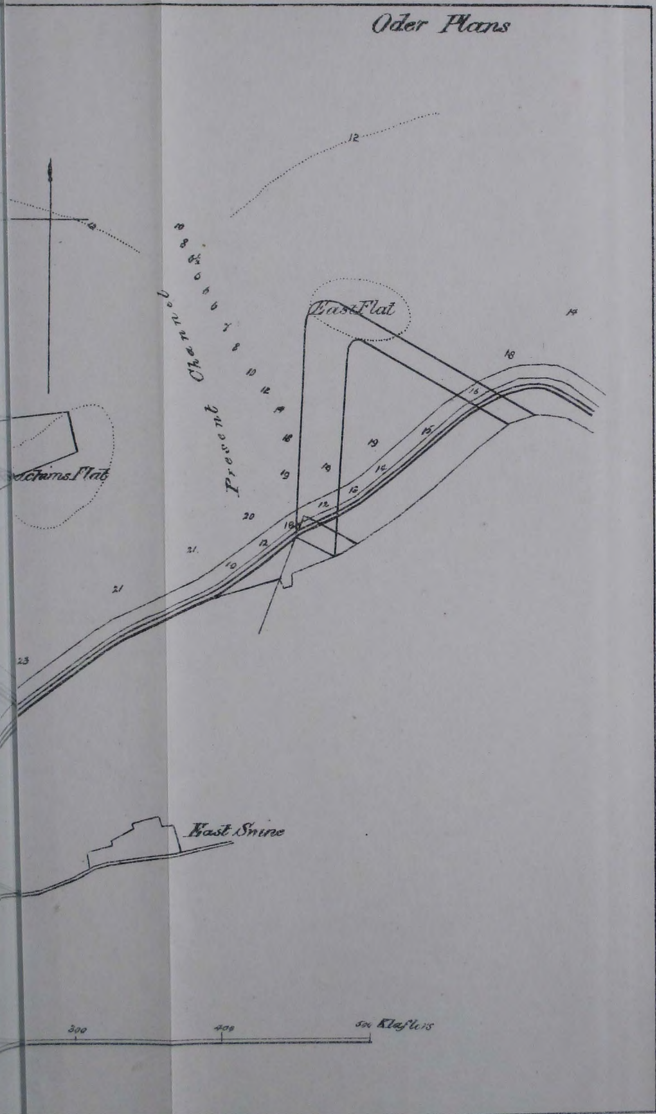


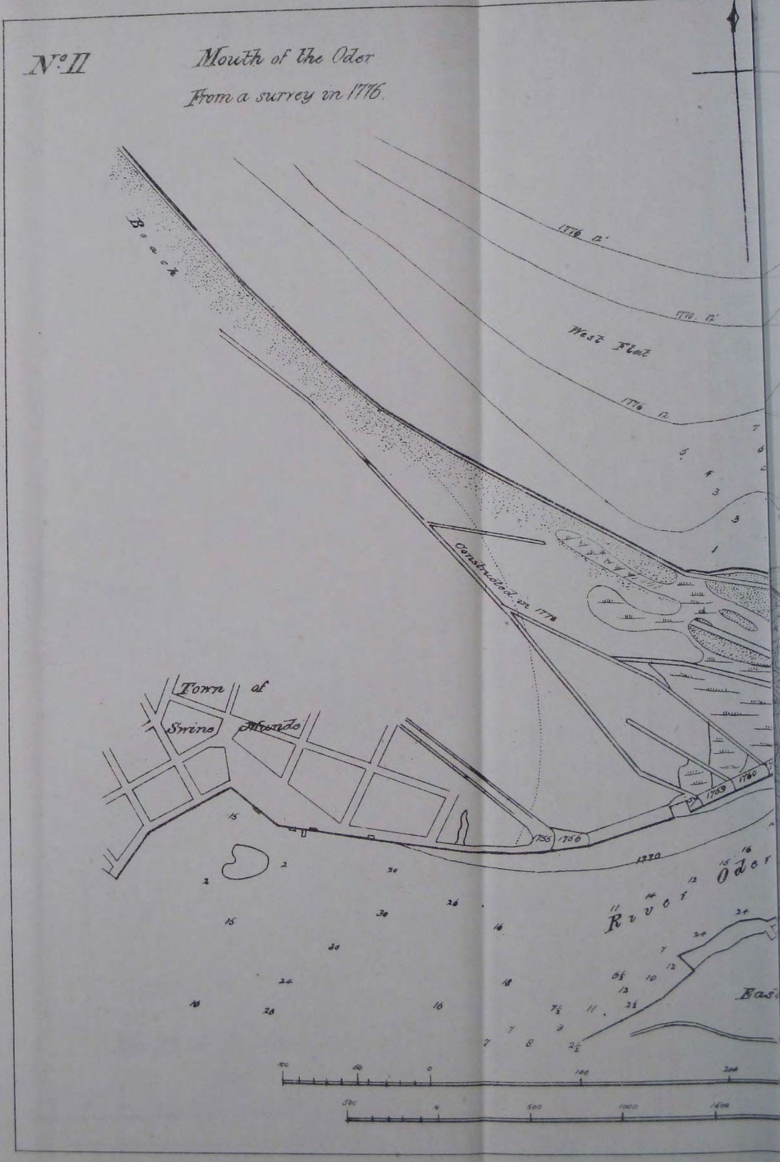
GENERAL PLAN
No 4
1°
41°
Tarragona
Port Fangal
R. Ebro
Unfinished Canal
MOUTHS of the EBRO
Port Alfaques



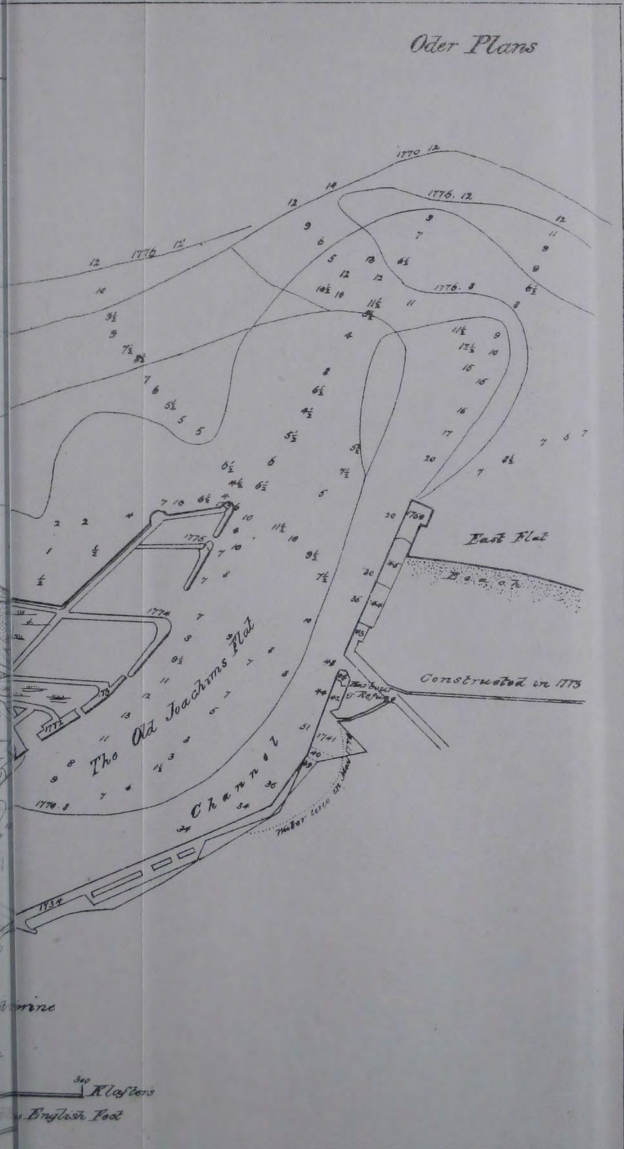


N.º 1 Plan of the Mouth of the Oder From a Survey 1739.


Oder Plans
12
12
Present Channel
8
8
8½
6
6
6
7
8
10
12
14
18
19
20
21.
21
23
East Flat
14
18
16
15
19
14
18
16
12
18
12
10
...ochims Flat
East Swine
300
400
500 Klafters

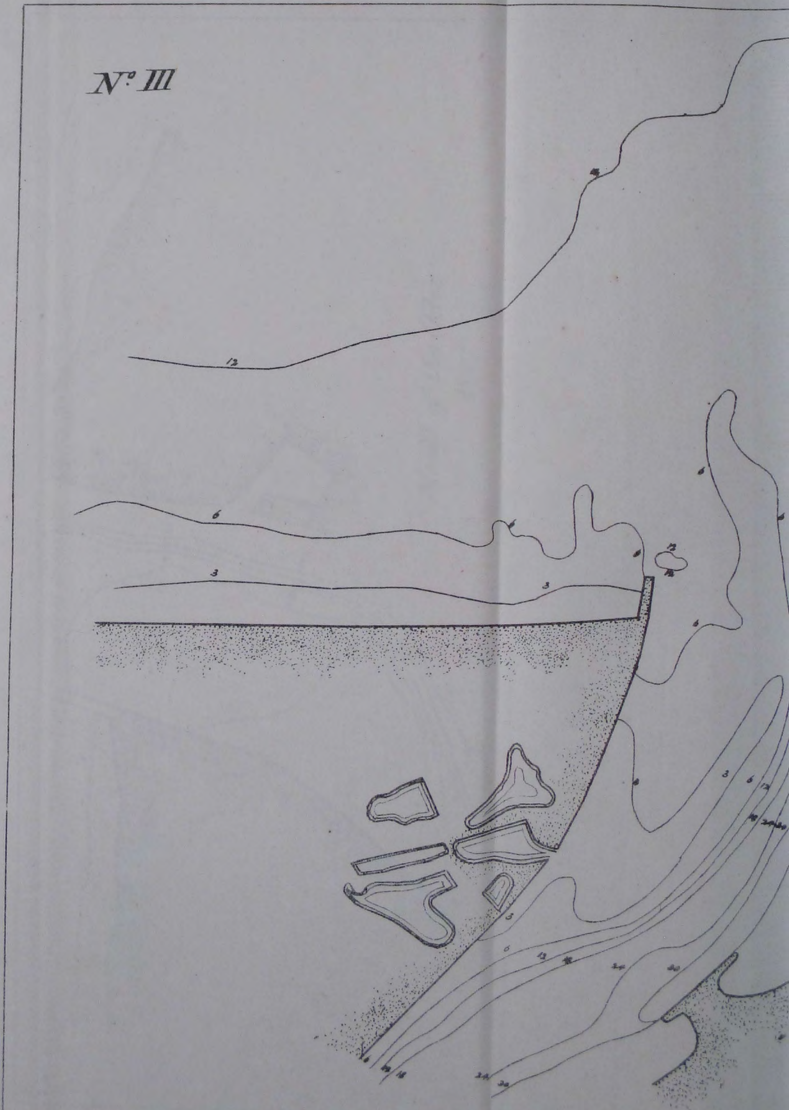


N.° II
Mouth of the Oder
From a survey in 1776.
Beach
West Flat
Constructed in 1778
Town of
Swine Munde
River Oder
East
1755
1766
1759
1760
1770

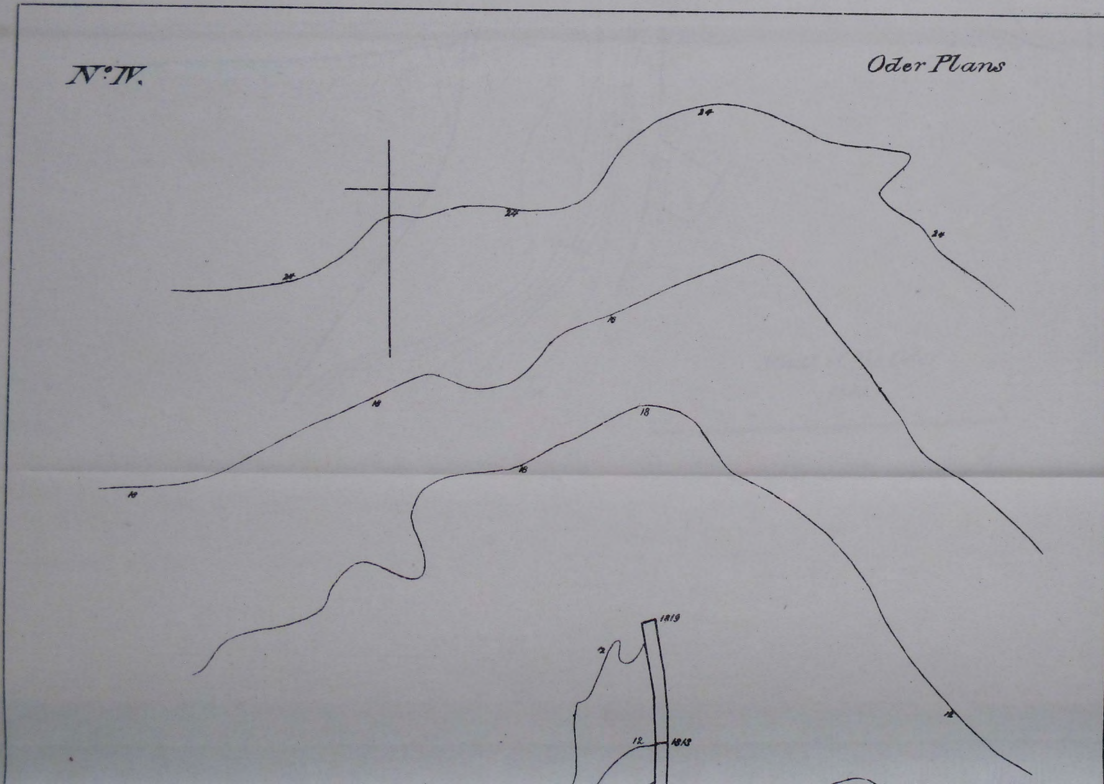


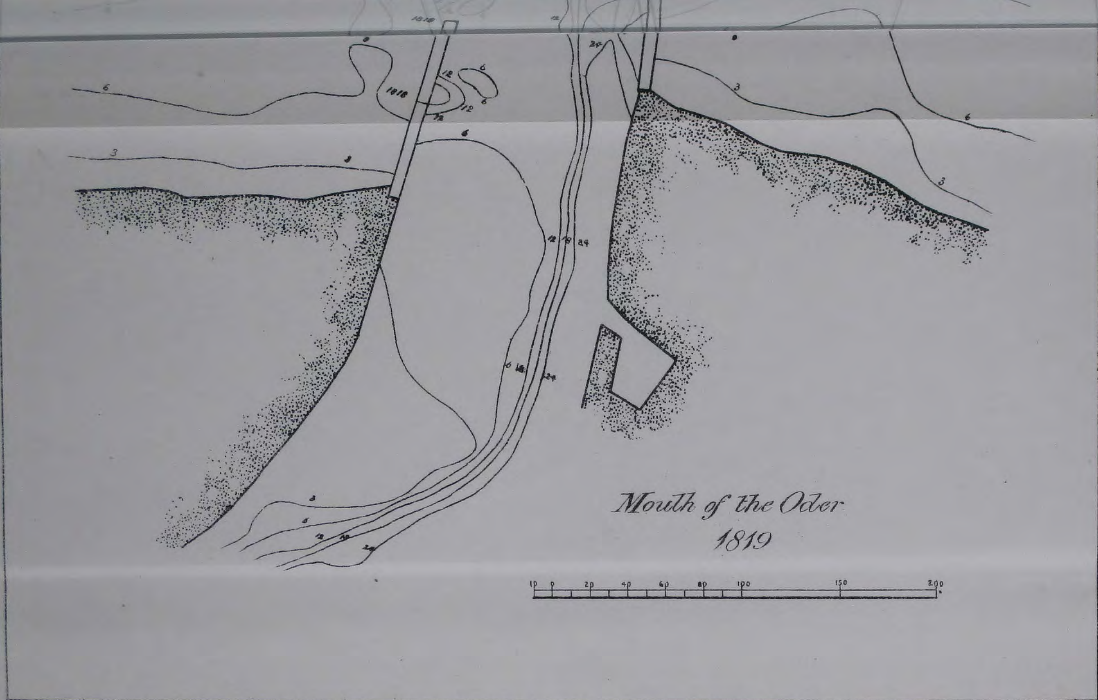
Oder Plans
East Flat
Beach
Constructed in 1773
Harbour of Refuge
The Old Joachims Flat
Channel
Water line in
Klafters
English Feet

Nº III



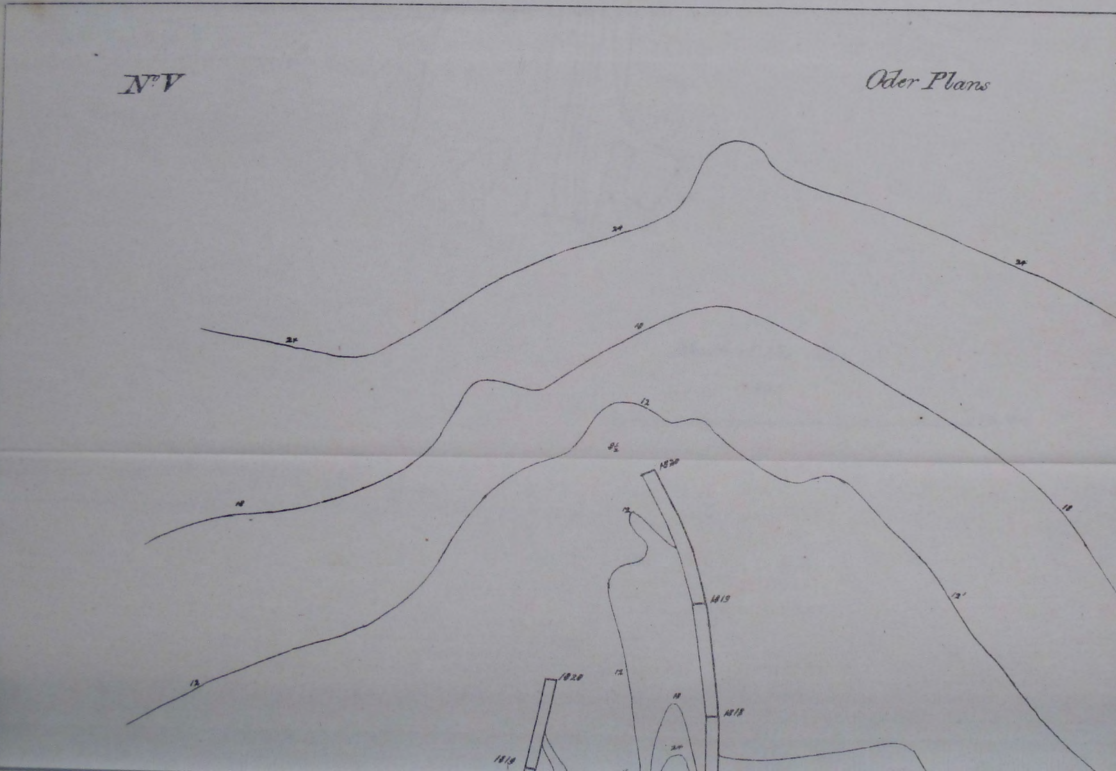
Oder Plans
Mouth of the Oder
1816

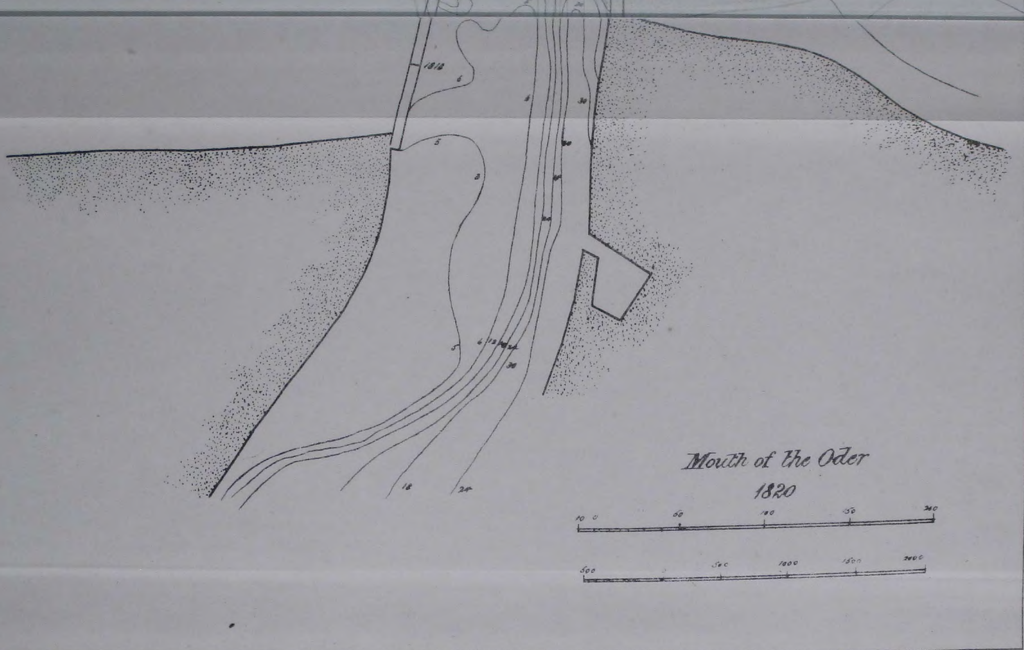

N° IV.
Oder Plans
24
24
24
24
18
18
18
18
18
12
1819
12
1813
12


Mouth of the Oder
1819
10 0 20 40 60 80 100 150 200

No. V

Oder Plans

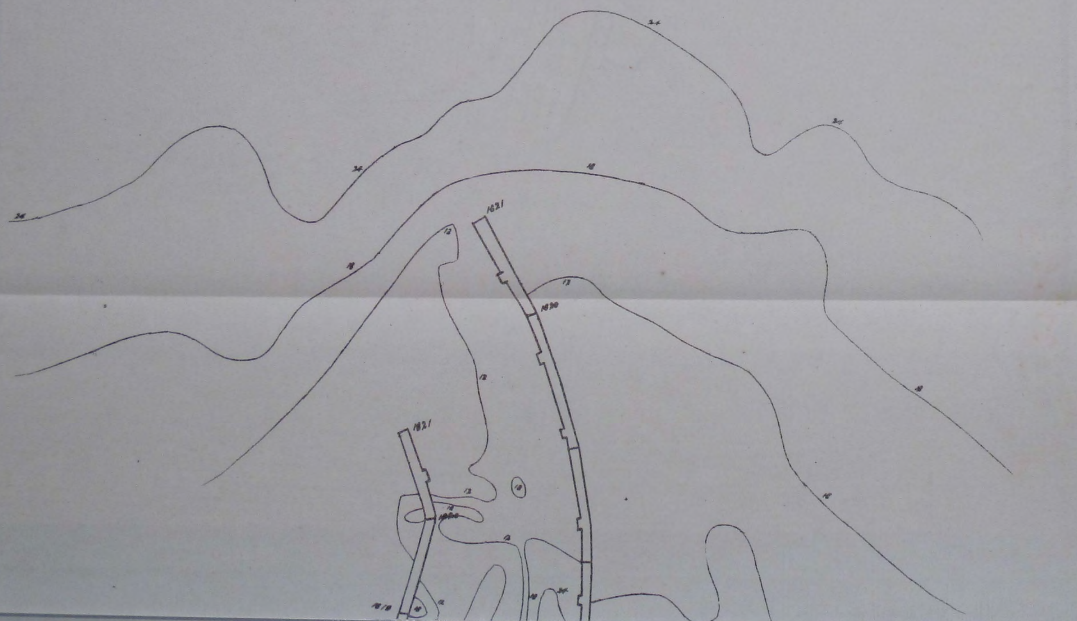




Mouth of the Oder
1820
1812

N° VI

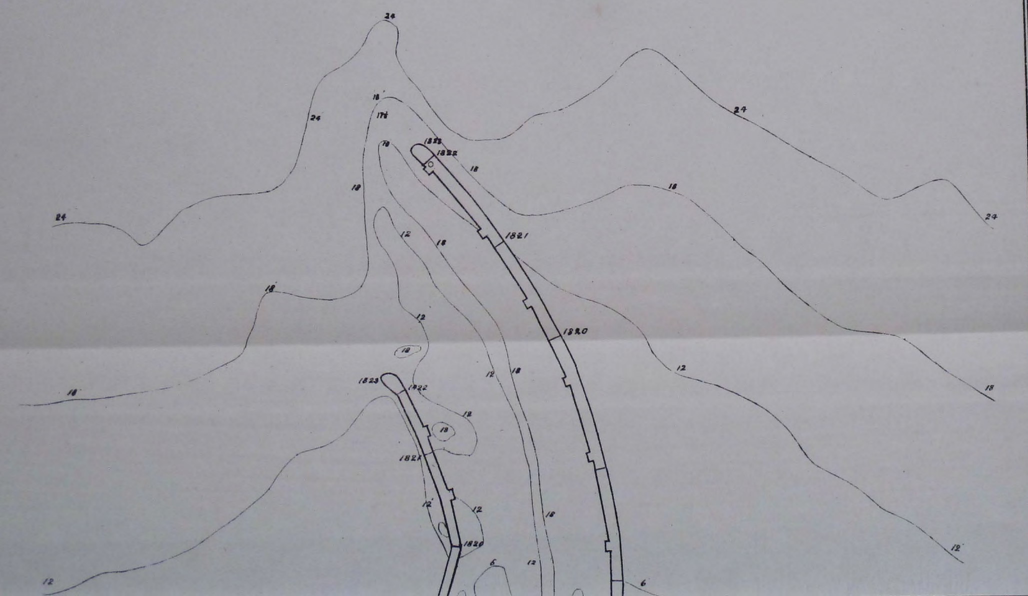
Oder Plans

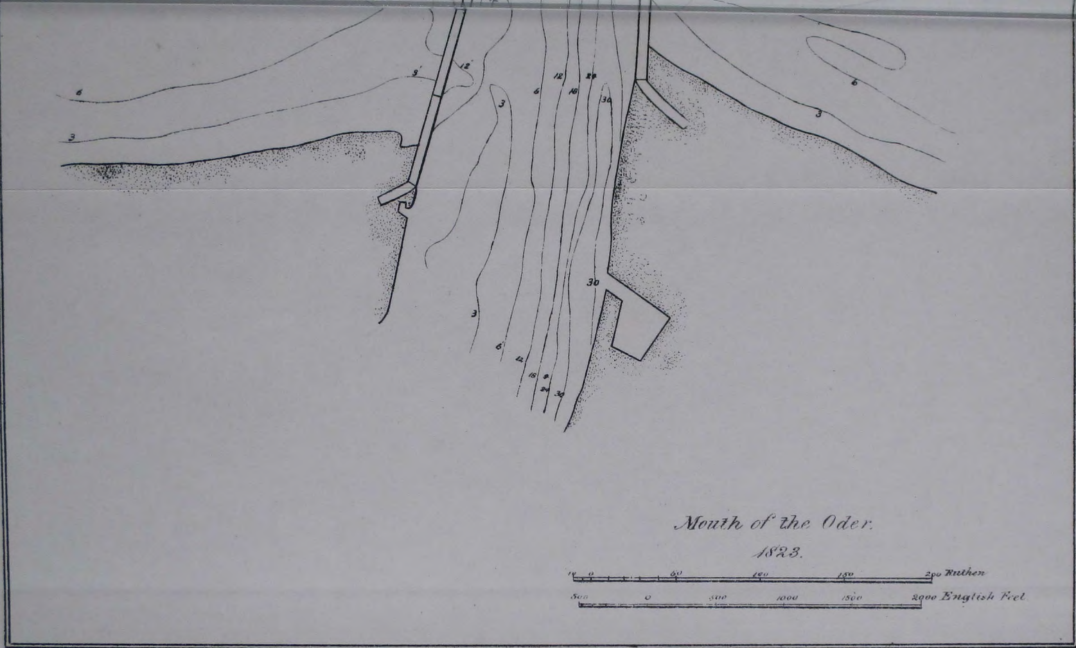



Mouth of the Oder
1821
Klafters

No. VII.

Oder Plans.



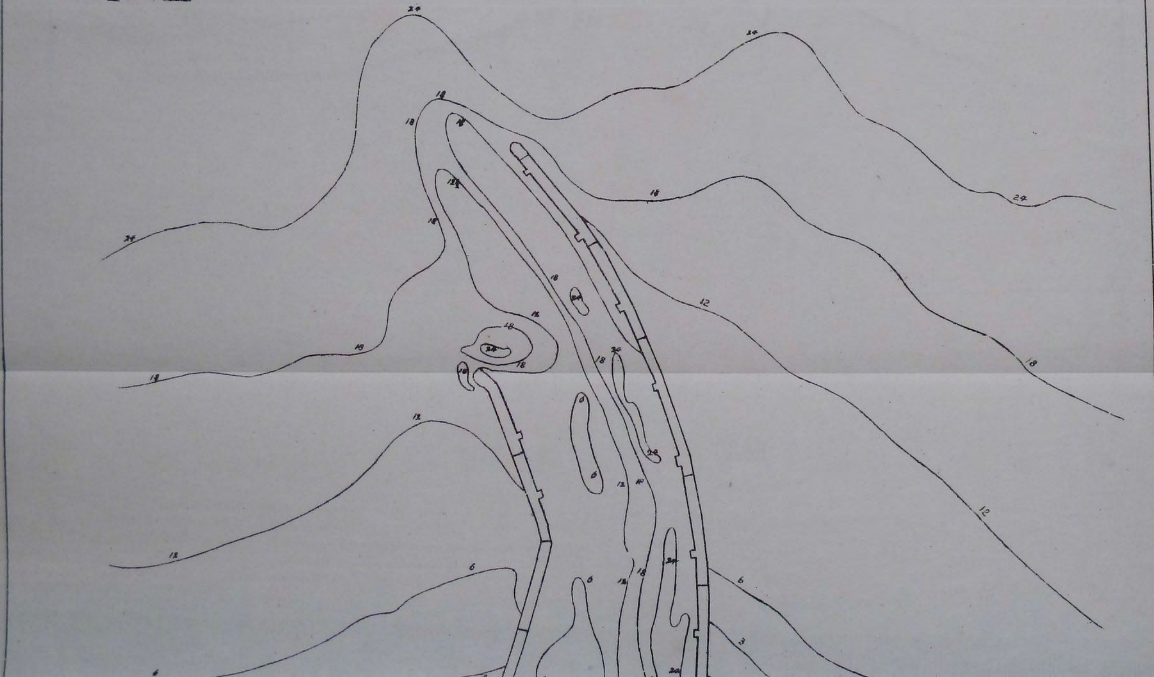


Mouth of the Oder.

1823.

N° VIII

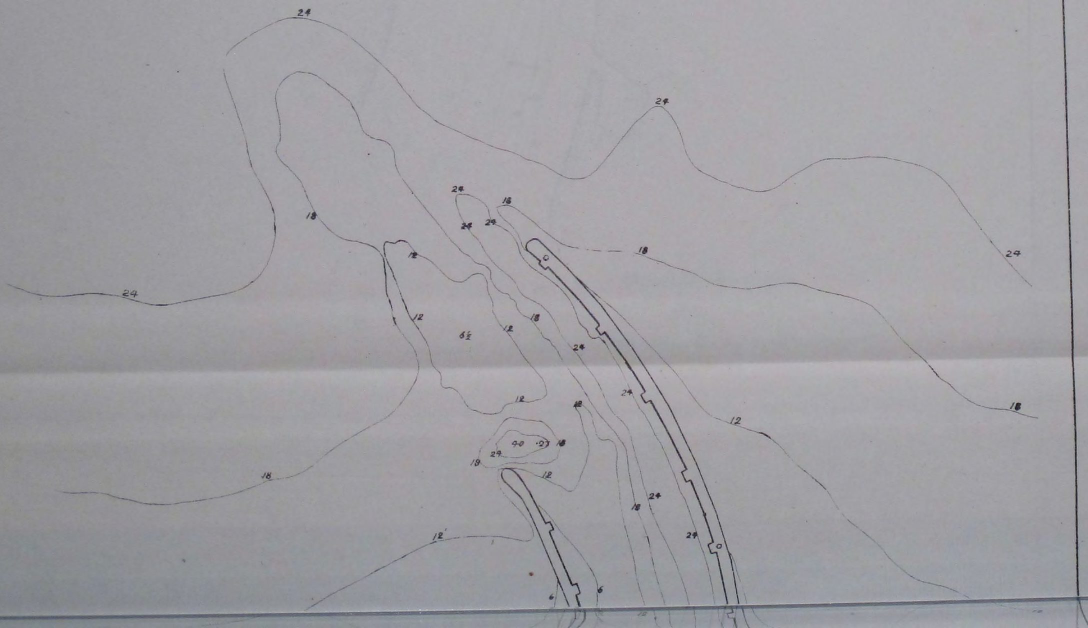
Oder Plans




Mouth of the Oder
1825

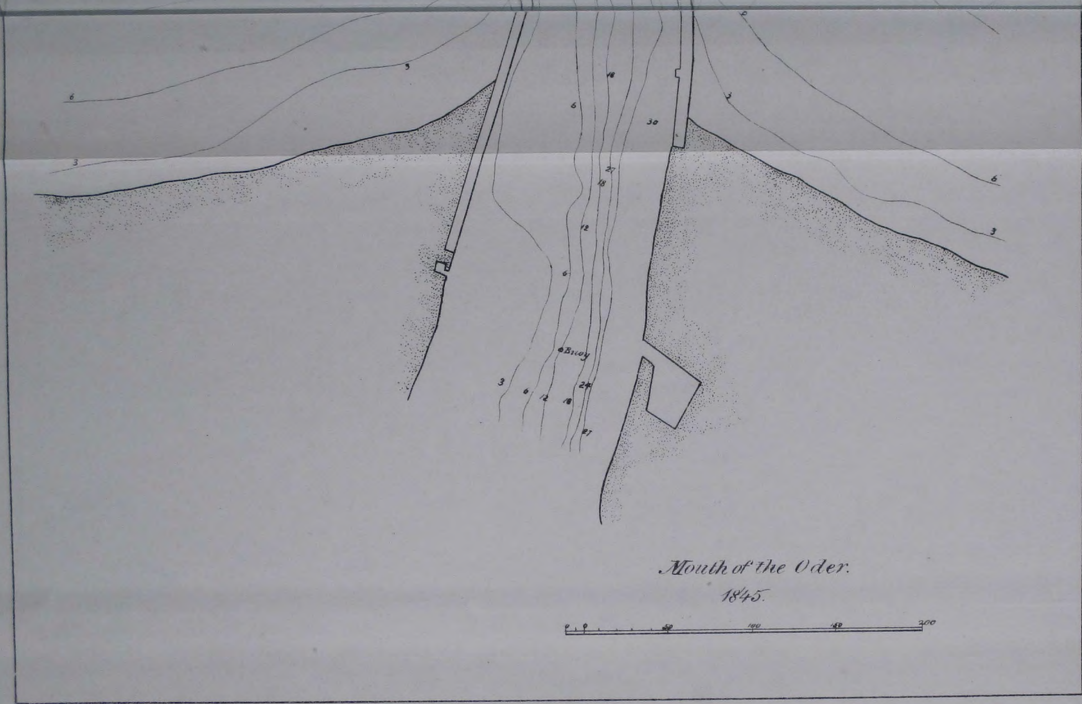
No. IX.

Oder Plans.



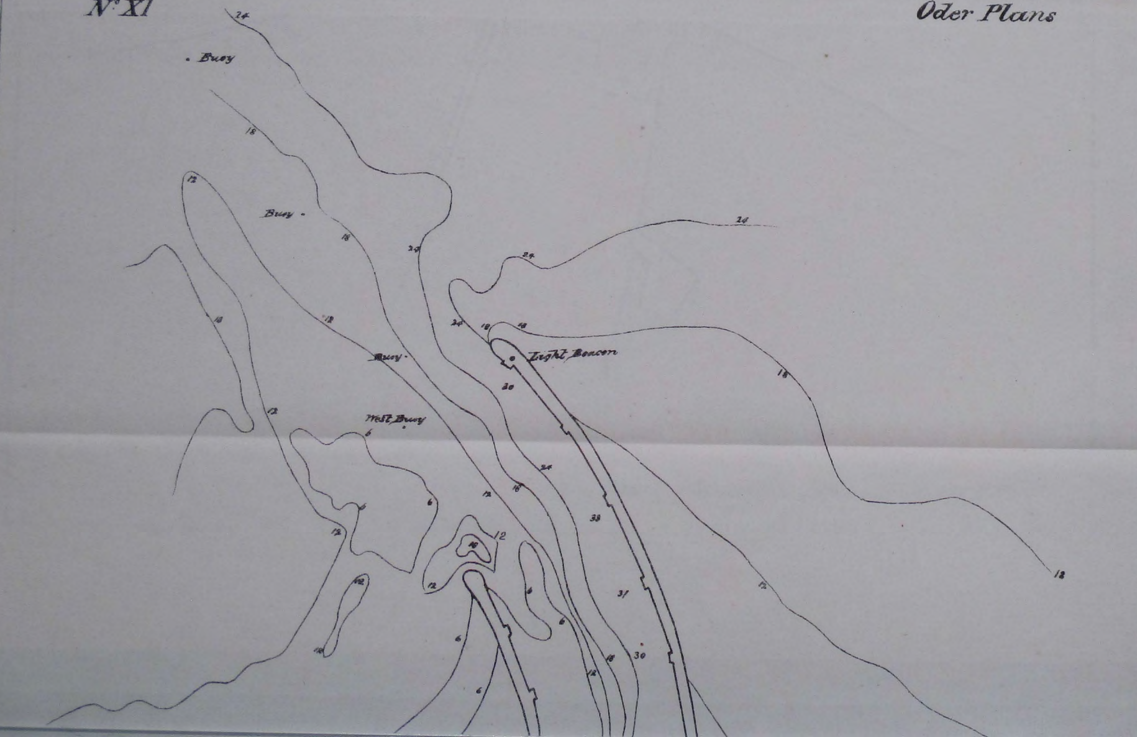

Mouth of the Oder.
1835.
Ruthen
Eng. Feet

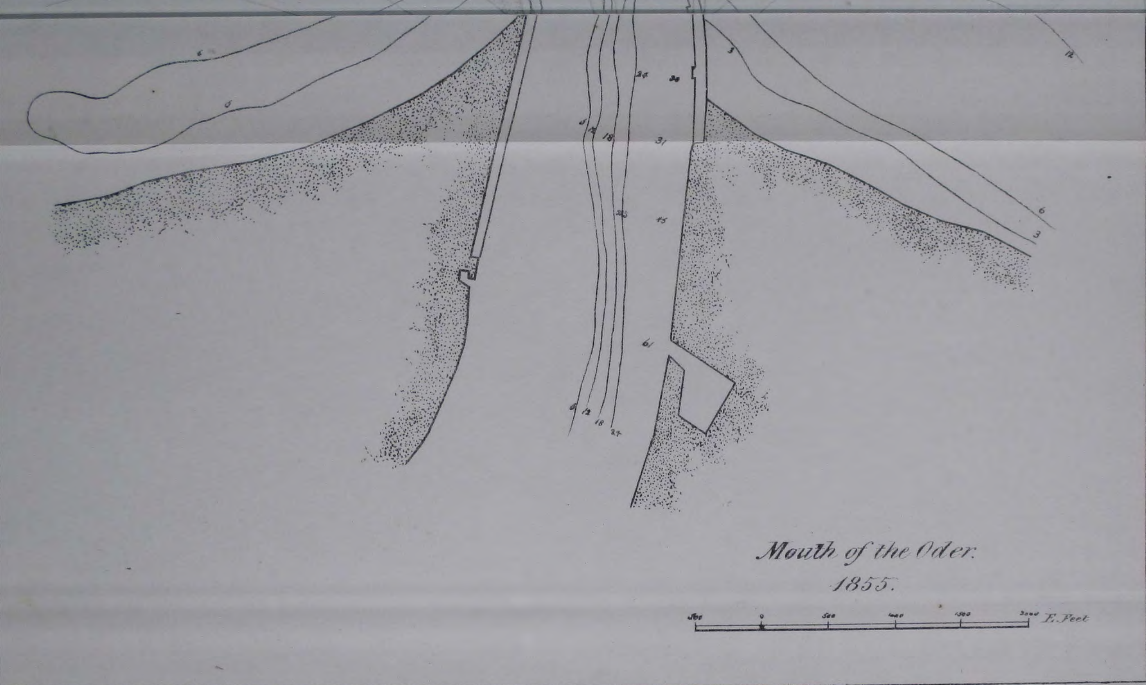

Oder Plans.
No. X.
Buoy
Buoy
Buoy
Buoy
Wreck Buoy
Buoy
Buoy

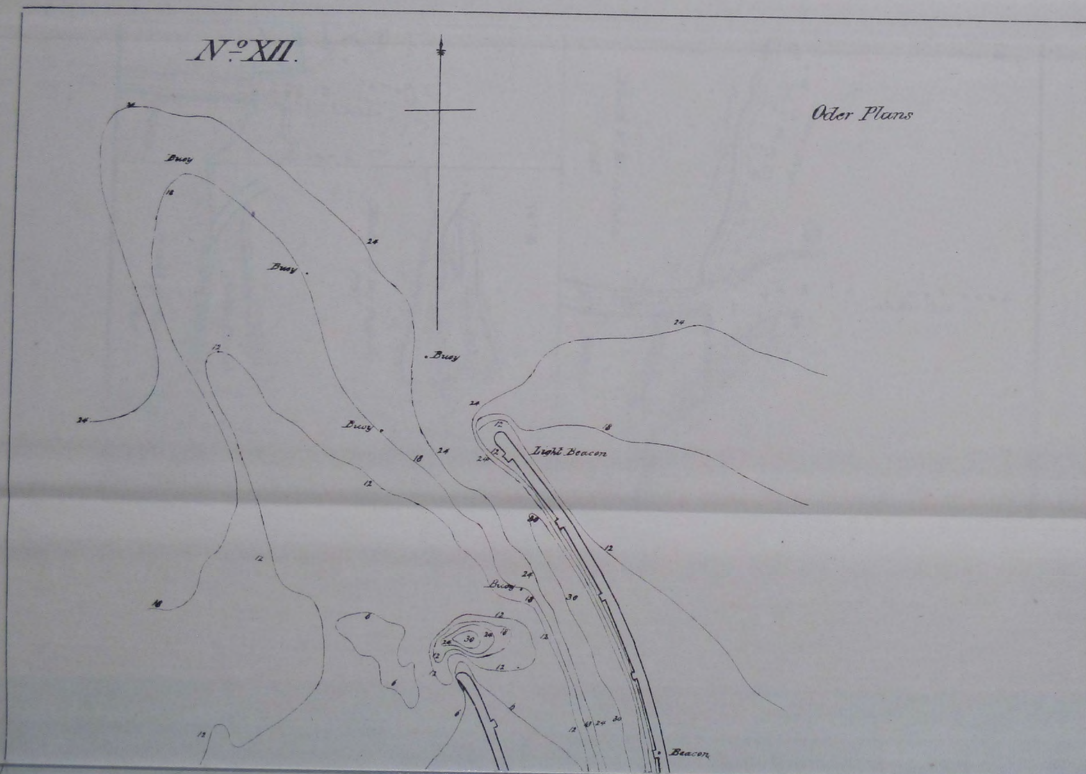

Mouth of the Oder.
1845.
Buoy
0
50
100
150
200

N° XI

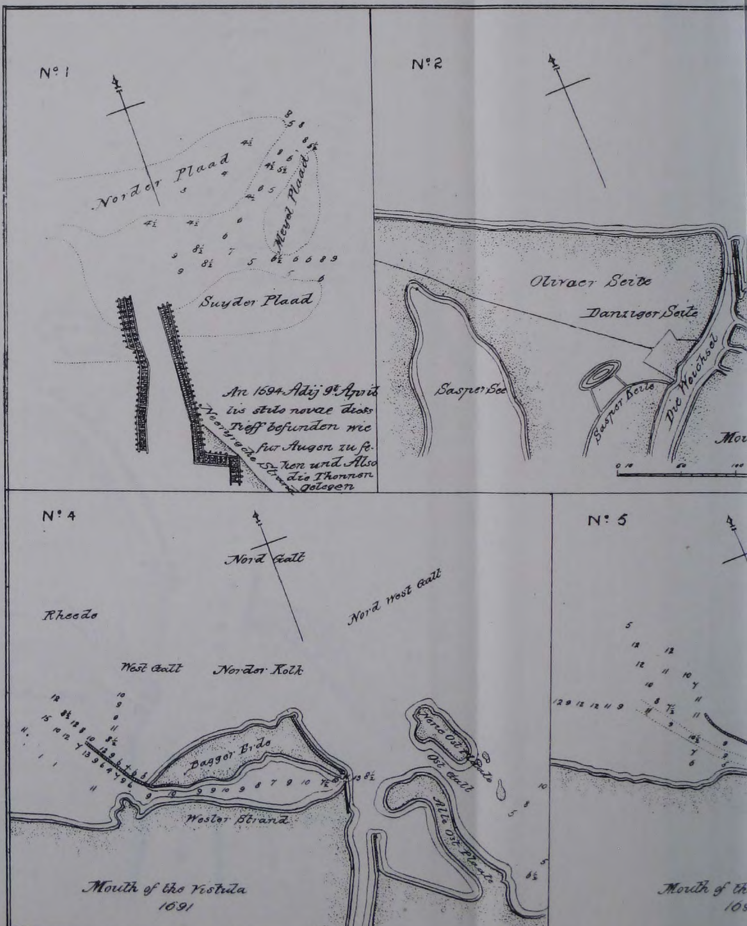
Oder Plans



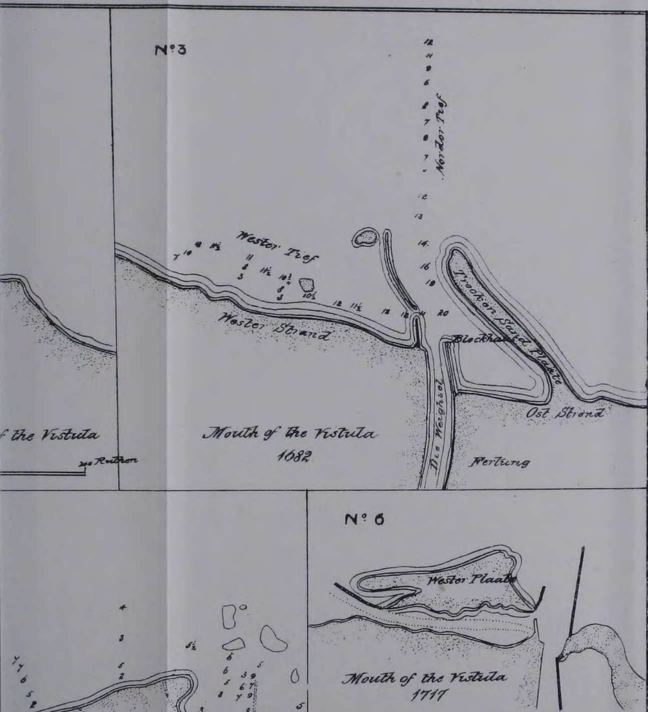

Mouth of the Oder.
1855.
500 0 500 1000 1500 2000 E. Feet


N.º XII.
Oder Plans
Buoy
Buoy
Buoy
Buoy
Buoy
Light Beacon
Beacon

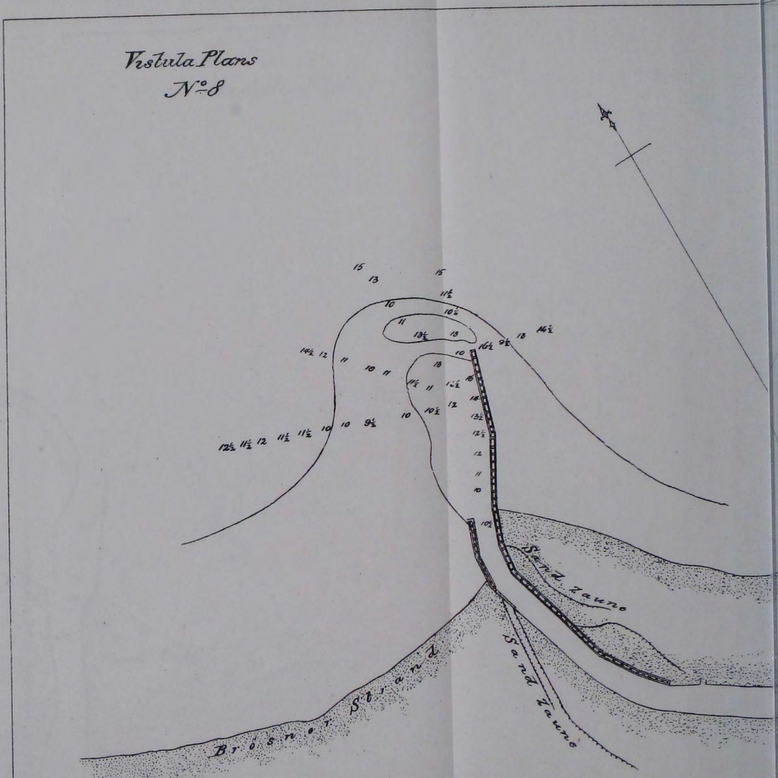

Mouth of the Oder
1858
0
500
1000
1500
2000
2500 English Feet

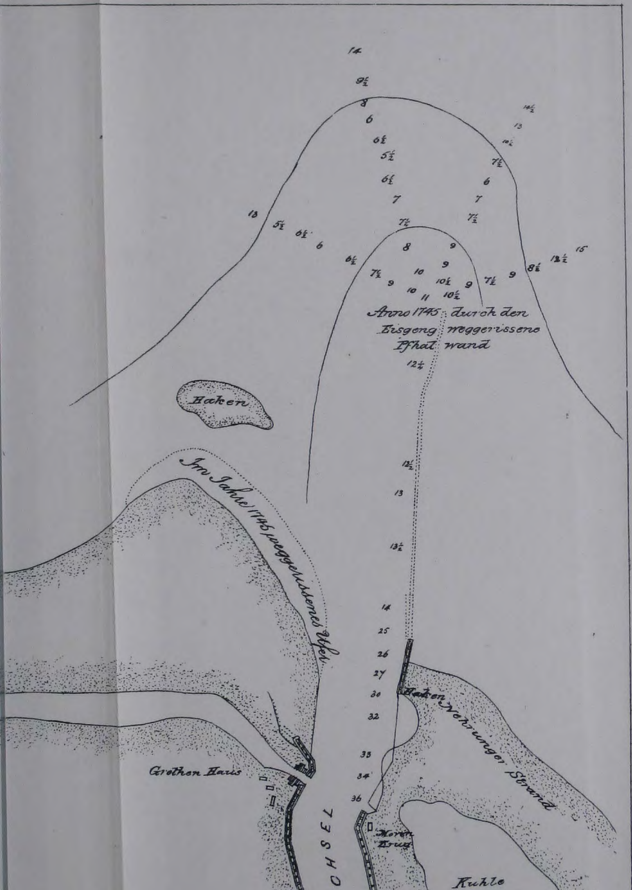


N° 1
Norder Plaad
Meyel Plaad
Suyder Plaad
An 1694 Adij 9t April
is stilo novae diess
Tieff befunden wie
fur Augen zu se-
hen und Also
die Thonnen
gelegen
N° 2
Olivaer Seite
Danziger Seite
Sasper See
Sasper Seite
Die Weichsel
N° 4
Nord Gatt
Nord West Gatt
Rheede
West Gatt
Norder Kolk
Bagger Erde
Wester Strand
Neue Ost Plaate
Ost Gatt
Alte Ost Plaate
Mouth of the Vistula
1691
N° 5



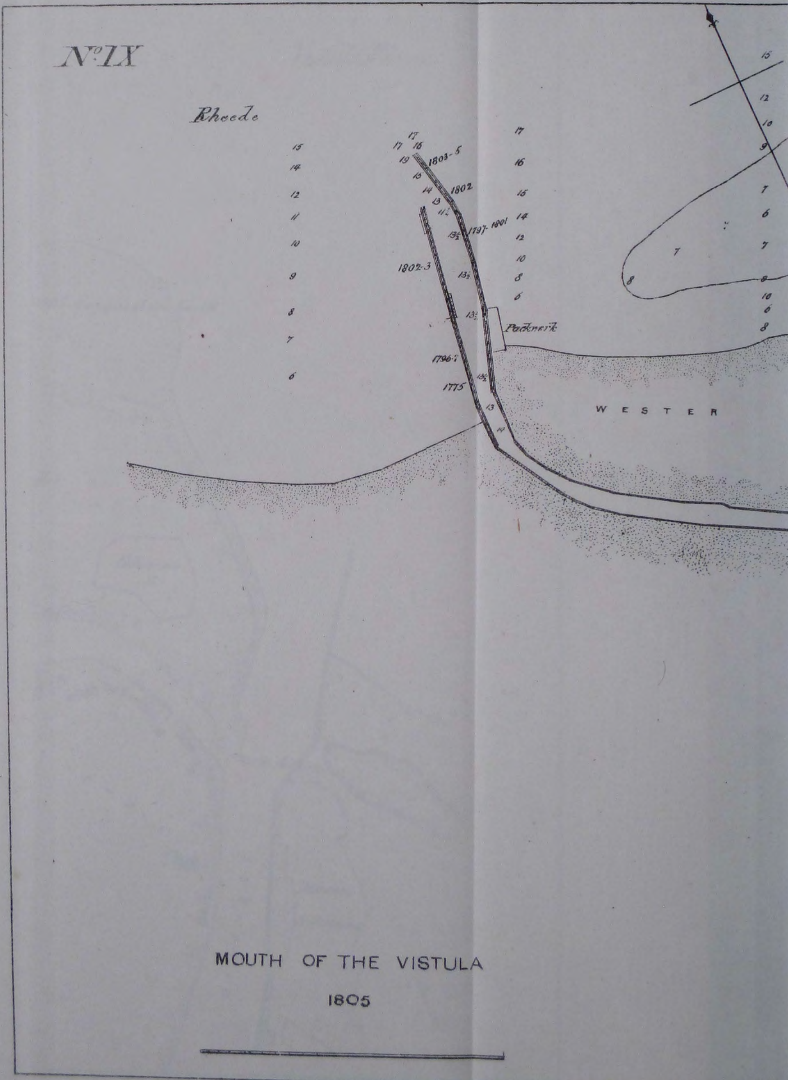
N°3
Wester Tief
Wester Strand
Blockhaus
Ost Strand
Mouth of the Vistula
1682
Die Weighsel
the Vistula
N° 6
Wester Plaate
Mouth of the Vistula
1717
Wester Plaate
Mouth of the Vistula
1724
Wester Plaate


Vistula Plans
No. 8
Sand Zaune
Sand Zaune
Brösner Strand
Sasper See
MOUTH OF THE V
1745



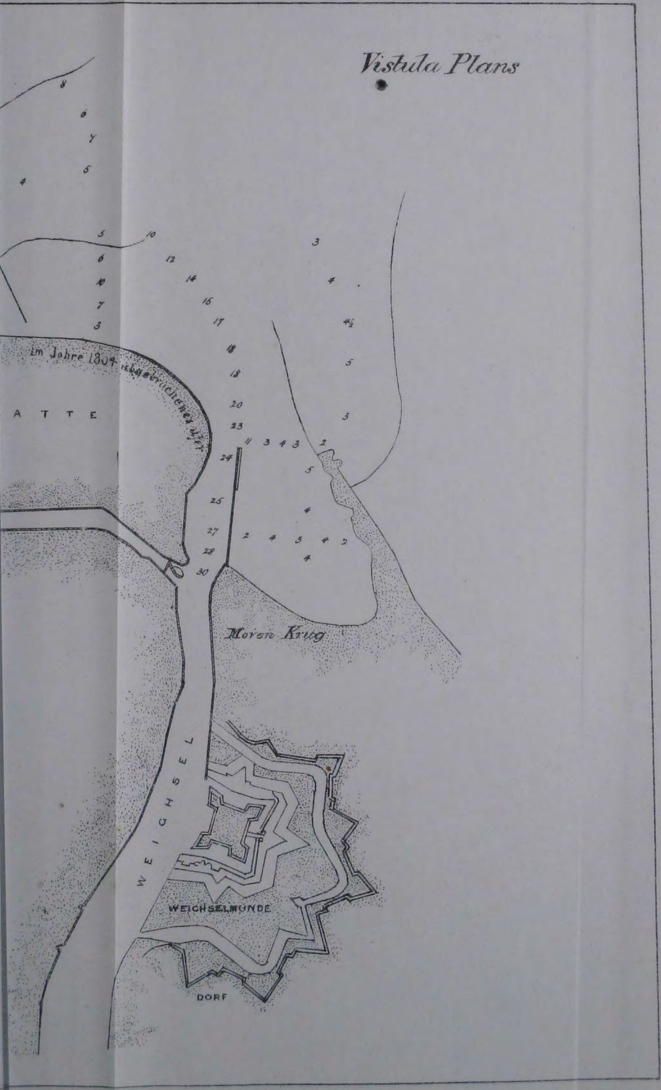
Anno 1745 durch den
Eisgang weggerissene
Pfhal wand
Haken
Im Jahre 1745 weggerissenes Ufer
Haken
Nehrunger Strand
Grothen Haus
Kuhle
WEICHSEL
ULA

No. IX



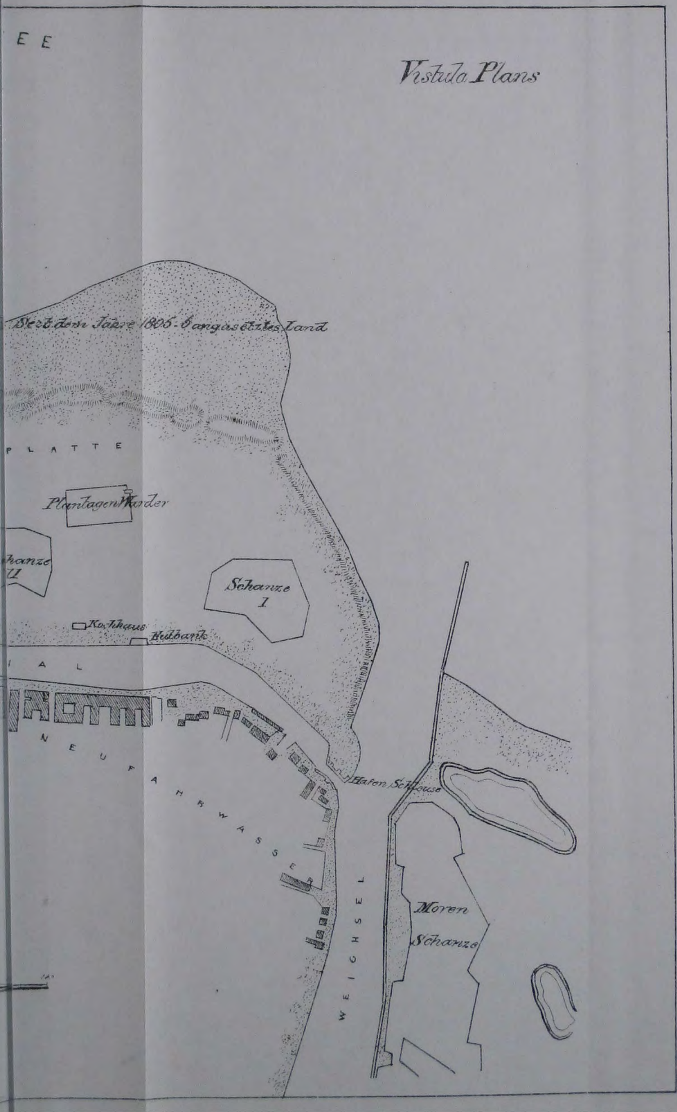
MOUTH OF THE VISTULA

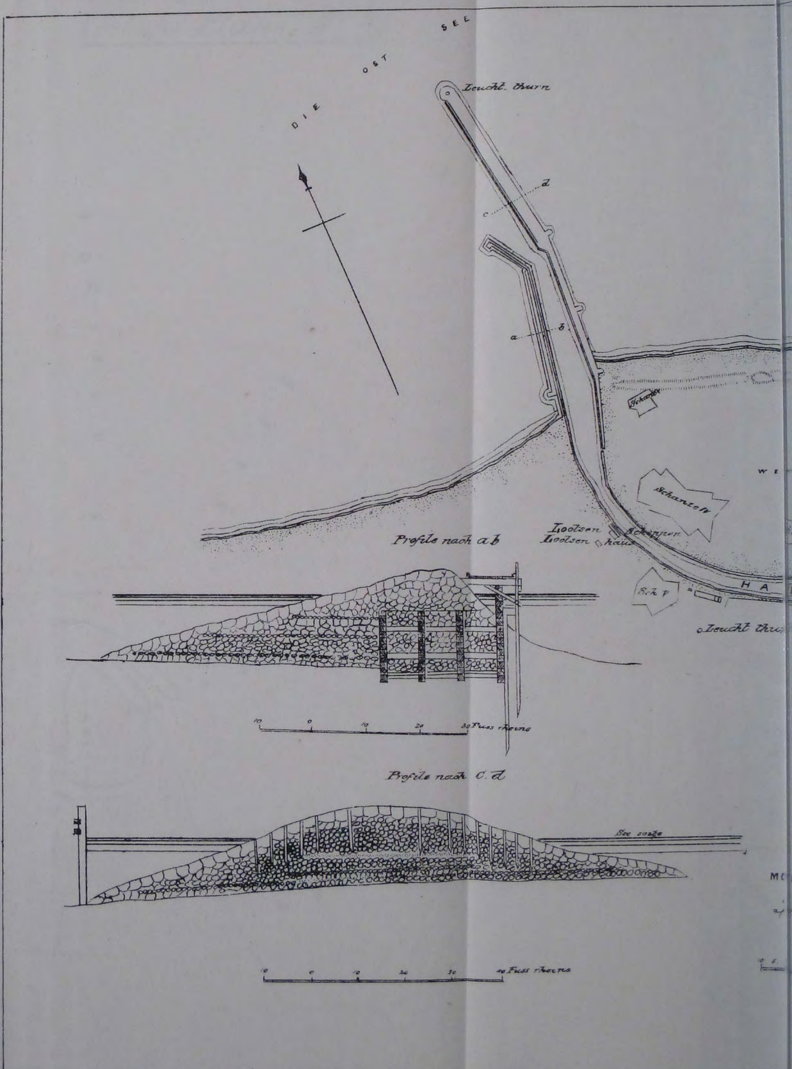
1805



Vistula Plans
Im Jahre 1804 abgebrochenes Ufer
A T T E
Moven Krug
WEICHSEL
WEICHSELMUNDE
DORF

MOUTH OF THE VISTULA
1815

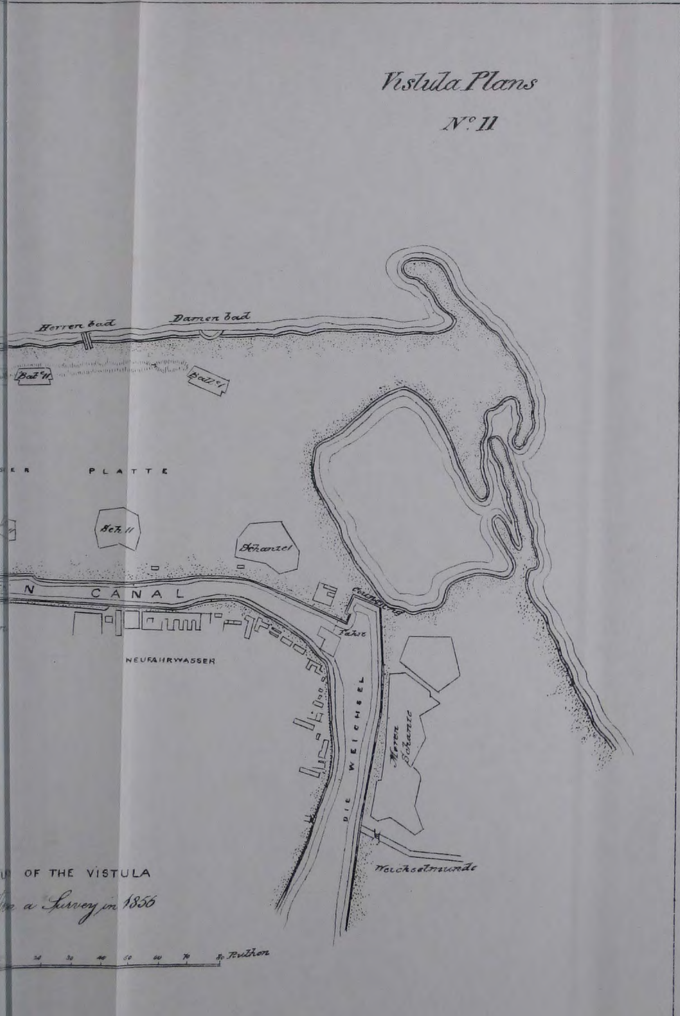

E E
Vistula Plans
Seit dem Jahre 1805 angesetztes Land
PLATTE
Plantagen Wärder
Schanze I
Kochhaus
NEUFAHRWASSER
Hafen Schleuse
WEICHSEL
Moren Schanze

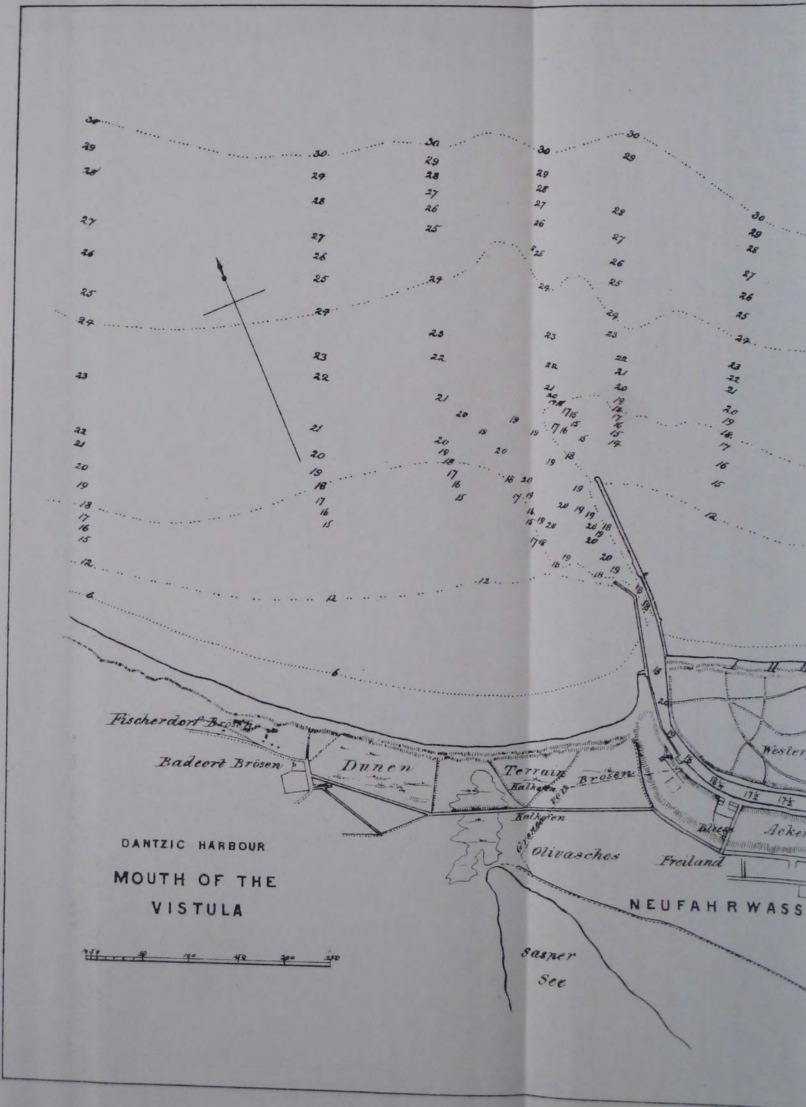


DIE OST SEE
Leucht thurn
Lootsen Schoppen
Lootsen haus
Schanze IV
Profile nach a b
30 Fuss rheins
Profile nach c. d
See sohle
40 Fuss rheins

Vistula Plans

No. 11

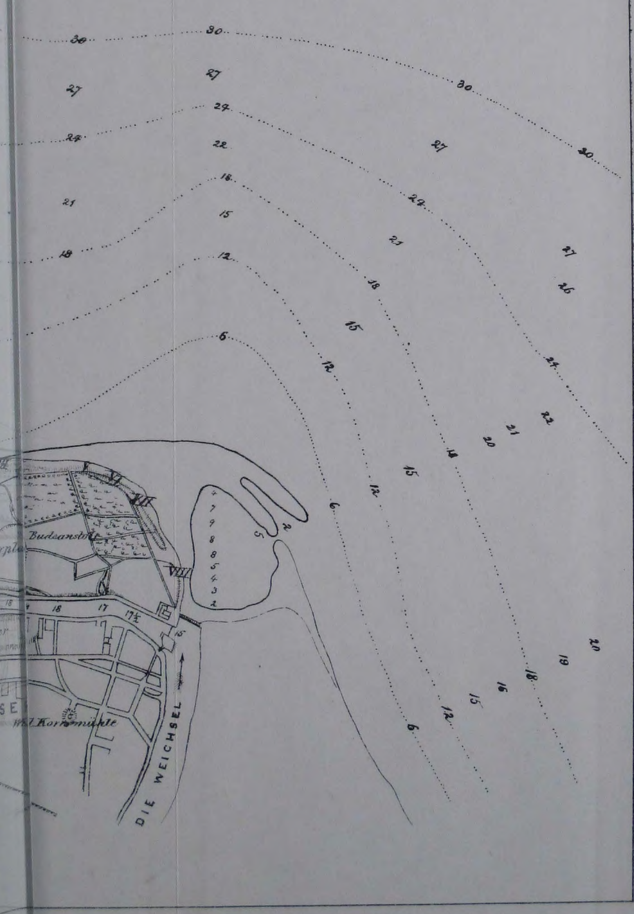




DANTZIC HARBOUR

MOUTH OF THE VISTULA

Vistula Plans. No. 12



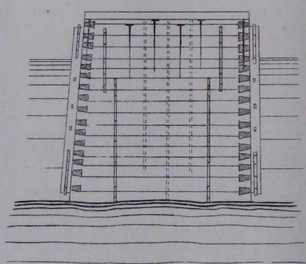
Sulina Detailed Drawings
No 1

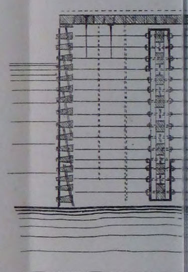
PROV

A

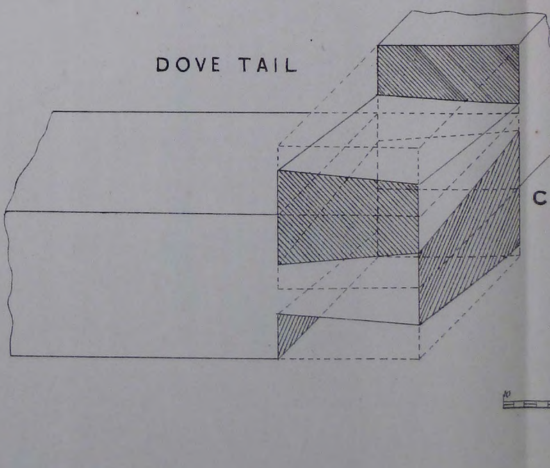
MOD

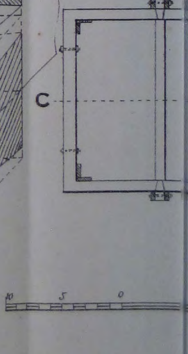
END ELEVATION





DOVE TAIL

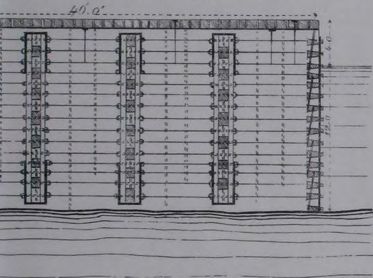




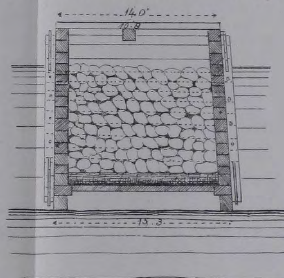
SIONAL WORKS
T SULINA

EL OF A CRIB

IDE ELEVATION

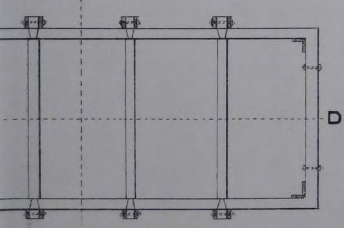


TRANSVERSAL SECTION A B



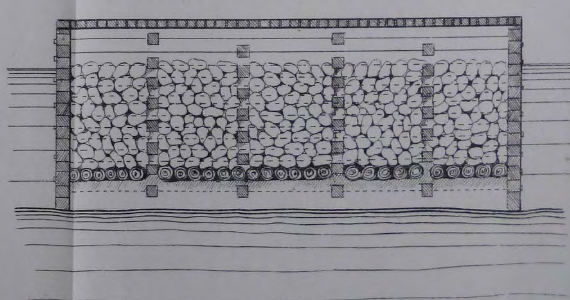
PLAN

A



B

LONGITUDINAL SECTION C.D



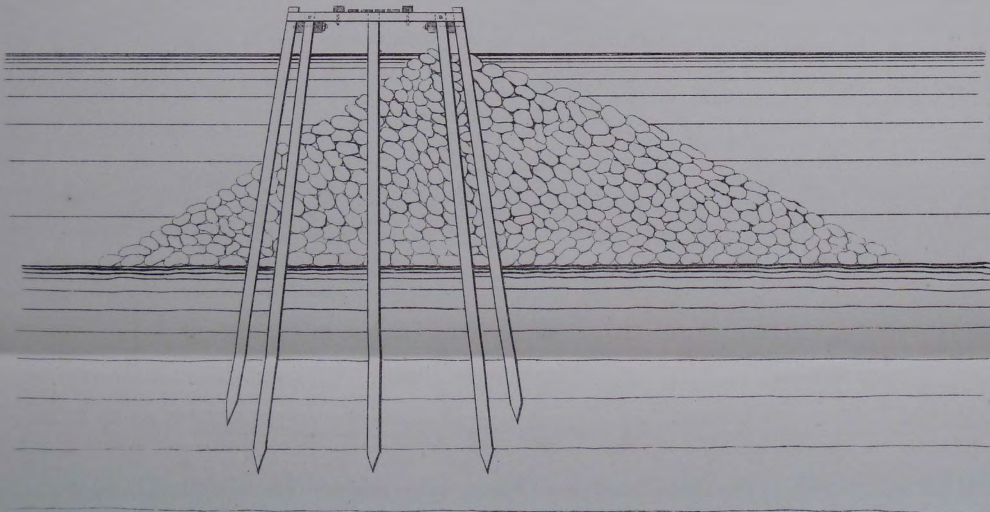
SCALE

Sulina Detailed Drawings No. 2

PROVISIONAL WORKS AT SULINA

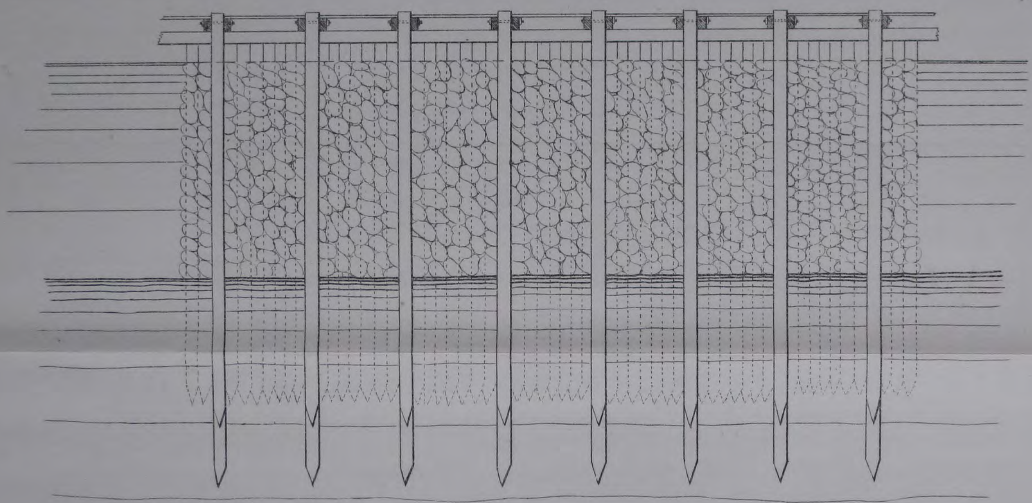
CONSTRUCTION OF PIERS

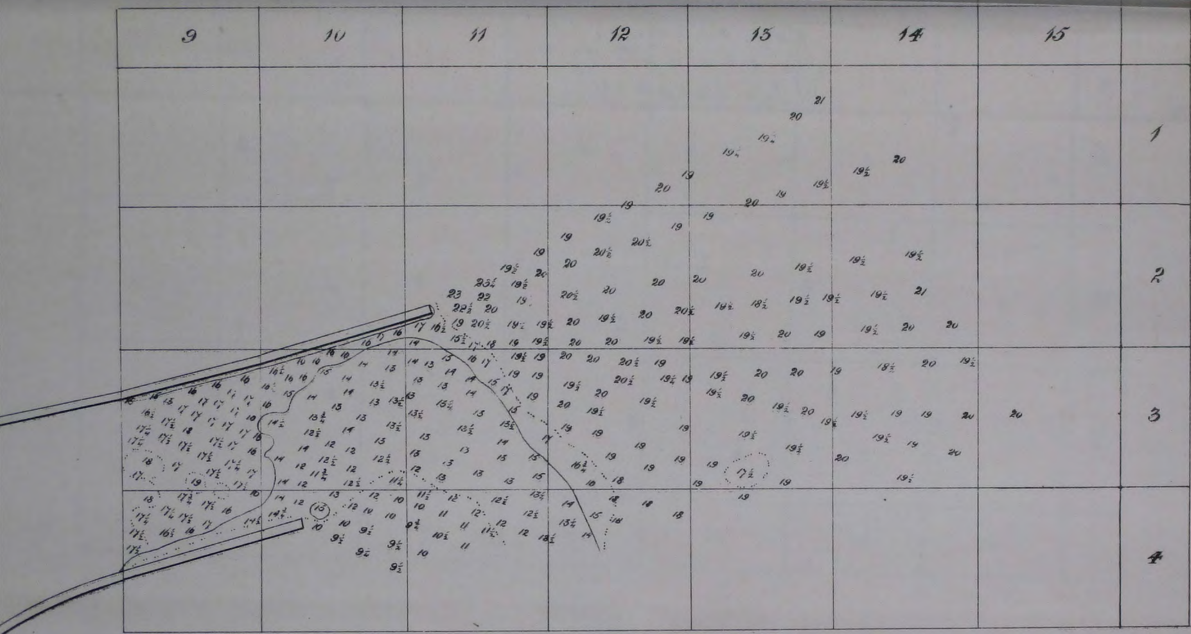
SECTION



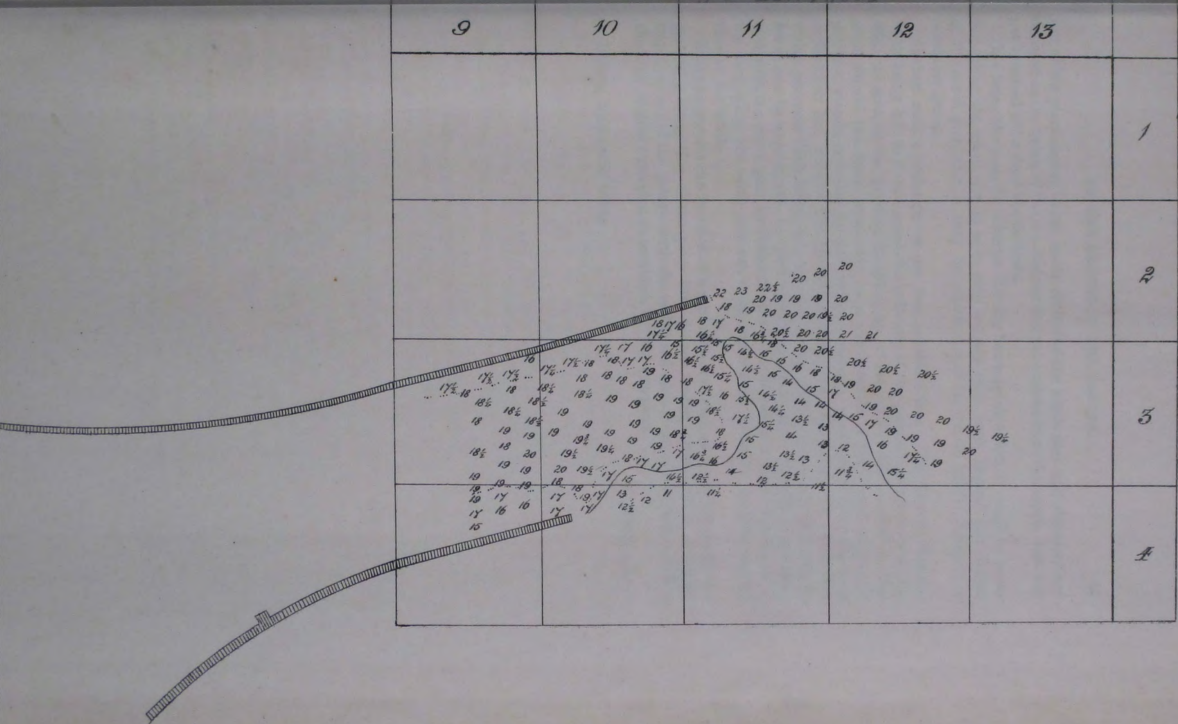
ELEVATION

ELEVATION





9
10
11
12
13
14
15
1
2
3
4



9
10
11
12
13
1
2
3
4

ism of the piers ceases, being under shelter of the north pier, and therefore not exposed to the break of the sea and the littoral current from the north, does not get removed till a flood comes down.

This being the case, Sir Charles Hartley has suggested that it would be better to prolong the south pier so as to push out any such bank beyond the shelter of the north pier, that it may be attacked and broken up by the breakers in northerly gales.

Against such a prolongation are two considerations. The first is, that the bank being left to form beyond the influence of the piers might spread over too wide an area, to the possible blocking up of the entry. The second is, that even should the bank form only in a continuation of the line of its present position, vessels entering the port with a northerly wind would have the bank under their lee, without the protection they now enjoy from the north pier, which prevents their being set on to the bank. This question will probably be set at rest by experiment, by prolonging the south pier. Should its co-extension with the north pier be found to offer more hindrances than advantages to the navigation, the north pier can be extended until it again projects beyond that of the south.

This experiment can be tried at a moderate cost, and, as it can but result in a general prolongation of the piers into deeper water, must lead to a decided improvement of the entry—with the additional advantage of showing which is the best relative extension to establish for the two piers.

J. STOKES.

Galatz, 23rd June, 1864.

PAPER VI.

TRIANGULATION OF PART OF THE CAPE COLONY AND BRITISH KAFFRARIA. 1859-62.

By CAPTAIN BAILEY, R.E.

A few Remarks respecting the Survey Operations for the Triangulation of the Cape Colony are noted down, in the belief that they may be interesting to some Officers of the Corps.

Previous to the triangulation by the Royal Engineers of part of the Cape Colony and British Kaffraria, South Africa had had the benefit of a most accurate geodetic survey conducted by Sir Thomas Maclear, Astronomer Royal at the Cape, for the measurement of an arc of the meridian: this survey extended north from Cape Point about 320 miles, and was based upon a base line of 42,819 feet in length, measured in Zwartland with Colby's compensation bars, exactly similarly to the measurement of Lough Foyle and Salisbury Plain bases in the Ordnance Survey.

The observations throughout were very accurate and numerous, and were elaborated in every detail of a geodetic survey, both in observations and computation.

Sir T. Maclear afterwards extended the triangulation round the coast eastward to Cape L'Agulhas, to form a basis for a hydrographical survey to that point, which requirement was provided for the west coast of the colony by the triangulation for the arc of the meridian.

There were however no data for the extension of the hydrographical surveys to the east of Cape L'Agulhas, for which part they were most required on account of its geographical position; it was known that the existing charts were very defective and inaccurate, and many wrecks had occurred along the coast.

The Admiralty consented to construct charts of the whole line of coast at their own expense, if the colony would supply a skeleton triangulation to work upon. Application was therefore made in 1858, by Sir George Grey, Governor of the Colony, for the services of a party of Royal Engineers to execute a new triangulation from Cape L'Agulhas eastward.

One sergeant and five men were obtained as volunteers from the survey companies, two of whom were fortunately most practised observers; five more men were selected from the service companies, and I was ordered to take command of the detachment.

Some very necessary survey stores (particularly observatory tents) were brought from the Ordnance Survey Office, Sir Henry James having reported them to be valuable components of the equipment.

The party arrived on the 16th March, 1859, and after an interview with the Governor, a letter of instructions was sent for the guidance of the officer in charge, from which the following extracts are taken:

"1. The object of the proposed undertaking is to fix geographic stations from Cape L'Agulhas to the frontier accurately by triangulation, for the purpose of forming a basis for the survey of the coast by the Admiralty.

"2. The nature of the operation affords an opportunity of triangulating at a trifling additional expense, a belt of 90 to 100 miles inland over the whole sweep, extending over a district the richest and most populous in the colony, and embracing the post route between Cape Town and the eastern frontier. The operation will therefore afford points for filling in at any future time.

"3. In order to effect this in the most satisfactory and economical manner, it is considered that you should carry forward a series of triangles having sides, where practicable, of twenty to thirty (20 to 30) miles, intersecting the most important line of country, and taking angles to intersect any objects of special importance, so as to fix their bearings and distances, and any other objects, within view of the theodolite stations, which may be considered of value by the Surveyor General or by the local authorities of the district.

"5. You will take up the survey from the point at which the Astronomer Royal, Mr. Maclear, left off, when verifying La Caille's measurement of an arc of the meridian. Mr. Maclear will have already furnished you with full information upon this point, and with valuable suggestions for the prosecution of your work, and the means of meeting the difficulties peculiar to the service in this colony.

"8. Your own experience upon the trigonometrical survey of Great Britain, and the experience of Mr. Maclear upon his survey in this colony render it unnecessary that His Excellency should furnish you with further detailed instructions.

"9. With regard to the arrangements for meeting the expenses of the undertaking, His Excellency has received a communication from the Secretary of State, from which it appears that the War Department expect the whole expense of the service to be borne by the colony, including the military pay of yourself and of the detachment under your orders."

The instructions were drawn up after conference with the officer in charge.

The instruments had been already procured and were in the Royal Observatory. They had been obtained from Messrs. Reichenbach and Ertel, of Munich, and were excellent instruments of their class; two of them were intended for use at all principal stations, they were each of 13½-in. azimuth circle, graduated very delicately to 4″, and read by four equi-distant verniers.

The junction of the upper and lower plates was made in the manner usual in German instruments.

One of these instruments was known as the " universal instrument," being a kind of theodolite having the telescope and vertical circle especially fitted for taking astronomical observations in connection with the terrestrial.

The telescope contained within its tube on the axis of the Y supports a glass prism capable of adjustment, and fixed so as to divert the image 90° horizontally, that is through the pivot (tubular) which carried the vertical circle, so that the tube of the eye-piece passed through the centre of the vertical circle.

The opposite pivot was pierced to admit light: there were five vertical cross-wires in the diaphragm for transits; and the vertical circle was of large size for an instrument of that class.

In consequence of the above arrangement, the weight at the pivot which bore the altitude circle was considerable, and therefore a counterpoise weight was fixed on the opposite end of the axis; as this was not adjustable and was not sufficiently equal to balance the opposite weight, I added a disc of lead to put it in equilibrium.

The instrument deserved its name of universal instrument, and was valuable for astronomical observations, being especially convenient for high altitudes, and it gave good results. At the same time the diagonal diversion of light retarded observations a little, and I consider that the top weight was too heavy for the supports, which were but of slight construction. It could be reversed by shifting in the Ys, or by turning over the telescope so as to point round 180°.

The $13\frac{1}{2}$-inch theodolite had a telescope of the usual description supported in Ys. The eye-piece was inverting, and its vertical circle smaller than that of the universal instrument. It made excellent work. The defining power of the telescopes was not sufficiently good, and I did not think highly of the mode of adjusting the instruments, which was complicated and uncertain. A 7-inch theodolite was also provided for use at minor stations. It was similar in construction to the $13\frac{1}{2}$-inch, but graduated to 10″.

Immediately after landing, the whole party was employed in making preparations for the field; the stores provided for the camp were about the same as those of an observing party on the survey of Great Britain.

A number of heliostats framed in brass were prepared, and stands made for the instruments, and tents, cooking utensils, stores, tools, &c., for the men, provided.

One of the first things to be attended to was to find transport, and this was a constant drag throughout the work.

It was necessary to have two camps at least, and the weight and bulk of things to be carried was necessarily considerable to meet the unavoidable requirements of so many men, especially in a country where supplies are not always handy. At that time also (April, 1859) it was peculiarly difficult to obtain transport on account of the drought which impoverished the western district.

I decided upon making a trial of waggons, and purchased spans of oxen and waggons, which were always retained as the means of transport. The waggons were very strong and roomy, well suited to the rough rocky roads of the country, and each drawn by a span of 12 or 14 powerful oxen, driven by natives. The oxen are slower, but are hardier, and can live on scantier pasturage than horses or mules, and can draw much larger and heavier waggons. Though they travel slowly they perform as long a journey in the day as mules.

Indeed it is certain that considering the nature of the service, and the wild and inhospitable country through which the greater part of the work was carried, horses or mules would have broken down completely; it is true that the oxen suffered much from the want of grass, aggravated by the severe drought, and also from change of pasture, and many died, but horses could not have got through it at all.

Before setting out I visited Sir T. Maclear at the Royal Observatory, where he supplied me with a printed account of his survey for the measurement of an arc, and with great kindness gave every information and assistance, for which he has my sincere thanks.

The theodolites were first packed in the boxes supplied with them, and these again were placed in other strongly framed packing cases, having the inside padded with cushions all round, and resting on springs, to carry the instruments as secure as possible from injury by jolting in travelling.

The field parties left Cape Town on the 27th April, 1859.

An inspection of the diagram will shew what points had to be first attended to.

The object was to extend a triangulation along the coast from Cape L'Agulhas eastward. Sir T. Maclear had made a triangulation in which he had occupied Zondereindeberg and Cape L'Agulhas stations, from both of which he had observed Potteberg; therefore the side from L'Agulhas to Zondereindeberg might be taken as a base to proceed eastward from, by occupying Potteberg as an instrument station.

I did not however consider it safe to proceed from one side only as a base, especially as there was an awkward elbow in the direction of the work at Cape Point, where the general line of the triangles changed to the east instead of being from north to south. I therefore determined to verify that line and to bind the work together with greater stability by connecting the station at Zondereinde with some other point in Sir T. Maclear's triangulation nearer to his base line through a direct series of triangles; and the country was carefully explored for this purpose. But in the first place, in order to commence work as soon as possible with the instruments, Potteberg was occupied as an observing station to complete the triangle Cape L'Agulhas, Zondereinde, Potteberg, while the piles were erected that were required for extending the work, and a minor triangulation for Admiralty purposes was executed between Potteberg and L'Agulhas.

In the mean time the piling was pushed forward and points were selected which fulfilled the requirements for checking the side Zondereinde to Potteberg. Sir T. Maclear's side, Kapocberg to Great Winter Hoek, was taken as a datum, and the following triangles observed, viz.:

1. Kapocberg, Great Winter Hoek, du Toits Kloof.
2. Great Winter Hoek, du Toits Kloof, Hex Riverberg.
3. Du Toits Kloof, Hex Riverberg, Zondereindeberg.
4. Zondereindeberg, Hex Riverberg, Anysberg.
5. Zondereindeberg, Anysberg, Zuurbraak.
6. Zondereindeberg, Zuurbraak, Potteberg.

Thus a new and independent value was determined for the length of the side Zondereindeberg to Potteberg, And further, in order to guard to the utmost against error at the commencement, I visited Table Mountain with an instrument, and tested the position of the new station at du Toits Kloof by the triangle Table Mountain, Kapocberg, du Toits Kloof, taking a fresh side of Sir T. Maclear's, viz., Kapocberg to Table Mountain, as a datum side.

When these triangles had all been computed, the length of the side Zondereindeberg to Potteberg, as deduced from them, was compared with that supplied as a datum by Sir T. Maclear; and the remarkably close approximation to coincidence, the difference being less than 3 inches (which must however have been partly accidental), was most gratifying as a test of accuracy and as affording a secure basis to proceed upon.

Finding by trial that the original number of men was insufficient to keep two observing parties constantly employed, and seeing the great advantages to economy and convenience in having two parties at work at the same time, I applied for, and obtained, the services of four men as volunteers from the 12th Company.

The work now proceeded eastward by a double chain of triangles starting from the stations on Anysberg, Zuurbraak, and Potteberg. The southern line of principal stations was fixed on the most prominent points along the coast; inland or north from these, two parallel ranges of craggy and precipitous mountains stretch nearly east and west as far as Plettenberg's Bay, at a convenient distance apart for triangulating; the Langebergen, which are known as the Attaquasbergen and Outeniqua Mountains towards the eastern extremity of the range, lie nearest the coast, and on their lofty summits (about 5,000 feet high) a central line of stations was selected, forming triangles on the one side with the stations along the coast, and on the other side with an inland chain of stations perched upon the rugged and still loftier peaks of the Great Zwartbergen, which rise to above 7,000 feet. Thus a double series of triangles was formed having common sides along the mutual line of the Langebergen.

At Plettenberg's Bay, the Langebergen fringe upon the shore, so that the coast line of stations had to be disconnected; the very serious difficulty of forming a good triangulation here was overcome by the occupation of the Cockscomb as an instrument station; the difficulty of ascent appeared almost insuperable, and it was well known as a so-called inaccessible mountain, but the value of the station to the work was so great that it was surmounted at some risk.

From hence the work was carried forward by stations along the Amatolas on the north side, and the Zuurbergen in the centre, and by a lower line along the grassy hills by the coast of the south, as far as the Great Fish River, and from that on to the Great Kei.

In addition to the principal stations, a number of points were occupied as minor stations in order to reduce the length of the sides to about 20 miles, more especially along the coast line for the use of the Admiralty surveyor; and many other beacons were erected, and fixed by observations taken to them from two or more instrument stations, though they were not observed from. These were especially intended to be used as theodolite stations in case of making a minor triangulation or a further extension of the work.

The total strength of the party was 1 officer, 1 sergeant, and 14 men.

It was found that the sergeant and one man were sufficient at first to keep up the office work. Two observing parties were formed of five men each, and a party of three men was continually employed in advance, putting up beacons or piles of stones.

Myself, and Lance Corporals Purdy and McConomy, were the observers, and took all the observations; these were conducted after the manner of the Ordnance Survey, which was always followed as closely as possible. When a station was to be visited the waggon was driven up the base of the mountain as far as practicable; it would startle any person unaccustomed to it, to see these waggons trekking over the most rocky, uneven, and shelving ground; the performances of the Cape waggons in this respect are notorious, and until I saw it I could not have believed that such ground could be passed over without accident, and I frequently had most anxious fears for the safety of the instruments.

In some few instances along the coast the waggon could be brought close up to the station, but at all the mountain stations the hills were precipitous from near the base. It was then very laborious work to get the observatory tent, instruments, &c., up such high and rugged mountains; the country being very thinly populated casual labour could not be procured, and the men had to carry up the stores on their backs with the assistance of the waggon drivers.

I had at one time an idea of trying pack oxen or pack mules, but dismissed it from the fear of accidents.

Great precautions were necessary in pitching the observatory tents on account of the prevalence of very violent winds. The guy-ropes supplied were quite insufficient and several strong extra ones were procured; sometimes a low wall of stones was placed round the bottom of the tent. No great difficulty was found in setting up the instrument-stand firmly, as the ground is nowhere mossy or unstable: it was placed either on the bare rock, or on stout pickets driven deep into the ground, the feet screwed down to the picket heads, and the stand weighted down with heavy stones to keep it steady.

The observer first selected a referring object, taking care that it was well defined, easy to bisect, with a favourable back-ground, and not liable to be obscured by mist.

In observing, the observer was assisted by a man to book his angles, attend to signals, &c.; the referring object or R. O. was first read, then any beacon, heliostat, or other object to be observed, and lastly the R. O. again. The coincidence (or approximation to it) of the two readings to the R.O. was a test of the "drag" of the instrument or of its having been disturbed. Each measure of this sort was termed an "arc;" by combining these, the angular bearing of every object from the R. O. was known, and as a consequence, the difference of the readings of two objects gave the included angle between them.

The instructions to the observer, who was the head of the party and responsible for everything, were, to be careful that the instrument was in good order and adjustment; to move the lower plate in azimuth on one arc, and to reverse the instrument every alternate arc; to book all observations in ink and add nothing afterwards to the entry made on the spot; to take no observations in unfavourable weather; to pay primary attention to observing the principal stations; to observe these not less than twenty times, and other objects not less than five times if possible; to prefer poles or piles to heliostats; to observe all permanent objects in sight, especially such as could be identified and fixed by observations from some other stations, such as churches, prominent hills, bearing distinctive names, &c., and to keep a constant look out in the hope of picking up any newly erected beacons; to take vertical observations four to six times, and to prefer the hours between 8 and 9 A.M. and 3 to 4 P.M. for vertical angles.

Every evening it was the duty of the observer to copy the observations taken during the day into observation sheets ruled in the same way as the book, to compare them, and send them by every opportunity to the office, not parting with the field book until he had receipts for all the observation sheets. Of the remainder of the observing party, one man took charge of the camp, and the other two were fully occupied at the discretion of the observer, either in erecting piles to be observed for secondary work, or in the very important duty of reflecting with a heliostat. The observer could usually judge those stations on which the beacons were not likely to be observed; to such stations he would send a reflector or signalman, who was ordered to reflect at every opportunity until he received some preconcerted signal. This was in many respects a very severe duty, for the distances between the stations were very long, and had to be performed alone and on foot, perhaps without a direct road, and usually where there was a very sparse population; but it was well and cheerfully done, and the rapid and satisfactory performance of orders in this respect was very gratifying.

The party of three men kept some distance in advance of the observing party to build piles, erect beacons, &c., travelled with a mule cart, and had with them a patrol tent, pocket compass, sextant, and a few necessary tools.

Diagrams were furnished them as rapidly as possible, shewing the state of the advanced work, and the requirements for the future.

They were directed to place permanent beacons on the most commanding hills, disposed so as to form good triangles, to mark the centre, and to take rounds of approximate angles at each point, which were to be sent to me without delay.

I chose the principal stations as far as possible myself. When I could not be personally present, use was made of the diagrams and compass bearings, assisted by my knowledge of the country.

Lance-Corporal Purdy was entrusted with the execution of the principal part of this duty, and was found to have capacity and will to do constant severe work with courage and perseverance, regardless of hardship and exposure. It is necessary to insist firmly that all beacons to be erected shall be of a permanent nature, and built evenly round the centre, which must be well marked. There is too much desire on the part of most men to push forward the progress and to leave a paltry and insignificant beacon where a substantial one should be built. This must be guarded against.

The selection of stations is not so easy a matter as it appears, especially where no good hand maps of the country can be got; and the slowness and uncertainty of postal communications over the mountain districts, with a flying party, when I was also constantly on the move, was a disadvantage. The result however was decidedly satisfactory, and a good series of well-conditioned triangles was formed. Sometimes there were especial difficulties in the way of keeping the work properly connected; for instance, from Krakeel River, de Beers Vley could be seen through a gap or opening in the intermediate mountains; this was a very important case, for no other point would have answered so well, and the only resource would have been to have reduced the sides to very small triangles.

Langebosch Kop was in the middle of Olifants Hoek Forest, and the instrument had to be raised on a stage to see over the forest.

From Newcastle station the ground could not be seen either at Breakfast Vley or Bekruip Kop, and *vice versa*, the whole range of the ground being cut off by intervening hills; but by elevating heliostats about 30 feet, the obstacle was overcome. Even then the light was seen to rise only in the early morning, and that not on every day, according to the refraction, which is greatest in the morning.

The above instances will shew some of the difficulties of laying out a triangulation.

It is an almost constant rule, that observations can be taken at the Cape only in the morning and evening; from about half-an-hour before the sun is up till about an hour after is generally favourable; though it will frequently happen that about sunrise there is a great deal of tremulous vibration in the air, which totally precludes observation and is excessively disappointing, for all may look perfectly calm, distinct, and clear to the naked eye. This sometimes subsides again in about an hour. When the day becomes hot, there is but little chance of observing, unless it clouds over, until late in the afternoon. I found observations in the evening, towards and after sunset, to be usually even better than the morning observations.

The greatest possible annoyance, and loss of time too, is often caused, especially in British Kaffraria, by the colonial custom of burning the veld*. When the grass is dry, the farmers set it alight in large patches, with numerous fires all round, clouds of dull smoke drift away obscuring the view for miles round, and not uncommonly rising to hide a beacon which has just become visible, and for which the observer may have been long looking out. Even for days afterwards the smoke hangs about as a light haze in the air, which is not cleared till after rain. Very distant observations were sometimes made to piles; for instance I observed the pile on Great Winter Hoek from Table Mountain, about 72 miles off, but on the whole I should think that England is quite as favourable for observing piles, while the Cape has a great advantage for heliostat work.

Heliostats may be observed in weather which would not do at all for piles; they appear pretty steady, when piles could not be bisected.

I preferred however to observe the piles or beacons whenever they could be seen, as it prevented the possible chance of error from inaccuracy in the laying out of the line by the signalman; but for all stations which were not relieved against the sky reflecting was absolutely necessary, and in some other cases also, particularly for piles in the north meridian.

We had two sizes of heliostats, one 3 inches, the other $5\frac{1}{2}$ inches in diameter; the former for short distances, up to 25 miles; and the larger size for long distances. The larger heliostats reflected too large an image when used for short distances, and were unnecessarily large and heavy for such use. The Cape

* Veld means a wide expanse of pasture country undivided by hedges or fences.

sky, so free from cloud, and so constantly sunny, was particularly favourable for heliostat observations, which could be taken almost every day.

The practice of using a referring object was found to be extremely convenient, though it was sometimes found to be obscured by mist, or by the vexatious smoke from fire; care should always be taken to place it in a position where the ground falls away suddenly in front of the instrument, so as to leave a valley between the latter and the R. O.; otherwise, if there is a flat space in front, the air is soon in motion near the ground in that direction, and the R. O. cannot be properly observed.

The observatory tents (hexagons) were found very useful, but they should be provided with wind shutters, and have a means of opening the roof for astronomical observations. Probably some light wooden observatory would be more secure and convenient than any tent. Wind and dust were very annoying when observing. A great deal of fine sharp gritty sand was carried into the tent by the wind, and even constant use of the brush would not keep the instrument free from dust.

The observer's camp was pitched as near the observatory as possible, but this was often at a very great distance, and it was a most severe climb to get up and down the highest mountains every day. The mountains were sometimes so excessively rugged, that not a spot could be found for pitching a tent. Firewood was found in abundance, but water was in places very scarce, having perhaps to be brought 7 or 8 miles in barrels.

Many of the mountains, especially in the Langebergen and Zwartbergen are high and apparently inaccessible; and the Cockscomb, Seven Week's Poort, Great Winter Hoek, and others, were very formidable hills to ascend, particularly when carrying up the instrument and observatory. It may truly be said that many of the undertakings were absolutely dangerous.

Lance-Corporals Purdy and McConomy (who were both experienced hands) set a most admirable example to the men of their parties by their persevering and invariable attention to duty; they were both practised and careful observers, and their excellent conduct had its influence upon the men. Lance-Corporal McConomy observed all along the Zwartbergen with the Universal instrument. When I was out in the field, I usually had the 13½-inch theodolite. When I came to the office I was replaced by Corporal Purdy who was at other times employed at the piling. It is needless to mention that difficulties abounded at the outset of the work. Almost all the men were totally unaccustomed to operations of this nature, and were suddenly placed in situations which required great energy and perseverance. In the midst of a strange country, ignorant of the prevailing language (Dutch is so universally spoken in the western districts, that but few people *can* understand a word of English, and some of them *will* not), they had to march singly very long distances, to ascend stupendous mountains which were commonly called inaccessible, and to depend upon their unaided individual exertions for success. Upon the whole the conduct of the men deserved very great praise: they met and overcame the obstacles with indomitable spirit, and took great interest in the work. Laudable emulation was encouraged, the men were inspired with a disregard for difficulties, and success was well rewarded. They soon learnt enough of the Dutch language to make themselves understood in conversation with the boers, in whose houses, for want of inns or lodging houses, they were obliged to put up; and in time could inspan the oxen, and even handle the long whip and drive them, when the native drivers absconded.

Much hardship and exposure were endured occasionally by every man of the party, and in some cases severe falls occurred in climbing the mountains, partly from the rugged precipices and partly from the slippery footing upon the long reedy glass. In many places forage was scarcely obtainable, provisions too were often at a very low ebb; and the heat was sometimes very oppressive for foot travelling, carrying a heliostat, for distances which completely astonished the farmers, sometimes over large wastes of white sand, sometimes over a desolate and barren country. But the freedom from confinement, the liberty enjoyed, and the wild grandeur of the mountain scenery, would compensate for many annoyances.

By the absence of wood and water the Cape loses the principal charms of scenery; its chief beauty in the lowlands consists in the vast extent of view; but the mountains are magnificent in form, and at sunrise and sunset the colouring is often splendid. Lunar rainbows are sometimes seen, and very curious and splendid views are obtained (when standing at a great height) of the tops of mountains, with every rock most distinctly seen; they appear like islands through the clouds which form a thick white carpet spread level below.

There was the relaxation of exciting sport for such as wished for it when work could not be done, which relieved the total absence from society; and in some places fish were caught.

We found the Dutch farmers generally hospitable, upon the whole more universally so than the English colonists. They were at first very suspicious of a government survey, and were afraid it would interfere with their property, but after a time became reconciled, though they could not see any object in it.

The sudden changes of temperature were distressing; I have known it at 32° on the grass at the first daylight, and to rise in the shade within a double tent to 100° in the middle of the day.

I used a tent lined with green baize, it lasted well, and was some protection from the heat and especially from the glare which would otherwise have been unpleasant to work in. The men had also double canvas tents, but patrol tents were often used in the mountains.

It was unfortunate that, during 1859 and 1860, while the work was going on in the western province, a very severe drought should have prevailed there, and that, when in 1861 and 1862, the work had advanced into the eastern province the drought should afflict that province, while the western province had abundance of rain.

This could not have been foreseen, but it added to the expense of the work.

In computing, the system of the Ordnance Survey was followed.

When the field books were received in the office the angles were protracted, and abstracts made of the observations. These were made by the "first process abstract," which consisted in reducing the angles between every object and the R. O., the means of which were taken. A certain amount of probable error was involved on account of the assumption that no error existed in the observations to the R. O. This would be very trifling, but was eliminated for the stations near the base line by the "second process abstract" which allowed to the R. O. its due proportion of error.

The angles thus obtained were then tabulated in a "general abstract," which arranged them regularly from 0° to 360°, in their bearings in azimuth from the south point round by the west, an arrangement of the greatest convenience to computers, who could thus take out the included angle between any two objects by inspection.

The three angles of all the principal triangles were observed so that there were no inferred angles in that part of the triangulation.

The triangles were computed from angles taken from the general abstract according to Legendre's theorem: the reciprocals of the weights were calculated by the formula $\frac{n}{2.\ \text{square of errors}}$, where (n) is the number of observations.

The spherical excess was computed and applied, and the residual error divided amongst the angles in proportion to the reciprocals of the weights. In determining the final lengths it was the practise to compute a side common to two or more triangles, as for example the sides all along the Langebergen were common to the north and south series of triangles, and a final length was given according to judgment, depending upon the number of observations, the weights of the angles, and the shape of the triangles, whether well conditioned or otherwise.

The solution of all the equations of condition might still have been done at any time, if the abstracts and observation books had not been lost at the wreck which occurred; but it was considered to be beyond the scope of the work. The corrections would have been very small and a vast amount of labour would have been involved. It was considered better to trust to a great number of carefully observed angles for accuracy, than to any mathematical distribution of errors according to probabilities. In fact, it may be considered that the accuracy of the work was mainly due to the number of observations.

The altitudes were determined by the observed angles of elevation and depression, based upon lines of levels run up from the sea to the stations at Kapocberg, Cape L'Agulhas, Mossel Bay, Cape St. Francis, Algoa Bay, the base line, and Cape Morgan. And it may be remarked that the computed altitude of Cape St. Francis carried over from Cape L'Agulhas, 275 miles in a straight line, agreed with that obtained by spirit levelling to within 23 feet, which was the largest discrepancy, so that when this was distributed there was probably very little error.

The latitude, longitude, and reciprocal azimuthal bearings were computed geodetically according to the formulary used on the Ordnance Survey of Great Britain, taking the points Kapocberg, Great Winter Hoek, Zondereindeberg, and Cape L'Agulhas, (so accurately determined by Sir T. Maclear) as data. The latitude, longitude, and reciprocal bearing in azimuth of any point was determined from two or more other stations and the mean taken.

The very clear agreements of the results proved that there were no errors in the computations, and that the bearings and distances on which they were based were not contradictory.

The latitude and longitude of every point fixed was calculated.

All calculations of every kind, reductions, abstracts, &c., were made independently in duplicate, compared, and checked.

Babbage's tables of logarithms were used, and the length of the radius of curvature and normal taken from Airy's Elements given in the Encyclopædia Metropolitana.

The necessity of measuring a base line of verification to test the accuracy of the work by a comparison of the length of one side of a triangle as determined by computation, with the same side actually measured on the ground, was foreseen at an early period; and Ramsden's steel chain was recommended to the Governor. It had given very consistent and satisfactory results on the Ordnance Survey, and there would be a great saving in time and expense in using it in preference to Colby's bars, and it was thought that the loan of the chain could be obtained from the Ordnance Survey. It was found, however, that Ramsden's chain was no longer available, and as time began to press, His Excellency decided that a base line of verification should be measured with the Royal Observatory standard chain.

After a very close and critical examination of the country, a line was selected suitable for measuring a base of 5½ miles long. It was situated on a narrow ridge of elevated ground between the Kap and Great Fish River, being a lower spur of the Drivers' Hill Mountain; there was a commanding view from each end of the base, which ends were reciprocally visible, the ground was free from bush or other serious obstructions, and sloped gently downwards at a nearly uniform incline from west to east. The ground was in some places hard and rocky or stony, but otherwise was favourable for the measurement.

The country in this neighbourhood presents very few spots which are suitable, for the greater part of it is closely intersected with steep and precipitous kloofs; the high ground is almost invariably broken, steep, and rocky; if level places are found in the valleys they are so closely confined as to command no view.

The measurement of the base was begun in June, 1862, after the completion of all the observations as far as the Great Kei River.

The chain was made by Cary, and was marked L 50 on the register scale. It was approximately 100 ft. long, and made in 40 links of steel in round rods ¼-in. in diameter, and each 2 ft. 6 in. long, which were welded at the ends to form loops for flexible joints. Handles of brass for drawing the chain tight were fixed on at about 6 inches from each end; and at the end of the first and last links oblong rectangular pieces of brass were fitted on; they had one side graduated, and a line was drawn across the middle of each shewing the points marking zero and 100 feet respectively.

This chain was of the same length as the Ramsden's chain, and so far similar in construction that both were made of links of steel jointed together, though the observatory chain was confessedly inferior to the Ramsden, and a loop-joint chain was necessarily less to be depended on than a bolt-joint: the mode of using them must therefore be necessarily somewhat similar. Colonel Mudge had written a very complete account, given in full detail, of the measurement at Hounslow with the Ramsden's chain, which was referred to, and apparatus provided accordingly, with such alterations as circumstances seemed to suggest.

The whole party was employed at the measurement. The two ends of the base were marked by brass plugs let into the rock and run with lead; in these plugs platinum wires were inserted, the terminal points being marked by dots.

The line was laid out by bandrols, which were placed in position by signals from the two large instruments centred over the terminal points.

The base line was measured in hypotheneuses of variable length according to the slope of the ground, and was also divided into three sections for mutual comparison by triangulation.

The line the chain was to occupy was traced through the air by boning-rods and a boning telescope, the vanes being set at the angle of slope of the hypotheneuse. The chain was supported in five open coffers, resting on tripod trestles, which were brought to coincide with the line of inclination of the boning vanes by spade work and wedges. The intermediate alignment was directed and preserved by the 7½-inch theodolite, mounted on a portable wooden stand which had a slight lateral motion by means of side screws working against a dovetailed plate.

The front end of the chain was dragged forward at an uniform tension by means of a weight of 43 lbs. attached to the front handle of the chain and running over a pulley. The rear end of the chain was held steady and brought into its proper position by hooking on to the rear handle a " drawing apparatus," which consisted of an iron for holding fast to the handle of the chain, attached to an iron bar; this bar was tapped as a male screw with a handle at the rear end for turning it round. It passed through a hole in a post driven for the purpose, in which hole was inserted a female screw through which the drawing bar passed, and by this means the chain could be drawn backwards by screwing up, or, if required, slackened out, in which case it was drawn forward by the weight over the pulley.

The positions of the front and rear ends of the chain were marked by metal register slides, which fitted on to posts driven in at the extremities of the chain. There was a vertical pin to each register slide which worked in a groove, so that it could be slipped backwards or forwards to any required point and there clamped by a screw for that purpose.

In registering the chain, the zero line on the rear end of the chain was brought by means of the drawing apparatus to coincide with the position of the vertical pin on the register slide at that end (which was clamped to shew the front of the last chain), and the chain being drawn tight by the weight and pulley, the front end was marked by sliding the pin on the front register slide till it agreed to visual coincidence with the 100-feet line on the chain, where it was clamped, and the chain carried forward for a fresh measure.

Three thermometers were placed alongside the chain in the coffers, their readings being noted in the books for every chain laid. Calico covers were provided for covering up the coffers when the sun was out. The measurements were recorded by two persons, separately, in the field books.

The altitude of the base line was determined by levelling down to the sea, and the inclination of the hypotheneuses determined by spirit levelling along the line.

To prevent the necessity of having to go back very far in case of any accident happening, or any doubt arising about any part of the work, the end of each hypotheneuse was marked by driving a stout picket into the ground, steadied by struts; the top was sawed off at the required height, and a circle of copper fastened on the top of it, on which the end of the hypotheneuse was scored with a knife, thus supplanting the register slide at that point.

The chain was compared for length during the work as follows:

At the commencement it was stretched exactly in the same manner as was done in carrying on the measurements, and the terminations scored on copper discs let into the tops of heavy stone pillars placed for the purpose; it was taken back to the same place and relaid at the end of the 53rd chain and at the end of each of the three sections. After correcting for temperature, the greatest difference in length was only ·03 of an inch, from which it may be inferred that the length of the chain had not altered very materially by wear and tear, and that the error to be expected in laying the chain on account of incorrect observation and adjustment was not large, and would not introduce much error into the measurement, as it might lay in different directions.

When the measurement was completed, the chain was sent down to the Royal Observatory, where Sir T. Maclear was kind enough to have it at once compared with the Cape standard bar, to obtain the correction for the difference between the actual length of the chain by measurement and 100 feet, which it was supposed to be. The correction when ascertained was applied.

The length of the base line was then computed; the hypotheneuse was reduced to horizontal distances, by dividing the square of the difference of height by twice the length, to find the correction. The hypotheneuses were reduced to sea level, and the mean reading of the thermometers taken, allowing an expansion or contraction of 0·00763 inches to the 100 feet for each degree of Fahrenheit. The measurement and reductions being completed, the length of the base line was found to be 28804·8502 feet, while by the geodetic calculation in the triangulation carried through from Zwartland base it was 28805·92—difference 1·07 ft., which shewed the total amount of error upon the calculated lengths.

The operation was executed with considerable minuteness of detail which is not here described, but it was as carefully and accurately performed as the nature of the chain would warrant and allow of.

The base line was divided into three sections, which were afterwards compared with each other by a triangulation, and the discrepancy being small, it may be inferred that the measurement was not far from the truth.

It would have been much better if a superior chain or other measure of length could have been obtained in time: the Ramsden's chain would probably have been sufficiently good for the purpose.

For determining the azimuth by astronomical observations, the universal instrument was used; a referring object, of the description recommended in the account of the triangulation in the Ordnance Survey, was set up, and a bull's-eye lantern was placed between the iron strips, which gave a point of light resembling a star. The direction of the meridian was ascertained by the mean between the greatest eastern and western prolongations of α Octantis and ϵ Pavonis, two well defined stars near the pole. On comparing the azimuth at the east end of the base determined by astronomical observations, with that computed geodetically, there was a difference of only 0·854″.

In observations for latitude the instrument was placed in the meridian; only meridian altitudes were used; sometimes they were taken with the instrument face east and face west, and sometimes by applying the zenith point. The refraction was taken from Bessel's table of mean refraction. At the east end of the base the latitude from astronomical observation was 33° 23′ 15·877″

Ditto geodetic calculation	33° 23′ 17·084″
Difference	0° 0′ 1·207″

Transits of moon-culminating stars were taken for the determination of longitude. No chronometers were supplied for the survey, and only a pocket chronometer could be borrowed from the Royal Observatory.

As soon as the measurement of the base line and consequent calculations were fully complete, the work was finished.

It was complete in every part, had stood severe tests, and was ready to be handed over in a state which gave great pleasure and satisfaction to those who had been engaged upon it. The triangulation had spread over a great extent of country, from Table Mountain, on the west coast, to beyond the Great Kei River, which bounds British Kaffraria on the east, being a belt of some 600 miles in a straight line, by about 90 to 100 miles, or nearly equal in size to Great Britain.

It consisted of a main principal triangulation, with a partial minor triangulation extending all along the coast line for the use of the Admiralty surveyor, and many other beacons had been erected and were fixed by observations, these beacons being especially intended for future observing stations.

The cost of the whole work, including every expense for the pay of officer and men, transport, hire of offices, and all sundry expenses, amounted to close upon £10,000.

The original letter of instructions directed that the triangulation should go to the eastern frontier of the Cape Colony, which is the Keiskamma; but Sir George Grey, then the Governor, told me it would be extended through British Kaffraria, Kafirland proper, and Natal Colony, and this only as a preliminary for secondary work and further extension. I accordingly selected the position of the base line of verification near the Fish River, intending to measure another at the north of Natal. Finally, however, it was decided that British Kaffraria should be included, but as funds were not forthcoming for the further prosecution of the survey, it was suspended at the Great Kei. The extension of the survey to Natal would have been very valuable, as providing data for the hydrographical survey especially.

The importance of a secondary triangulation, reducing the lengths of the sides to four or five miles, was pointed out, but could not be undertaken for want of funds. Its value to a colony can scarcely be over-estimated, and it would be a measure of great convenience and ultimate economy. At the Cape all titles to landed property are registered, with an accompanying diagram or plan of the property, in the Surveyor-General's office. There is much dispute, litigation, and expense connected with the land, more especially in a colony where by law the property is divided amongst the children on the death of a parent.

Surveys are made which disagree with the old plans, and resurveys are again made which still do not satisfy. There are many skilful surveyors in the colony, but they greatly require the assistance of established data to determine the position of their work geographically and to test its accuracy and value. At present if two surveys disagree there is no means of deciding which is correct.

If a secondary triangulation were made all private surveys might be attached to it, and thus the way paved for accurate plans of the country in course of time. It would be of the greatest value in laying out roads, railroads, works of irrigation, &c., for the distances between the beacons would be short and the general line of the road could be traced at once with tolerable precision and filled in accurately. It may be considered certain that many public works are not attempted on account of the want of proper plans representing accurately the topography ; and the want of accurate plans must necessarily be an obstruction and hindrance to the commencement of undertakings of private companies.

Whatever objects relating to the land may seem the most important to individuals, whether it be registration of property, statistical enquiry, divisional and local wants, sales of government lands, irrigation, civil engineering, roads, geological or military surveys, or agricultural wants, and comprehensive schemes for improvement, it is quite manifest that for each and all of them the first and indispensable requirement is the possession of accurate and reliable maps or skeleton secondary triangulation, from which they can be readily constructed; the absence of these must operate greatly to the disadvantage of the government, and be a stumbling block to Parliamentary action and to the proper development of individual enterprise.

This is especially the case in a new country like the Cape Colony, where there is not even a good travelling map of the country ; the desideratum can only be supplied by the execution of a secondary triangulation, reducing to sides of four or five miles, conducted under the auspices of the government so as to give it the prestige of authority and the impress of perfect reliability, and which would be gradually expanded into a general map.

Before commencing a survey of this kind it is desirable that the full scope and object of the work be fully discussed and decided upon, that no interruption may take place. It would be an advantage to have it done by a larger party of men if possible, for the cost of superintendence necessarily figures as a large item in work of this nature when done with a small party; and there is another great advantage in the power of selecting men for the work with more varied attainments and abilities. For this sort of work it is decidedly of great importance to have a good staff of qualified observers, so that in case of illness, or the necessity of relieving an observer temporarily from severe duty, the work would not be hindered. Some of the observers should be well practised in astronomical observations, which can now (through Sir H. James's care) be so well studied by officers and men in the Observatory at the Ordnance Survey Office, Southampton. There should be in the party, if possible, men well acquainted with all the forms and computations used in the Ordnance Survey, and skilled in general surveying and drawing in every branch, and in laying out a triangulation.

It was not to be expected that all this could be obtained by so small a number as one sergeant and five men from the survey companies. Taking the party as a whole, they deserved the highest praise for their energy, ability, and good conduct; some of the men took their discharge in the colony on the completion of the work, amongst others, Corporal Purdy, a most invaluable observer, who took employment under the Admiralty surveyor.

The survey office at the close of the work was at Graham's Town, and it only remained to proceed to Cape Town to hand over the work in its complete state before leaving for England.

The party embarked on board the coasting steamer "Waldensian," having with them the instruments and stores, with the greater part of all the observation books and sheets, calculation books of every kind, diagrams, and abstract books, and other documents connected with the work, together with copious notes I had made upon the geology of the country, based upon a geological survey by Mr. Wyley. The vessel struck upon a reef of rocks off Struy's Point, and soon broke up into a total wreck. Of her cargo nothing could be saved as it was dark at the time and the hold immediately filled with water; the vessel was a long way from shore and crowded with passengers. The whole of these important papers were therefore lost to my infinite regret and annoyance.

It was a serious blow to the work to lose unexpectedly its original records of observations and so much of what was deduced from them, and it may appear highly imprudent to have exposed them to the risk of sea passage. The books, however, were in daily use and could not, without loss of time, be sent down by the previous steamer, and such a mass of books and papers could not be sent by horse post. I looked upon a passage of two or three days in a coasting steamer as not more dangerous to the work than the chance of fire at the office. This was wrong however, for complete abstracts should have been sent down, and the duplicate observation sheets and calculation books by the next steamer (which would have caused a month's delay). It is easy to see this now.

My personal mortification was immense at the loss of so much of the original documents belonging to the work which had just been brought to a successful conclusion; and I deeply regretted the loss sustained by the colony, the effect of which might be to throw discredit upon government surveys and discourage the desire to prosecute them further.

Every effort was made to recover anything that could be got from the wreck, and careful search instituted for any of the lost papers, but not a scrap was recovered, principally owing to the strong current along the coast.

It remained as the only resource to gather in from every quarter such portions of the work as were available, and to reconstruct it afresh as far as was practicable.

The whole abstract of the coast line triangulation had been supplied officially to the Admiralty surveyor. The whole of the abstracts east of the Great Fish River, with observation books or sheets, had been sent in to the Government of British Kaffraria. Portions of the abstracts had been supplied to the Surveyor General and to others; and some books had been sent down by post.

From the above data, and from other sources, the work was again compiled and reconstructed with the greatest care, so that more remained than probably might have been expected after so serious a catastrophe.

Though the greater part of the field books were lost, there still remained a sufficient number of them to be taken as a fair sample of the whole, and these might be examined and tested with every severity. In the various abstracts, lists of latitude and longitude, and other papers which had not been shipped on board the "Waldensian," there was contained abundant intrinsic evidence to prove the general correctness of the work.

There was no flaw or deficit with regard to the principal stations; almost all the horizontal distances were collected again, with the determinations of latitude and longitude quite complete, so that though some of the vertical heights and the reciprocals of weight, and processes of abstract were lost, there remained enough to supply all the most important objects of the survey—of which in primary importance was the provision of data for the hydrographical survey.

This was fulfilled by supplying to the Admiralty surveyor exactly the same information as would have been done if no wreck had occurred; valuable data were also supplied to the Surveyor General, and the triangulation as left will form a basis for future operations, should such be undertaken.

The following documents were handed in:—

(1.) A general abstract of all the angles, tabulated for the use of computers, and containing all the distances in feet, with the altitudes and reciprocals of weight.

(2.) A book containing descriptions of all the beacons erected during the survey.

(3.) Lists of the latitude and longitude of all the stations, piles, beacons, and permanent objects observed, together with the altitudes where known.

(4.) A large diagram on a scale of four miles to an inch, shewing the whole triangulation.

(5.) A small diagram of the principal triangulation.

(6.) A sketch diagram of the apparatus used at the measurement of the base line.

With a report containing an account of the operations, and drawing especial attention to the reliance to be placed in the materials used for reconstruction.

The Governor, Sir Philip Wodehouse, wishing for a confirmation of my views on this matter, and desirous to have the true value of the work ascertained, requested Sir Thomas Maclear, Astronomer Royal, and Mr. Bell, Surveyor General, to examine the work and express their opinion on the value of the work done.

They appear to have critically examined it in detail after I left for England, and wrote a report upon it which is given below.

W. BAILEY.

REPORT.

Opinion of SIR T. MACLEAR, Astronomer Royal, and CHARLES BELL, Esq., Surveyor General, on the substantial value of the Trigonometrical Survey executed by CAPTAIN BAILEY, R.E.

In compliance with the memorandum of His Excellency the Governor, under date the 23rd of March last, we have to submit the following as our opinion as to the value of the work done by Captain W. Bailey, Royal Engineers, on the trigonometrical survey of a portion of the colony and British Kaffraria, and as shewing in how far we concur in the concluding portion of his report forwarded to the Honourable the Colonial Secretary on the 18th March, 1863.

1. The work, so far as we have been able to examine it, appears to us to have been carried out with judgment and ability. The system adopted in measuring, registering, and calculating the work, seems to have been similar to that pursued on the Ordnance Survey of Great Britain, on a modified scale, taking the com-

mencing data for length, latitude, longitude, and azimuthal bearings, from points established in the Cape arc of the meridian; and a prominent instance of his intention to perform the operation with all practicable accuracy is given by his falling back about 150 miles to triangulate up from a second distance of the arc of the meridian chain of triangles, for the purpose of comparing the result with the already measured distance, Zondereinde to Potteberg, rather than depend upon one determination only. Another instance is furnished by the solicitude he displayed in obtaining permission to test his work, when nearly completed, by means of a base of verification in the Eastern Province, the most severe test that can be applied to a geodetic operation. And a third, by comparing the latitude and azimuth of a point at the base of verification, derived from direct astronomical observations, with the latitude and azimuth of the same, resulting from the geodetic operation derived by calculation through the chain of triangles he had measured.

2. The close agreement of the first test was remarkable, the difference being only one-fifth part of a foot. The result from the base of verification was a difference of 1·07 feet, or 13 inches nearly, which quantity represents the accumulation of errors through a chain of triangles extending from Zwartland near Malmesbury in the West, to near Graham's Town in the Eastern Province, presuming the base of verification to have been rigorously accurate.

3. The third test he proposed, and which he carried out, involves the element which presents the chief difficulty in geodetic operations undertaken for determining the dimensions and figure of the earth, namely, *local attraction*, the effect of which, in the neighbourhood of mountain masses, or inequalities of density below the surface, is a discrepancy of more or less magnitude between the astronomical and terrestrial determinations of latitude and azimuth, no matter how correct the observations may have been*. Therefore if Captain Bailey's astronomical observations had been more refined than they were, still the test could not be accepted with perfect confidence. However, it so chances that the disturbing force in azimuth amounted to only about $\frac{8}{10}$ of a second, and in latitude to about 120 feet, referred to a great circle on the earth's surface.

4. These proofs are a sufficient assurance that the operation was conducted with the requisite degree of accuracy; therefore, the next step is to inquire how far the loss of records, which were on board the "Waldensian" when that vessel was wrecked, affects its usefulness.

5. We learn that the whole of the observation books and calculations founded thereon, all complete, disappeared with the vessel. This statement refers to the triangulation of the colony only. The registers and calculations of the triangulation in Kaffraria, including the adjacent stations of the colony, had been left at Graham's Town in all their integrity.

With respect to the survey of the colony, he had most fortunately supplied the Surveyor General, the Admiralty Surveyor, and Dr. Rubidge, with large sections of it; he had, moreover, other documents for reference, which he specifies.

* An instance appeared at one of the arc of the meridian stations in this colony of several hundred feet in the direction of the meridian.

6. By assuming the usual arrangement of trigonometric documents, we shall be better able to describe what were lost or saved.

(*a.*) *Observation or Field Books.*—These contained the whole of the original measures and observations made at each station. They are lost, but a copy of a portion, shewing the horizontal angles, is extant.

(*b.*) *General Abstract of Angles.*—The original is lost, but Captain Bailey constructed another from the several sources he has stated.

(*c.*) *Calculation in detail of Triangles.*—This document is lost, but the reconstruction is extant.

(*d.*) *Calculation of Latitudes, Longitudes, and Azimuths.*—A large portion, if not the whole, of the original, is extant. It has not been closely examined. Judging from its appearance, there is little doubt that the corresponding document lost in the "Waldensian" was a fair copy of this*.

(*e.*) *Calculation of Heights.*—The distances required for the calculation of the heights of the principal stations and many of the intersected objects are extant, and the altitudes of upwards of seventy points have been given; but many of the angles of elevation or depression were lost in the field books.

(*f.*) *A General List of Latitudes, Longitudes, and Heights of Stations.*—This document is complete except as to heights.

(*g.*) *Astronomical Observations.*—The originals are wanting; the results are given in detail †.

(*h.*) *Measurement of the Base of Verification.*—The original register of this operation is lost.

(*i.*) *Description of all the Beacons erected during the Survey.*—This document is complete.

Of these the most important are *b*, *d*, *f*, and *i*.

The proof of the accuracy of the triangulation is given by the base of verification, and an approximate proof by the astronomical determination. We are, therefore, of opinion that the data reconstructed by Captain Bailey may be received with confidence and employed as elements for a correct geometric ground plan of the surface he has triangulated.

7. The geometric plan gives, with extreme accuracy, upwards of two hundred and seventy points, and other data, many of them fixing, or giving the means of easily ascertaining, the exact position of towns, villages, or important geographical features, and all referable to the land register of the colony, at a small cost, by connection hereafter with existing or future surveys.

8. With regard to the land registry, it is scarcely possible to estimate the value of such an important aid in rectification, where required; and we think

* It was one of the duplicate calculation books.—W. B.

† Only partially, some were lost.—W. B.

that, with due care in the selection of the surveyors to be employed, and due allowance for instruments, and extra work, according to circumstances, the ordinary property surveys within the beacons or piles now established, may be made to meet nearly all the purposes proposed by the secondary triangulation suggested by Captain Bailey*.

9. From this it will appear that the loss of the documents by the "Waldensian" has affected the usefulness of the work to no very serious extent. †

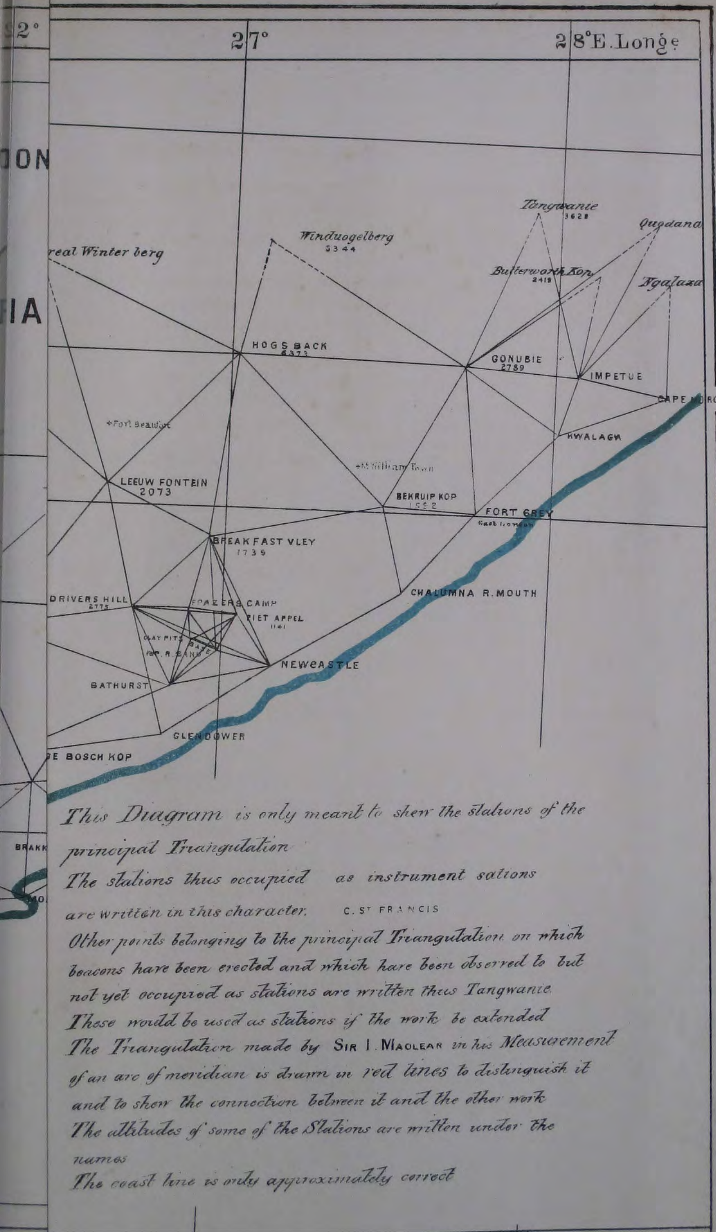
10. In conclusion, we advise the immediate and accurate multiplication of copies of the "General Diagram," "General Abstract of Angles," and "Description of Beacons," for safe deposit and circulation wherever they are likely to be preserved and used, so that the valuable data now acquired may not be again exposed to such risk as that to which they have been already subjected; for even in the safe of the surveyor general's office they are not in perfect safety from accident by fire and other damage.

(Signed) T. MACLEAR,
CHARLES BELL.

Cape Town, 6th May, 1863.

* Doubtless by selecting good surveyors, &c., the work may be filled in; but decidedly the best and cheapest course would be to make the secondary triangulation, and thence gradually maps and plans, by Government surveyors or Royal Engineers.—W. B.

† The work of re-construction was very tedious; from the nature of the materials used, minor and unimportant discrepancies will have been introduced, for many of the abstracts and diagrams shewing the distances which were used for re-constructing had been sent away from the office early in the work to the several persons who required them, perhaps before the final lengths had been definitely decided. However, as these would seldom have involved corrections of more than an inch to a mile, and would not have affected the main lines and abstract of angles, the work may be considered practically as accurate as before. It was not thought worth while to re-compute the triangles and equate the errors over again with the imperfect data which were left available.—W. B.


27°
28°E. Longe
Tangwanie
3628
Qugdana
Winduogelberg
5344
real Winter berg
Butterworth Kop
2419
Ngalaza
HOGS BACK
6373
GONUBIE
2789
IMPETUE
CAPE MORGAN
Fort Beaufort
KWALAGH
LEEUW FONTEIN
2073
BEKRUIP KOP
FORT GREY
East London
BREAKFAST VLEY
1739
DRIVERS HILL
2775
FRAZERS CAMP
PIET APPEL
1141
CLAY PITS
BASE
CHALUMNA R. MOUTH
NEWCASTLE
BATHURST
GLENDOWER
BOSCH KOP
This Diagram is only meant to shew the stations of the principal Triangulation
The stations thus occupied as instrument sations are written in this character. C. ST FRANCIS
Other points belonging to the principal Triangulation on which beacons have been erected and which have been observed to but not yet occupied as stations are written thus Tangwanie.
These would be used as stations if the work be extended
The Triangulation made by SIR I. MACLEAN in his Measurement of an arc of meridian is drawn in red lines to distinguish it and to show the connection between it and the other work
The altitudes of some of the Stations are written under the names
The coast line is only approximately correct

PAPER VII.

NOTES ON THE JARRAH TIMBER OF WESTERN AUSTRALIA,

WHICH IS PROOF AGAINST THE WHITE ANT AND SEA WORM,

EMBODYING THE EXPERIENCE AND THE SUBSTANCE OF VARIOUS REPORTS MADE BY

LIEUT. COLONEL HENDERSON, CAPTAIN WRAY, CAPTAIN GRAIN, AND CAPTAIN DU CANE, OF THE ROYAL ENGINEERS.

Communicated by CAPTAIN DU CANE, Royal Engineers.

The timber in question is commonly called "mahogany" in Western Australia, and it very much resembles that wood in appearance. The native name is "jarrah" and the botanical name of the tree "eucalyptus." It has properties which make it peculiarly applicable for works in the tropics or on the sea coast, viz., that neither the white ant nor the sea worm will touch it, and that it suffers very little from exposure to the sun or atmosphere.

Captain Wray, Royal Engineers, says in a report,—"As regards its properties, I have myself used upwards of 3,000 loads of it in buildings, jetties, and bridges, and I have examined timbers which have been exposed to the action of the white ant and sea worm, in situations where it would have been destroyed, if liable to destruction from either of these causes, and I never saw any penetration deeper than the sap-wood, though deal or other timber close by was completely eaten away. This indemnity from destruction is generally attributed to its containing large quantities of gum resin. The strength and elasticity are about equal to Riga fir. This was ascertained by a series of experiments on beams with a bearing of 12 feet, conducted by Mr. Manning, clerk of works at Freemantle. I know of no objection to it, except that it is somewhat slow to season, and if exposed before seasoned, will fly and cast perhaps rather more than other timbers. The plan lately adopted in Western Australia to season it, was to leave the logs in the sea for a few weeks and then draw them up on the beach, and cover them with a few inches of seaweed, taking care to prevent the sun getting at their ends. My experience led me to the conclusion that logs might lie in this way without injury for almost any length of time. Boards were cut seven inches wide, and stacked so as to admit a free circulation of air for five or six months before using."

The consulting Engineer of the Madras Railway says,—" The wood is well spoken of by our Engineers. The trial has not as yet been long enough to enable the qualities of the wood to be thoroughly tested on the Madras railway;" but the Engineer says, in January, that "those placed on the road in July, are in good condition at this date and form an efficient substitute for teak in girder bridges."

A specimen forwarded to be exhibited in the Great Exhibition of 1862, was certified to have been used as a door-step at Freemantle, where the white ant is most destructive, *for about* 30 *years.*

The accompanying copy of a report by Professor Abel, chemist to the War Department, tends to shew that the immunity is due to the wood containing poisonous matter powerful enough to affect even mice.

Report as to Jarrah Wood from Western Australia.

Royal Engineer Office, Freemantle, Dec. 20th, 1861.

Sir,—Referring to your letter of the 2nd August, 1860, authorising the transmission of pieces of timber of this colony for analysis, and of the 19th March, 1861, I have the honour to inform you that I have selected four pieces, which will be forwarded by the ship "Gloucester," addressed to the chemist, War Department, Arsenal, Woolwich.

No. 1—5 feet 4 inches long, by 2 feet in diameter—is *tuart* from the southern district. It is a hard, compact, and durable wood, and has been shipped to England in considerable quantities for the Dockyards.

It grows upon light soil with limestone base. It is subject to the attack of the white ant and the teredo navalis.

No. 2—3 feet long by 1 foot 7 inches in diameter—is *jarrah*, from the southern district.* This timber is very durable both in and out of water. It is impervious to the attack of white ant and also of the teredo navalis.

Neither of these insects have ever been known to attack this timber when sound, but it is frequently defective of heart, and it then loses its quality of resisting these insects, *so far as the defects extend.*

In any order, therefore, for this timber, it is very desirable to have it in flitches, so that the defective portion may be cut out in the colony and the good only exported.

No. 3—3 feet long by 1 foot 6 inches in diameter—is a defective piece of jarrah, to show the difference, and in order that the cause of its losing its properties of resisting the white ant, &c., may, if possible, be ascertained by analysis.

These specimens grew upon the iron-stone country, which is the best description of country to obtain it from.

It also grows in sandy swamps, but the timber is not so good and does not stand so well.

No. 4—3 feet long by 1 foot 4 inches in diameter—is *gardan.* It grows upon sandy or clayey loam, and has invariably a clay substratum. It can be obtained in very long lengths, but is destroyed by the white ant and the teredo navalis. It is also very full of gum. I shall be glad to receive the result of the analysis.

I have, &c.,

(Signed) E. M. GRAIN, Captain, R.E.

The Director of Works, &c.

* Of Western Australia.

Royal Arsenal, Woolwich, Feb. 4th, 1863.

Memorandum for the Director of Works, &c., with reference to Samples of Wood forwarded for examination to the Chemist of the War Department, by the Commanding Royal Engineer in Western Australia.

A careful comparative examination has been instituted between the specimens of sound jarrah wood, and of tuart and gardan woods for the purpose of ascertaining whether any cause of the immunity of the first-named wood from the attacks of insects could be traced by chemical means.

Undoubted evidence was obtained, as the result of this investigation, of the existence in the specimen of sound jarrah wood of a highly astringent organic principle, of the presence of which the other kinds of wood furnished no indications.

This principle appeared, as far as could be judged from its properties, in the comparatively impure form in which only it could be obtained, to resemble greatly some other bitter organic principles obtained from vegetable sources, which are possessed of poisonous properties. The effects of it were tried on small animals (mice) and were undoubtedly of a powerfully poisonous character. No positive deduction can of course be drawn from this circumstance regarding its possible effects upon insects such as the white ant and teredo navalis.

The above result constitutes the only peculiarity traceable by chemical means, which can be pointed out as having a possible connexion with the circumstance that the jarrah wood is found to be proof against the attacks of insects.

The specimen of jarrah wood, defective or decayed at heart, which accompanied the other samples, did not furnish any satisfactory evidence of the existence, in the defective parts, of the bitter principle above referred to, as occurring in the sound wood.

This circumstance, coupled with the statement made by the Commanding Royal Engineer, Western Australia, that the decayed or defective wood does not resist the attacks of insects, favours the supposition that the superiority of the jarrah wood in its sound state, over other woods, may be ascribable to the above cause, which the results of the chemical examination indicate.

(Signed) F. ABEL.

As regards cost, every information will be found in the following extract from a letter from a timber cutter at the Vasse, Western Australia:—

[EXTRACT.]

"Approximate prices of timber put alongside a ship in a safe anchorage on the coast of Western Australia, *i.e.*, at a place where a ship may anchor with reasonable safety:

JARRAH TIMBER.	Per load of 50 cubic ft. £	s.	d.
Sawn scantling averaging not less than 12 inches in section	3	9	0
1-inch or ¾-inch boards	5	14	0
Sleepers 10 ft. 2 in. × 10 in. × 5 in. on average, 1-in. wane on the edge of every 4th sleeper	3	0	0
Or if the specified wane be allowed on each sleeper	2	18	0

(Sleepers taken as $14\frac{4}{10}$ to a load.)

	£	s.	d.
Hewn logs with average 2-in. wane on each angle and tapered, not exceeding a ratio of 1½ inches on each face for every 20 feet :—			
11 inches and under 16 inches mean side	3	2	0
16 inches - 19 inches -	3	5	0
19 inches - 22 inches -	3	10	0
If sawn without taper, additional	1	2	6
Sawn planks, 1½-in. average wane allowable on one-fourth of the angles :—			
Sections not less than 162 inches	3	11	0
Ditto - - 98 inches	3	13	0
Ditto - - 72 inches	3	15	0

These prices, for lengths not exceeding 18 feet 6 inches, an addition of 5 per cent. to be made for every extra 5 feet in length.

Thus for any length over 18 ft. 6 in. up to 23 ft. 6 in., the addition would be 5 per cent.; for any length over 23 ft. 6 in. up to 28 ft. 6 in., the addition would be 5 per cent. + 5 per cent. = 10 per cent., &c.

This timber can be supplied between the 15th September and 15th May at the rate of 800 loads per month, or even more, but in the outset it would be necessary to allow 3 months for the first 800 loads, so as to admit of the organization of the work, *i.e.*, if intended that the orders be on a large scale.

The foregoing rate of shipping is subject to the contingency of obtaining vessels to accept the freight; it is probable that no difficulty would arise on that head, it being probable that the freight would be very acceptable to the coal ships from King George's sound.

This timber resembles mahogany in appearance and weight, its relative and longitudinal strength bears a favourable comparison with other hard woods, its durability, under all ordinary circumstances, is very great, with the additional recommendation that in circumstances where other woods decay rapidly, it remains perfectly sound, underground or in contact with it,* under water or between wind and water; where the *teredo navalis* (the sea worm), white ant, and other timber-destroying insects prevail, it remains perfectly sound. It has been here used for upwards of 30 years for house carpentry, piles, shipbuilding (unprotected by copper), and all ordinary purposes.

These conditions productive of decay, including sea worm and white ant, all exercise full influence here, yet we have not a single instance of actual decay of sound timber piles after many years exposure; coasting vessels, and every other work, all confirm the belief that the timber is durable in a remarkable degree.

The longer the period of notice which can be given beforehand for the preparation of every lot of timber, so much the better, opportunity is thereby afforded for seasoning, which materially enhances the qualities of the timber.

When ordered as hewn logs, it must not be expected that the logs can be hewn to one specified size, the order should allow to arrange an average within the sizes quoted. If specific mean side be wanted, then it would be necessary to charge extra."

* The ground.—Ed.

The jarrah timber supplied for the use of the War Department at the Mauritius cost 1s. 3d. per cubic foot delivered at Freemantle, Western Australia, and 1s. 3d. for cubic foot freight to the Mauritius, making 2s. 6d. per cubic foot.

The cost of teak, which is sometimes used on account of its offering resistance to the white ant, has been, at the Mauritius and at St. Helena, 8s. to 10s. per cubic foot.

The white ant has been found very destructive in China, where it is understood that the teak failed to resist its ravages.

This timber is, it is believed, peculiar to the colony of Western Australia or Swan River; and it is therefore necessary to be careful not to confound it with woods of a similar *species* found in the other colonies of Australia, but which, not possessing its peculiar properties, have, perhaps, in some cases caused this wood not to be properly appreciated.

E. F. DU CANE.

PAPER VIII.

ON A NEW INSTRUMENT FOR TRACING ROADS.

By LIEUT. COLONEL DE LISLE, R.E.

The want of a convenient instrument for tracing roads in difficult sidelong ground has often been felt in India. In some cases the faces of the cliffs or ghauts are so steep that it is difficult to use a theodolite without great risk of destroying it.

It is hoped that the little instrument which is now to be described may facilitate the work of tracing roads in sidelong ground by affording the means of getting a guage path with sufficient accuracy for ordinary roads.

The instrument is an improvement on Colonel Emy's reflecting level. The lower part is a very ingenious application of the bent lever balance, and is the invention of Mr. Cooke, jun., of Messrs. T. Cooke and Sons, opticians, 31, Southampton Street, Strand.

The instrument is in two parts, which divide at the dotted line (Fig. 2), and are fastened together by the thumbscrew *(a)*. When the semi-circular arc *(b)* is opposite the mirror-face, the instrument will give descending slopes; when on the same side as the mirror, it will give ascending slopes; and for packing it can be placed in the same plane as the mirror, with the weight *(e)* on the left hand. It then fits into a wooden case, 5¼ in. × 3⅜ in. × ⅞ in.; the instrument itself weighs little more than 5 ounces.

The mirror is square, hung diagonally by a ring with connecting link and knife edges. The square opening has a triangular mirror on one side, the other half being quite open so as not to obstruct the light. The mirror-frame terminates in a square bar shewn by dotted lines in Fig. 2. This bar fits into a socket in the cylinder attached to the semi-circular arc. The arc has two radial bars moveable on a central pin provided with a clamping nut *(i)*. One bar *(c)* is plain, only carrying a stout pin *(d)* to serve as a handle, the other bar *(f)* carries a heavy weight *(e)*.

When the instrument is required for levels, the bar *(f)* is raised until it touches the screw-head stop *(g)* Fig. 3, and the bar *(c)* is pushed home into a grooved recess in the weight *(e)*. This position is shewn in Fig. 1.

For a slope of 1 in 50, let the bar *(f)* remain against the stop *(g)*, but move the bar *(c)*, by means of the handle *(d)*, until it touches the screw-head stop *(h)* Fig. 1. This position is indicated by dotted lines in Fig. 1.

For any other slope, leave the bar *(c)* against the stop *(h)*, and set the bevelled edge of the bar *(f)* to the required division on the graduated arc of the semi-circle, as in Fig. 3, where the instrument is shewn set to a slope of 1 in 20.

The weight *(e)* slides on the end of the bar *(f)* and is secured by a screw; this gives the adjustment required for a true level, and also the means of correcting the adjustment should it get out of order.

When set, the bars can be secured in their places by tightening the clamp-screw *(i)*.

To use this instrument an assistant is required with a staff and sliding vane, which must be fixed at the height of the observer's eye.

The observer then places himself at his starting point, and sends the assistant to a convenient distance, say 50 feet, and makes him move the staff up or down the slope of the hill, until the reflected image of the pupil of his own eye coincides with the centre line of the vane as indicated in Fig. 2.

A peg is then driven in at the foot of the staff and the observer recommences the same operations from this new station and so on.

The maximum gradient allowed in India (Bombay) for mountain passes is 1 in 20; the higher gradients given by the instrument to 1 in 5 are however useful for ascertaining the slopes of existing roads, many of which are very steep.

It is sometimes convenient to suspend the instrument in a wooden case mounted on a staff and provided with sight holes. In this way the instrument can be held more steadily, and there is less oscillation from the action of the wind.

The instrument might be made available for flatter gradients than 1 in 50, by having the face, corresponding to the bar *(c)*, also graduated from 1 in 50 to level. It would then be useful for trial sections for rail or tramways. In this case the bar *(f)* would be kept against the stop *(g)*, and the bar *(c)* only should be set to the required division.

The figures which accompany this description are drawn to full size.

A. DE LISLE, Lieut. Colonel,
Royal Engineers.

Red Hill, 22nd June, 1864.

Fig. 1.

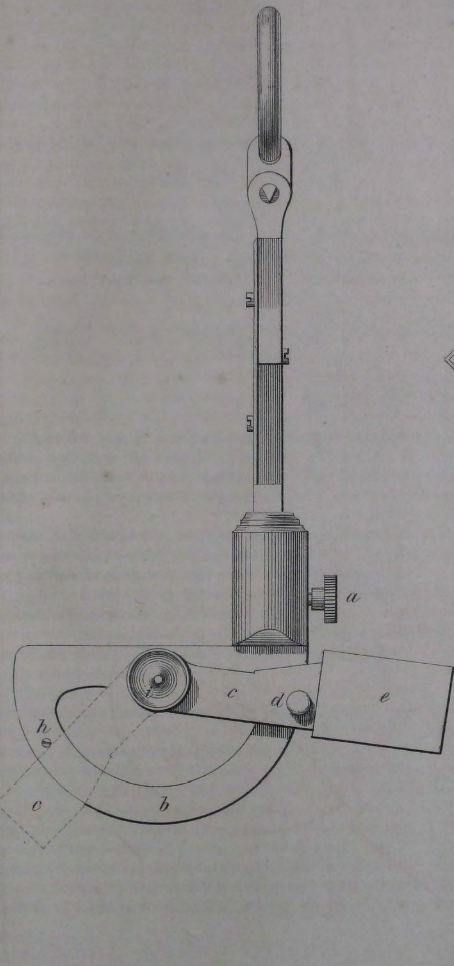
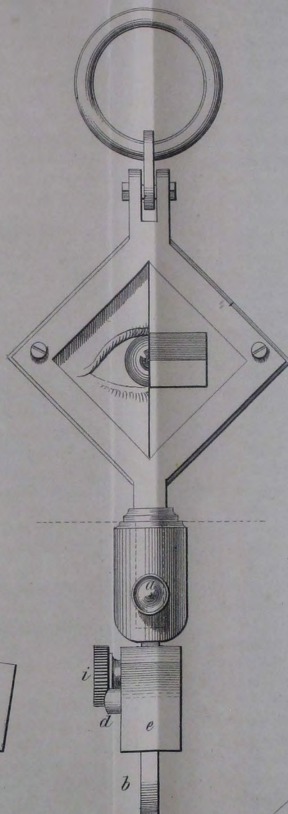
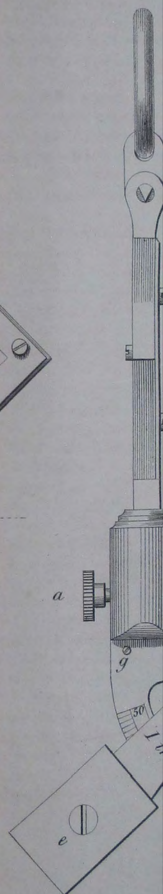


Fig. 2.





Lith[rs] Castle S[t] Holborn.

PAPER IX.

ON THE NEW WORKS OF FORTIFICATION AT ANTWERP.

EXTRACTS FROM A REPORT BY LIEUT. COLONEL GRATTAN, R.E., TO GENERAL SIR J. F. BURGOYNE, BART., G.C.B., INSPECTOR GENERAL OF ENGINEERS, &c.

[Printed by permission of the Secretary of State for War.]

Royal Engineer Office,
Tregantle, 26th December, 1863.

SIR,

I have the honour to report that I proceeded to Antwerp on the 26th of September, and from the date of my arrival (the 28th), until the date of my departure (on the 11th October), devoted myself to obtaining as full an insight as possible into all particulars connected with the new works of fortification in progress.

I propose in this report to describe the arrangements made for carrying out the vast works constituting the new fortifications of Antwerp, and to remark upon any difference of system from ours in similar operations.

General Description of the Works.

In the first instance it may be desirable to give a general idea of the nature and extent of the works.

The accompanying little sketch is intended merely to shew the position of the works. They may be divided into two parts.

1st. The great enceinte.

2nd. The detached forts.

The great enceinte forms an irregular polygon enclosing the town at a distance from its centre, varying from 2,700 to 4,400 yards. It rests at each extremity on a citadel. The two citadels, one on the south side of the town, the other on the north, are close to the river Scheldt. The first is the old citadel of Antwerp, taken by the French in 1832. The second is a new citadel covering a large extent of ground about 132 hectares (326 acres).

The great enceinte is about 15 kilometres (9 miles) in length. Its trace, as well as that of the detached forts, is on the polygonal system.

The enceinte comprises ten fronts, each about 1,100 metres (1,200 yards) in length, and flanked by a caponier in the centre, and on the south terminates by a face about 1,100 yards in length, forming the junction with the old citadel, by which it is flanked. The rampart varies in breadth at the terreplein level from 18 to 20 metres (19 to 21 yards); its parapet is from 6 to 8 metres (19 to 25 feet) broad at the top; command from 7 to 10 metres (22 to 32 feet). The rampart is unrevetted and preceded by a wet ditch from 70 to 75 metres (77 to 83 yards) broad, which can be supplied with water to a depth of 2·50 metres (8 ft. 2 in.). There are two sluices at the new citadel, and one at the old. The four fronts adjoining the new citadel, being protected by inundations, are not so strong as the others. The caponiers are casemated, those on the inundation fronts have 6 guns on each side, the others 14; the latter are covered by ravelins, and, on the two fronts most liable to attack, also by lunettes. The whole enceinte is encircled by a covered-way. A casemated barrack for 1,200 men is provided in rear of each main caponier, and the latter can accommodate men enough for the service of the guns. Ample provision is also made for stores and powder magazines. The communications with the exterior are fourteen in number, viz., one on the inundation fronts, one near the old citadel, and one on each side of the six main caponiers. The gateways fronting the town are very fine structures, the arched openings being about 8 metres (25 feet) broad, by 10 metres (32 feet) high.

The detached forts, 8 in number, are on a line, about concentric with the enceinte, and at a mean distance of about 4,000 metres (4,374 yards) from it. They are at regular intervals of about 2,000 metres (2,187 yds.) from centre to centre, and give a front of about 15 kilometres (9 miles) to the intrenched camp. The forts are all on the same plan and cover a space of 36 hectares (89 acres) each. They have earthen ramparts with a command of 9 metres (29 feet); a wet ditch from 40 to 50 metres (43 to 54 yards) wide, and covered way, bomb-proof barrack accommodation for 1,200 men, magazines, stores, and a large keep in brickwork, affording, besides its independent stores and magazines, accommodation for 200 men. The ditches are flanked by caponiers.

A good notion of the extent of the works of the great enceinte and detached forts will be conceived, when it is stated that they comprise 1 million cubic metres (1,308,000 cubic yards) of brickwork and masonry, and 13 million metres (17,004,000 cubic yards) of excavation. To complete them in the prescribed time will necessitate the employment of 13,000 workmen daily. The expenses of the contractors in establishing workshops, stores, enormous brickfields, quarries, in constructing quays, in purchase of timber, and in plant, including 71,570 running metres (74,934 yds.) of railway, 7 locomotives, 158 horses, and 600 waggons, are estimated at £400,000.

The estimate for the works, including purchase of land, is about £2,000,000.

Besides the works previously enumerated, a fort is also in course of construction on the left bank of the Scheldt, about five miles below Antwerp, at a point where the river takes a sharp bend. This fort, named St. Marie, is an irregular pentagon of a bastioned trace, earthen ramparts, and broad wet ditch, with the front commanding the approach to Antwerp by the river, forming a strong casemated battery for 33 guns. This fort was designed, and its cost voted, previous to the adoption of the general project for the new fortifications.

Contract. The discussions in the Belgian Parliament on the question of the fortifications, in the year 1858, were very exhaustive of the subject. A matter of such great national importance was not hastily disposed of, and the best intelligence in the country was brought to bear on its full consideration. Committees of general officers and others were appointed to consider and report upon various projects; finally, in September, 1859, an act was passed authorizing the execution of the works as now being carried out, and providing the requisite funds.

Tenders, by public competition, were called for on a schedule of prices, and a contract entered into in December, 1859, with Messrs. Pawels and Hobin for the execution of the entire project of the enceinte and detached forts.

The terms and conditions of contract are very stringent, and comprise a greater range of stipulations than is customary in the War Department contracts of which I have cognizance. I propose to quote such of them as bear on the general arrangements for carrying out the works, and some others not usually inserted, or which materially differ from those in our contracts.

The value of the works to be executed was estimated approximately at from 35 to 40 million francs (one million four hundred thousand to one million six hundred thousand pounds), and the time allowed for their completion was four years. The penalty for delay is £20 for each day beyond the time named. The contractors are also bound to maintain the works for six months after completion, and then hand them over in a perfect state.

All persons tendering had in the first instance to deposit a sum of £40,000 as security. This sum was restored to those whose tenders were not accepted immediately after the adjudication thereon; but with regard to the successful competitor, it was to be retained until the conclusion of the contract; a rate of 3 per cent. interest yearly is however paid to him, commencing sixty days after the deposit was made.

The contractors have to provide two personal securities, whose solvency is subject to the same test as that laid down for themselves; they are together and separately responsible for the due execution of the terms of the contract. In the event of the death or failure of either of the securities, the contractor is obliged immediately to appoint another, subject to the approval of the Minister of War. In case of the contractor's death, the government has the power to call upon his heirs, or the securities, to complete the works. Should the execution devolve upon the contractor's heirs, the securities remain bound to the government, and should they be selected to carry on the works, the heirs are to take their place as securities.

Any breach of the terms of contract, or of the conditions specified in the schedule of prices, subjects the contractor to a penalty of from one to eighty pounds, the amount to be determined by the Minister of War, according to the importance of the case.

The works are divided into 13 sections, the north citadel and the enceinte comprising 5, and each of the 8 detached forts forming one. The accounts of each section are quite distinct, and payments made on each when work to the amount of £4,000 has been executed; this amount is subject to a reserve of 5 per cent. When the reserves reach the sum of £4,000, the contractor is entitled to have it invested in the Belgian $4\frac{1}{2}$ per cents, and to receive the interest; and when they amount to $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and the whole of the caution money, £40,000, (all the clauses and conditions of the contract having been faithfully fulfilled), he is entitled in each case to have $\frac{1}{4}$ of that amount refunded to him.

The amount of reserves will form the last payment, when the works are finally handed over, six months after their completion.

All workmen are to obey the orders of the superintending officer. The Commanding Engineer has the right to order the immediate discharge of any of the contractor's overseers, and foremen, and the superintending officers have the same control over the workmen.

Without due authority from the Minister of War, all brickwork and masonry can be executed only from the 1st of April to the 15th October.

In case of the works not being carried on at such a rate as to ensure their completion within the prescribed time, and that the contractor does not take, by a named period, the requisite steps to expedite them, the Minister of war has the power to employ other persons to continue the work, using the contractor's plant and the building materials which have been delivered and approved of.

The plans of the works can be at all times consulted by the contractor in the Engineer's office, but he is not permitted to take copies of them. He is to be furnished with detailed drawings of such parts of the works as are in progress, but must return them to the superintending officer as each portion to which they refer is completed.

The War Department reserved the right of employing soldiers for the execution of such portions of the work as thought proper. The expenses resulting from this measure to form part of the total estimated cost of from 35 to 40 million francs. The contractor is bound to furnish building materials and plant for such works, on the requisition of the Commanding Engineer, at the rates specified in the schedule of prices, subject to the per centage determined by the contract.

Observations.

I have not many observations to offer on this part of my subject. The advantage of combining all the works in a single contract is manifest; nevertheless they were at first offered for tenders in several lots, and only on the failure of that measure united in one undertaking.

The personal control, given to the Commanding Engineer and superintending officers over the contractor's overseers and workmen, appears advantageous, as making their influence generally felt, and as an additional security for the proper execution of the work.

The insertion in the terms of contract of stipulations which cannot be enforced, is, I think, to be deprecated. For instance, in our contracts it is usual to insert a clause to the effect that the judgment of the Commanding Royal Engineer must be considered *final* with reference to any difference of opinion as to the quality of work. I observed no clause of similar import in the Belgian contract.

Employment of soldiers.

The reasons which induced the Belgian government to carry out part of the works by military labour were:

1st. The difficulty of collecting the large number of artificers and labourers required in one locality without risk to public order; and the injurious effect on works of private enterprise by the diminution of labour or excessive rise in wages.

2nd. The importance of a rapid execution of works which were to constitute the system of defence for the country.

3rd. The advantage of completing the military instruction of the troops by exercising them at works of fortification.

It was in the first instance intended to employ soldiers only for earth-works, but a threatened deficiency in bricklayers gave rise to the establishment of a military school of instruction in that trade. To appreciate the spirited resolve to surmount difficulties indicated by this measure, it must be premised that the Belgian soldier raised by conscription has to serve only two years under arms in time of peace, so that he would only be of account to the state in his capacity of bricklayer, for the balance of that period remaining after his instruction in the trade was completed.

The training of the men was commenced in November, 1860. In the month of June of the following year, 331 of them were turned out qualified to compete with civil bricklayers. They were employed in the construction of a bridge and of one of the large casemated caponiers of the enceinte, and by the 1st of November, 1861, had completed 5,620 cubic metres (upwards of 7,000 cubic yards) of brickwork.

The measure having proved completely successful, the training of the men was continued, and at the time of my visit to Antwerp there had been for some time 800 military bricklayers engaged on the works. They had been exclusively employed in one of the sections of the enceinte and at No. 7 detached fort, and had executed about 100,000 cubic metres (upwards of 130,000 cubic yards) of brickwork, which was considered, and appeared to be, of excellent quality.

The officer who had recommended and undertaken the training of soldiers as bricklayers, informed me that their instruction was completed in *three months*. The period selected for the course was during the winter, when building on the works was suspended. Intelligent men were chosen, and those, who after a trial proved deficient in capacity for acquiring the trade, were rejected.

The great bulk of the soldiers however were employed at the earthworks; they were detailed to particular sections, from which civil labourers and excavators were excluded. Besides a small proportion of Engineers, the men were selected from the different regiments of infantry, volunteers being preferred if able-bodied. They were formed into companies. Their working-pay in the first instance amounted to 4½d. a day; of that sum 2½d. was to be expended in extra rations, 1d. towards clothing (each man being supplied with a working dress), and 1d. for pocket-money. After a few months they were paid by task work, calculated so as to ensure to ordinary workmen a daily profit of 2d.

The bricklayers fared not much better than labourers in regard to pay, but the advantage of learning a trade which they could turn to their own account after a short service was a great boon.

The number of soldiers employed daily on the works for the first year was about 5,000, and was increased during the further progress of the works. In a report submitted to the Belgian Parliament in January, 1862, the financial result of the employment of soldiers on the works is given, and shews a benefit over civil labour of only 3 per cent.; but as it applies to the earlier stages of the undertaking, before the men had acquired much skill, it can hardly be taken as a fair test of the saving effected by military labour. The report, however, states that the Belgian War Department had no intention of making the employment of the troops a matter of speculation, and only adopted the measure to accelerate the works and complete the instruction of the soldiers. In a sanitary point of view the men employed had a decided advantage over the garrisons of Antwerp and of the other towns in Belgium.

The benefit to the men in learning a trade or the business of excavators, and the development of intelligence accruing to them under the direction of their officers, are dwelt upon as not only adding to their efficiency as soldiers, but rendering them more valuable as citizens when their period of service expires.

I have been induced to give full information with regard to the employment of soldiers on the fortifications at Antwerp, as our men are but very sparingly turned to account in a similar way.

If some control could be exercised with regard to the disposition of the working-pay such as is practised at Antwerp, it would, I think, be a beneficial measure, and check the intemperance which, not unfrequently, may be attributed to the additional means at the soldier's command.

Belgian officers of Engineers.

The new fortifications at Antwerp were commenced in the spring of the year 1860. The time allowed for their completion was four years, subject to an extension corresponding to any delays which might occur in giving the contractors possession of the sites of any particular sections of the works. Such delays actually took place in certain localities, and the contractors are, I believe, considered entitled to an extension of time to the end of the year 1864.

As far as I could judge from the present advanced state of the works, there can be but little doubt that they will be completed by that time. Of their magnitude I have previously endeavoured to give some conception. Their construction involved many engineering difficulties, for though a flat country offered facilities for the transport of materials, the soil being saturated with water necessitated powerful means for its exhaustion during the progress of the excavations and other works. The enceinte crossed railways at various points, syphon ducts had to be constructed under two canals to keep their waters separate from those of the ditches, and large sluices to be built for the supply of the latter from the river Scheldt. A considerable extent of the work is on marshy ground, which involved difficulties with regard to the earthworks as well as the casemated buildings. I was much impressed by the rapid construction of these great works as well as by the excellence of their execution, and the causes which have led to these remarkable results appear to me well worthy of being examined.

In the first place, the highest person in the realm has given an irresistible impulse to the undertaking, which is looked upon as a safeguard to Belgian nationality.

Next, the contractors are unexceptionable in all respects, and their zeal and enterprise have gone far towards ensuring success.

Lastly, the Belgian Engineer officers have proved themselves equal to the occasion, and as the construction of the works has been carried on under their entire control and direction, to their efficiency is mainly due the favourable issue of the enterprise.

The Belgian Engineer officers are in a certain proportion raised from the ranks, but obtain their commissions principally from the Military College at Brussels. A severe competitive examination has to be passed to gain admission into that institution. The course of instruction pursued there is divided into two equal periods of two years each. During the first period the studies are the same as at the "Ecole Polytechnique" at Paris; after an examination the cadets are then promoted to what is styled the "Ecole d'Application," and designated for Engineers, Staff, or Artillery, under the title of "Elèves sous-lieutenants." Most of the studies during this second period of two years are in common, but the candidates for the Engineers have specially to go through a complete course in the art of construction. When commissioned they join the Regiment of Engineers, and for a period of two years have to be instructed in drill and sapping and mining before they are employed in the general duties of the corps.

The officers of Engineers, commissioned from the Military College, have no further examination to pass during their service, but those raised from the ranks have examinations for each step up to the rank of captain inclusive. The four years of instruction at the college are reckoned as eight years' service towards obtaining a pension.

The Belgian Corps of Engineers consists of 110 officers of all ranks, and to them are attached 50 "Gardes du Génie" (subordinate officers), who are selected from the non-commissioned officers of Engineers, and have to pass an examination for the appointment; five of them are styled "Gardes principaux," and the remainder are divided into three classes. On the "Gardes" devolve the superintendence of repairs to barracks and other military buildings, and such other minor duties on which the services of highly educated officers would be comparatively thrown away.

The Regiment of Engineers, about 800 strong, is officered from the corps. All officers have periodically to join the regiment so as to maintain a perfect efficiency in the duties connected therewith, and a thorough acquaintance with drill.

When the works at Antwerp were first commenced, two Commanding Engineers were appointed, one in charge of the great enceinte, the other of the detached forts. Later the two commands were amalgamated into one.

The officers employed consist of one Commanding Engineer and two Assisting Staff Officers; 25 officers to the enceinte, viz., 5 to each of the five sections, and 24 to the intrenched camp, or 3 to each of the eight detached forts.

The officer in charge of each section (of the rank of major or captain), has the title of "Commandant," and has the entire responsibility as regards expenditure and the proper execution of the works, subject to the general supervision of the Commanding Engineer.

When the adoption of the polygonal system for Antwerp was resolved upon, designs of the works were sent to the various officers who were to carry them out, with permission to offer observations on them, as the system departed from the course of instruction at the Military College. Some modifications and ameliorations to the designs were adopted on the suggestions of the officers concerned.

Although the general designs were given to the Commandants of sections, the detailed plans and the estimates were prepared by them and the officers under their command.

The routine of duty was as follows:—The "Commandant" divided his section into sub-sections, giving charge of each of the latter to one of his officers, whom he held responsible for the proper execution of the work. The officers were expected to be on the works during the whole of the time they were in progress. Pavilions were erected on the spot for their accommodation as quarters and offices. At the period of my visit the working hours were from 7 A.M to half-past 6 P.M., out of which $2\frac{1}{2}$ hours were allowed for meals and repose. The working drawings were made by the officers. The contractors at the earlier stage of the works were only entitled to payments on every £4,000 worth executed in each section, but later an advance was permitted for work executed to the value of £1,000. Weekly measurements were taken by the Engineer officers and the contractors or their agents. The office records, diary, measurement books, &c., were kept with great regularity and very complete.

There are no civil officers corresponding to our clerks of works in the Belgian Engineer Department. The duties of designing, estimating, and measuring work, devolve altogether on the officers, but they have ample assistance for the superintendence of work, and no lack of clerks and draughtsmen. For superintendence they employ a class of men styled "Surveillants Civils," well qualified practical men, who have in most instances been artificers. They are paid 4 francs a day, which estimated at the comparative value of wages in the two countries, is equivalent to from 5 to 6 shillings a day in England. I found at one of the detached forts where military were partly employed under the superintendence of non-commissioned officers, that six "Surveillants Civils" were engaged on the works, and at one of the sections of the enceinte as many as nine. They are entirely under the control of the "Commandants," who have the power of discharging them on their own authority.

The contractors are held to be competent to carry out the works, but virtually the direction of means used in their construction, and to surmount engineering difficulties, rests with the officers of Engineers.

In describing the duties performed by the officers of Belgian Engineers at Antwerp, I have stated that they are on the works during the whole period of the working hours, such time as they may be engaged in office business, (which is reduced to a minimum,) of course excepted. Such continual labour appears to be excessive. A workman, whose employment subjects him only to bodily fatigue, is found quite capable of an average task of ten hours daily, but when the mental faculties are largely brought into play, the case is very different, and more time for relaxation is required. Most of the Engineer officers whom I met, and who had been long engaged on the works, expressed themselves over-wearied by their continued exertions and longing for the time of completion. And without the cessation of the works during the winter months and in early spring, there can be but little doubt that they would be unable long to support the wear and tear of such onerous duties. In our service the assistance of clerks of works lightens the task imposed upon the officers, and such assistance, if merely of a subordinate nature, and not allowed to supersede the necessity for efficiency on the part of the officers, is, it appears to me, advantageous to the service. For although the construction of works forms the preponderating element in the employment of officers of Engineers in time of peace, it is by no means the most important charge they must be prepared to fulfil. It can only

SKETCH
SHEWING THE NEW FORTIFICATIONS AT ANTWERP.

be looked upon as secondary to the duties they have to perform on active service, which require varied acquirements, every branch of the art of war being their legitimate study, not only to perfect them as military Engineers, but to qualify them for the higher commands in the army, to which they have every claim to aspire. Works and buildings should not therefore monopolise their attention; the charge of those other than fortifications falls to them merely to enable the corps to which they belong to be kept up in sufficient strength to meet any sudden exigencies of war, and if permitted to be an exclusive duty, the main object in the establishment of the corps would be frustrated.

I have the honour to be, Sir,

Your most obedient humble servant,

(Signed) A. O'D. GRATTAN,

Lieut. Colonel, Rl. Eng.

Gen. Sir J. F. Burgoyne, Bart., G.C.B.
Inspector General of Engineers, &c.

PAPER X.

CARRIAGES FOR ELEVATING AND DEPRESSING GUNS ABOUT IMAGINARY AXES IN THEIR MUZZLES.

By CAPTAIN INGLIS, R.E.

The great importance of keeping the openings of embrasures as small as possible has long been admitted, but as modern cannon increase in accuracy, and projectiles become more and more destructive, a little further attention to that subject, at the present time, may not be unprofitably bestowed.

By the happy adoption of the raised racer laid to a curve struck from an imaginary centre under the muzzle of the gun, the *width* of the embrasure-opening has been reduced to a minimum, and this, perhaps, has made more apparent than before the want of some arrangement whereby also the vertical movement of the gun may take place round a point similarly situated. If this be effected, of course the opening can be at once reduced to a circle but little larger than the muzzle itself.

That it is possible admits of no doubt; that it is not easy to do in a thoroughly practical way, may be inferred from the number of schemes of a contrary character which have been devised.

To aid the solution of this matter, I give here two designs (Plates I and II), which I submitted to the Ordnance Select Committee in the autumn of last year, and which they have reserved for further consideration, only until another experiment in the same direction shall satisfy them that the general principle deserves fuller enquiry.

The main point involved is this—that in elevating and depressing a gun about an axis in its trunnions as usually placed, you deal only with the "preponderance," *i.e.* with a few cwt. in a gun of many tons; whereas in elevating and depressing about an axis in the muzzle, the whole weight of the gun, or, at any rate, a very large part of it, must be borne.

It involves therefore mainly the mechanical question of how best to apply power so as to gain the necessary movement of considerable weights with sufficient speed.

Apart from this, all the considerations now allowed to guide in the construction of gun carriages have to be observed.

I will at once proceed to briefly describe the drawings:—

One (Plate I) represents a wrought iron carriage admitting of the vertical movement of a 68-pdr. or 110-pdr. service gun through an arc of 20°, *i.e.* 12° of elevation and 8° of depression.

The other (Plate II) shews an iron platform or cradle fulfilling similar conditions in a different manner.

With regard to Plate I, it will be observed that the design provides for the reception of guns as they now exist in the service, without any alteration to them whatever. And that the carriage, although shewn mounted on a special platform, is adapted to the ordinary traversing platform of the service on raised racers of the established pattern.

As shewn in the drawing, it is intended for guns in casemate with an iron front, but the carriage is susceptible of adaptation to ship's slides, or ground, or other platforms.

It will also be seen that the gun is held by its trunnions, and that the shock on discharge is conveyed to the carriage in the same manner as at present. In fact all the shock is borne by the carriage, and none of it by the lifting gear.

The principal lifting power is applied to the trunnions in a *vertical* direction. By this means the movement of the gun takes place about a point which slightly changes its position, but as this is only to the extent of little more than $1\frac{1}{4}$-inch in a gun measuring 6 feet from the trunnions to the muzzle, no practical inconvenience is caused, while great advantage is gained in simplicity of construction.

The lifting power is applied by means of a simple arrangement of the endless screw, working into toothed wheels connected with the main vertical screws—this combination being in principle very similar to the ordinary lifting jacks in use.

There are two or three main lifting jacks for raising the trunnions, and while these are working, a proportionate movement takes place in two screws which bear the weight due to the "preponderance" of the gun; and as the speed given to them is to that of the trunnions in the proportion of the radii representing their respective distances from the muzzle, it follows that the muzzle remains stationary during the elevation or depression of the gun.

One of the chief peculiarities in the arrangement is that of the lifting screws themselves not working up or down; they are in fact stationary, except as to horizontal revolutions, and the vertical movement of the gun is due to their turning in collars which form part of the lifting gear of the gun.

To this contrivance considerable importance is attached, as by it *height* is saved, which is a great consideration, and I believe it thus effects this object more completely than by any other means.

An elevating screw on the ordinary principle, working in a moveable stool bed, is provided under the breech of the gun to admit of final and accurate adjustment by the person laying it.

Provision is also made whereby, if necessary, the trunnions can be brought to the position occupied by the gun in ordinary carriages, the breech disengaged from the rear elevating screws, an ordinary stool bed substituted for the special one shewn, and the gun worked in every respect as if mounted on a service carriage.

Due regard has also been had to the facilities for mounting and dismounting the gun in confined positions.

Part of the gear projects a few inches beyond the outside of the traversing platform, but not to an extent to curtail the lateral traverse of the gun to any appreciable degree.

By reference to the drawing it will be seen that suitable speed is gained with a very moderate exertion of power. The total power gained is as 295·4 to 1. In round numbers, five turns of the handle give one degree of movement in the gun, and by twenty turns of the handles per minute, the gun goes through the whole arc under five minutes, and this, with the exertion of only about 20 lbs. on each handle. With double power on the handles, the requisite elevation or depression would of course be gained in half the time.

There is nothing to prevent such a carriage being constructed of timber, although wrought iron appears to be a much more suitable material for the purpose, and offers great facilities in construction.

Next with regard to Plate II. Here a special platform or cradle is provided for the reception of a gun mounted on a special service carriage and platform. But it must be remarked that, if necessary, an ordinary service carriage and platform may be used with it, by simply removing the trucks from the service traversing platform, and transferring them to the special platform or cradle. In this platform provision is made for raising and lowering the gun, carriage, and platform, through a vertical space of about 25 inches, and it will be readily seen that by a corresponding movement in the breech of the gun, obtained by the ordinary means of elevating screws or quoins (this movement being, by the way, exactly equal to that now required for any given elevation or depression), the muzzle is always brought to the same point, and therefore the same object is attained as if the muzzle had never moved.

A very simple system of gear is provided for this movement. It is similar in fact to that shewn in Plate I, that is to say the principle of the common lifting jack is adopted, as well as that arrangement by which the main screws are free from any movement up or down.

It will be noticed that these screws have nothing but the vertical lifting work to perform, and take none of the shock due to the recoil of the gun; this latter is borne entirely by the cradle, the form and structure of which are specially designed to resist it.

As in the former case, the movement of the gun and its carriage, &c., is obtained with a very moderate expenditure of power and in reasonable time. The total power gained is as 246·9 to 1. About four turns of the handles give 1° of elevation, and at twenty turns per minute the whole 20° is moved through in about $4\frac{1}{2}$ minutes, and this, with only about 30 lbs. on each winch handle.

The handles by which the gear is worked are so placed as to be out of the way in casemates or other confined positions.

This arrangement has another advantage, inasmuch as it affords facilities for applying power equal to the weights of the largest guns.

It also admits of a very simple application of hydraulic power, which, I feel sure, could be made to fulfil all the necessary stringent conditions of service, with a certainty and effectiveness unattainable by other machinery.

I wish also to point out that by means of the special platform here suggested, a gun may be made to fire over any height of genouillère ranging from about 3 ft. 6 in. to 5 ft. 6 in. (or more if necessary), without any reference to the special object here treated, namely, that of gaining vertical movement about a centre situated in or near the muzzle; in other words, by the use of the special platform, a gun is at once mounted "en barbette" as well as for service in embrasures.

I would also observe that the principle admits of modification to any extent. For instance, if it be thought too much to attempt the entire movement for both elevation and depression about an axis in the muzzle, the embrasure might be made of sufficient height to admit of all *elevation* taking place in the ordinary way about the trunnion, all the *depression* being given about the muzzle by lifting the gun bodily in a modified cradle. By this means the embrasure opening would be materially lessened in size, the extreme height through which the gun would have, at any time, to be raised, would be reduced in a proportionate degree, and of course the cradle and its gear very much simplified and abridged.

In conclusion, I would draw attention to the fact of my having used wrought iron as the material for these structures; this I have done after due consideration, and in order to test an opinion long held that this material is eminently suited for use in gun carriages and traversing platforms.

T. INGLIS,
Captain, Royal Engineers.

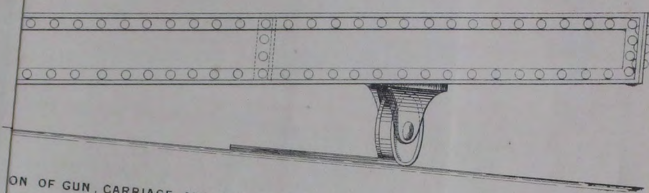
PLATE I.

DESIGN FOR A CARRIAGE

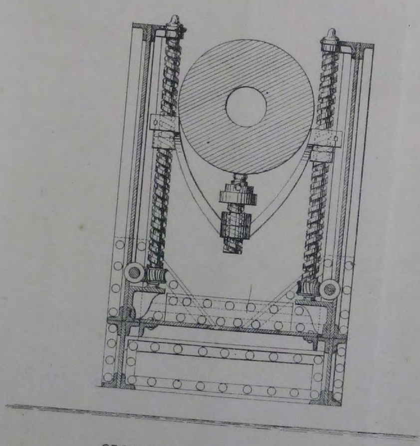
...mitting of Elevation and Depression of the Gun about the ...zzle, as a Centre suitable for either the 110 Pr. or 68 Pr. Service Guns

Scale of Feet

12 9 6 3 0 1 2 3 4 5

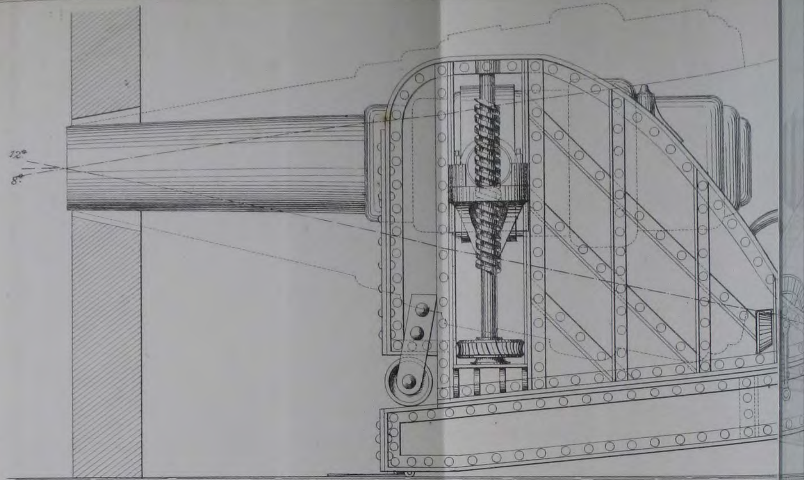


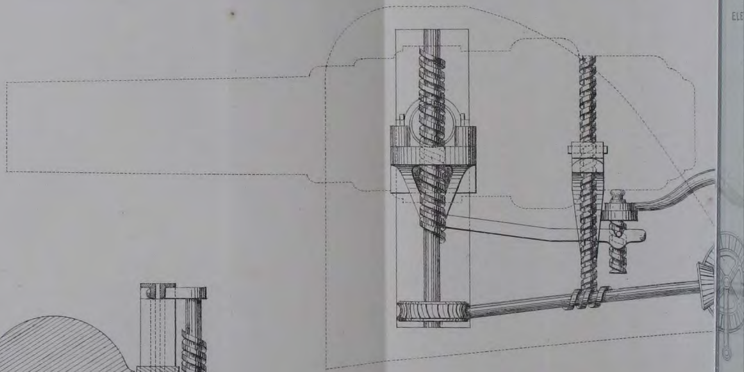
...ON OF GUN, CARRIAGE AND PLATFORM COMPLETE.



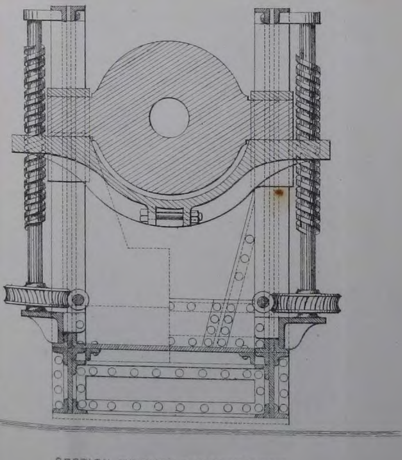
SECTION THROUGH THE BREECH.

Kell Bro^s Lith^rs Castle S^t Holborn.

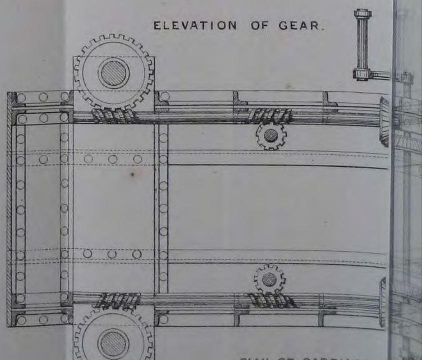




ELEVATION OF GEAR.



SECTION THROUGH THE TRUNNIONS.



PLAN OF CARRIAGE.

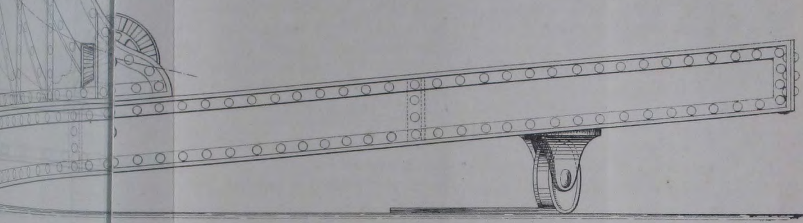
G. D. Bellamy, Draftsman.

DESIGN FOR A CARRIAGE

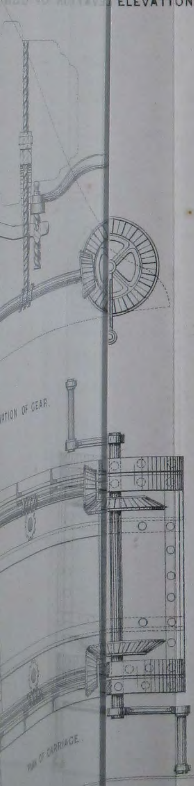
Admitting of Elevation and Depression of the Gun about the Muzzle, as a Centre suitable for either the 110 Pr. or 68 Pr. Service Guns

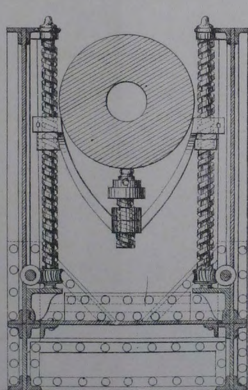
Scale of Feet

12 9 6 3 0 1 2 3 4 5



ELEVATION OF GUN, CARRIAGE AND PLATFORM COMPLETE.





SECTION THROUGH THE BREECH.

Kell Bros. Lithrs. Castle St. Holborn.

PAPER XI.

ON THE BRIDGES OF FORTIFIED WORKS.

By GENERAL SIR J. F. BURGOYNE, Bart., G.C.B., I.G.E.

There is great reason to believe that the ordinary system of bridges over the ditches of fortifications may admit of modifications tending to a saving of expense, without detriment to the defences.

The old stereotyped bridge, usually of timber, with its drawbridge at the entrance gate, has been so long established as a matter of course, that, amidst the suggestions for improvements to the lines of works, that one portion of the construction continues to be included in all, in its old shape, without thought of a possibility of amendment.

The inspection of various works, where this defective arrangement has been very apparent, has led me to the persuasion that the ordinary *rule* might, with advantage, in very many cases, make way for measures better founded on *principle.*

In many works, mere sea batteries enclosed at the gorge, on a scale barely sufficient to resist a rush into them by a coup-de-main, and into which no vehicle enters for weeks, perhaps for months together, may be found timber bridges and drawbridges of substance and dimensions, with perhaps gateways architecturally ornamented, fit for the main entrance of a great populous fortified town, quite out of proportion to the work, and which could be much reduced and simplified.

In one instance, I have seen a bridge across a ditch of a fort, of the usual raised timber construction, the roadway of which was only 4 or 5 feet above the bottom of the ditch, and which, being in the curtain of a bastioned front, might, without the slightest disadvantage, have consisted of an embankment of earth with its sides sloped. In another, to a fort occupying a projecting point at the entrance of an estuary, where a fine demi-bastioned front, with ravelin and sunken ditch, all of a more than respectable profile, occupies nearly the whole neck of land, I found the same fine and costly bridges and drawbridges to the ravelin, and from thence to the curtain, although at the same time there was a more convenient road, all on a level, along the space between the front and the sea, and leading to a retired gateway on one of the sea sides of the fort, which, with other existing sally ports, was equal to every purpose either of peace or war.

All these are clearly exaggerations that might be avoided in various ways that circumstances will admit; but even in fortresses some expedients might no doubt be devised that, in many cases, would give a passage into the place, equally advantageous for the traffic and defences, more substantial and durable, and less costly.

Such bridges *on a front of attack* are neither of use nor disadvantage to the garrison; it is expected, as a matter of course, that in the early days of a siege they will be destroyed, and that all communications from the place on that front will be by the sally ports, which are constructed for that object; and it is not easy to explain what would be the evils to the defence, if the passage were effected by a substantial bank of earth, with the sides in slopes directed up to the sills of the embrasures of the flanks on either side; or if it were of masonry with vertical sides, loopholed, and acting as a caponier, those sides themselves protected by loopholes in the curtain. It is probable that the defences would be even improved by such measures, but at all events the progress of the besieger would not be facilitated, as these bridges would be established in the least assailable part of the front; or if it was thought possible that such would be the case, a few countermines, of which the construction would be very easy, would more than establish the equilibrium.

The drawbridges require distinct consideration, their *sole* use is against a surprise; that is, all this refined and costly apparatus is devised against the possibility of a gross neglect of ordinary precautions.

It is assumed that an individual or two might, if there were no drawbridge, place a bag of powder at the gate in the night, unobserved, and that there would be no inner obstacle to prevent an assault being made into the body of the place by that opening.

It appears to me that all this may be perfectly guarded against, without the very clumsy contrivance of a drawbridge, and the entrance rendered fully as secure against attack, sudden or methodical, as any other part of the contour of an enclosed work, by much more simple means.

This reasoning will shock old-established and hitherto undisputed ideas; but it is worthy of attention and investigation how far these costly constructions, which remain, year after year of profound peace, subject to deterioration and to expensive repairs and renewals, might be replaced, at least in very many instances, by what would be less costly and equally efficient.

J. F. B.

16th July, 1864.

PAPER XII.

NOTES ON ARMOUR PLATED TURRETS, COMMONLY CALLED CUPOLAS.

BY CAPTAIN E. HARDING STEWARD, R.E.

The cupola is an invention of Captain Cowper Coles, R.N. Since the idea was first presented to the public it has been greatly developed by the inventor and now assumes the form of a turret. Priority of invention is claimed by the Americans for Captain Ericcson, but it is contested that his invention appeared subsequent to the publication of the accounts of Coles' Cupola in the English journals, and in Blackwood. This latter magazine has an extensive circulation in America; so it is difficult to imagine that Captain Ericcson could have matured his invention, and have been at the same time in ignorance of what was going on, of the same kind, on this side of the Atlantic.

In America the turret has been accepted without reserve, and notwithstanding the defective arrangements of the American model, and the adverse reports of the commanders of Monitors employed against Charleston, it continues to hold its ground, the construction of improved ones being still carried on.

In France, the turret was at first badly received, and its serviceableness doubted; but now different views are entertained, and two turret ships are being built. This scepticism on the part of the French, and their subsequent recognition of the merits of the turret, is a strong argument in its favour. A commencement having been made, the employment of turret ships in the French navy may be considered certain. From ships to forts is only a step.

In Belgium the turret has been adopted and applied to land defences. At this present time, one of the redoubts at Antwerp is being prepared to receive three turrets. One only of these has as yet been put into the hands of the contractors (Messrs. Brown and Co., of Sheffield). This it is expected will be established towards the middle of July of this year, and in the event of all the details proving correct, the remaining two will be commenced forthwith.

Russia has one turret ship building in this country, and fourteen small ones, on different models, in her own.

Italy and Prussia have both ordered a two-turret vessel in this country.

Denmark has been for some time in possession of the "Rolf Krake," which is the first vessel of this class that has been put to the test of actual warfare in European waters.

In this country the turret has, like other novelties, been received with considerable caution, and although all naval officers who have become intimate with it are warm in its favour, it has yet to win its way with the services at large. We have altogether four sea-going turret vessels, viz., "The Royal Sovereign," with one two-gun and three single gun-turrets, at present fitting out at Portsmouth. The " Prince Albert," with four single gun-turrets, under construction at Woolwich, and the two notorious Mersey Rams, which have each two turrets.

The turret principle has been subjected to severe tests in actual warfare. In the attack on Charleston several defects were brought to light; but these are from errors of construction, and will be shewn subsequently to belong exclusively to the American model. The defective working of the turrets, consequent on injuries received, was urged by the American commanders as the cause of the failure of the attack. That some monitors were silenced owing to the jamming of the turrets is true; but the real cause of the failure may be found in the disproportion between the artillery of the two sides, in point of number of guns.

In Danish waters, the "Rolf Krake" has furnished us with an interesting experiment, the more so as its turrets are constructed on the ***English model.*** In the case alluded to, this gun-boat, which carries four smooth-bore 70-pdrs., in two turrets, was despatched, unsupported, to destroy a bridge in face of shore batteries. The shallowness of the water prevented it approaching within view of the bridge, so after engaging the shore batteries for more than an hour, it withdrew, *but with its turrets in working order and its gun detachments untouched**. The bulwarks, and everything on deck, were destroyed, which fact proves that the vessel was under a heavy fire. A great deal was expected from the "Rolf Krake," so its withdrawal, without having effected any brilliant exploit, has, in the absence of correct information, been put down to the account of the turrets. In England there is only the peaceful experiment with the "Trusty" to record. The experimental turret on board had 69 shots fired at it from a 68-pdr. and a 70-pdr. (rifled gun); out of which it received 44 hits, resulting in the piercing of the backing at one point where the hits lay close, and the dismounting of the gun. At the conclusion, the turret was worked with the same facility as at first, contrary to the expectations of all but the inventor. The turret employed in this instance was similar to that given in Pl. I, fig. 3.

Setting aside sea-going qualities, a turret-ship has the following advantages over an ordinary one:—It can carry heavier guns and in a more secure position, owing to the ability of turning the ports away from the enemy whilst loading; it can also bring all its guns to bear on any point without having to alter the position of the ship, or only to a very slight extent. These are great advantages, but how far turret-ships will supersede broadside ships remains to be proved.

Turrets are admirably adapted for coast batteries, as on account of the facility of turning, they can be made to bear continuously on vessels in motion, and from their great lateral range can keep them in view a long time. From this cause it may be safely asserted that a two-gun turret is an equivalent for six guns behind embrasure shields arranged for the defence of the same area, and in some

* The nine casualties that occurred were caused by a shell plunging through the deck and bursting below, near the door of the gun-room.

cases for even eight, where the area to be covered by fire is very extensive, involving under ordinary circumstances a battery with several faces.

Now that a large and expensive gun is about to be introduced into the service for coast defences, the material reduction of the number of guns is of importance for motives of economy. The reduction extends also to the works themselves, for with turrets a large development is not necessary, and what is equally important, the force required to work the guns is also considerably reduced, in consequence of having machinery to aid in working them. This machinery allows of the guns being worked with very much less fatigue to the gunners; hence a sustained fire can be kept up for a longer time with fewer reliefs of men.

The ends of moles and breakwaters, the headlands and islands in harbours, including of course sea forts, are the places where turrets will be employed to the greatest advantage, for they can sustain an attack on all sides and reply in any direction.

The turret for land service can be made stronger than for a ship, and the roof, which is splinter proof, can, if necessary, be strengthened also. The turret may be considered as secure, for only chance vertical fire can injure it. Under cover of the turret improved metal slides can be used, and mechanical appliances brought into play without liability to injury.

We have in the turret a high development of the barbette battery, with more than its advantages and none of its insecurity. We have moreover the guns moved laterally by machinery, by which an immense amount of labour is saved, and a rapid fire on objects in motion can be sustained without distress to the gun detachments. The port, owing to arrangements for elevation and depression, is reduced to a small opening, 30 *inches by* 20 *inches*. The advantage of this reduction is daily becoming more apparent, and on this score alone the turret can claim a marked superiority over the embrazure shield, which, when used with the present service carriage, exhibits an opening of 3 *feet* 6 *inches by* 2 *feet* 4 *inches*. Through this opening the gun may be dismounted, the carriage reduced to a wreck, and casualties occasioned among the gun detachment.

Having mentioned the embrazure shield, I must here say a few more words about it. The port, before alluded to, is its most defective part, and this, unfortunately, with the present service carriage, cannot be reduced, without confining the gun to very low angles of elevation and depression. This opening occupies one-eleventh of the entire shield, and amounts to one-sixth of the exposed surface of the shield when fixed in an earthen battery. Efforts are being made to remedy this defect. A new carriage invented by Lieut. Colonel Shaw, R.A., so far succeeds, that with it the port can be diminished to an opening little larger than the muzzle of the gun, which remains, comparatively speaking, stationary, during the process of elevation or depression. This result is obtained by fixing two arcs to the breach and middle portion of the gun, and elevating and depressing along these curves, the muzzle being the centre from which they are struck.

Description of Coles's Cupola.

Coles's cupola for two guns has an external diameter of 23 feet 6 inches. The space inside is 19 feet broad and 9 feet high in the clear. The plating on the sides is $5\frac{1}{2}$ inches thick, except at the ports, where an additional 4-inch plate is used. The backing consists of $7\frac{1}{2}$ inches of teak, confined by a layer of trellis-work made up of bars 6 inches by

$\frac{3}{4}$-inch; then come the ⊢ irons, 10 in. by 6 in. by $\frac{1}{2}$ in., filled up between with solid teak; the whole finished off inside with a skin made of $\frac{1}{2}$-inch boiler plate. At the top, additional strength is obtained by fixing a large metal ring, 14 inches by 2 inches, round the inside. The roof is made of double ⊢ irons, 6 in. by 5 in. by $\frac{1}{2}$ in, placed two inches apart. A space is left for the pointer or captain of the turret, also five holes for ventilation. The centre girders are arranged for removal, for the guns have to be mounted and dismounted through the roof.

Platform, &c. The circular platform (vide section to Fig. 3, Pl. V), on which the cupola revolves is of cast iron and made up of quadrants bolted together. The broad bevelled racer on which the trucks run forms part of these castings. The turret runs on 22 trucks made of iron, and connected with the centre by stout iron ties. The pivot round which the whole works is, on board ship, an eighteen-inch cylinder, this passage being necessary for the ventilation of the deck below. In a fort this would be replaced by a solid iron pin 12 inches thick.

Entrances. The sides of the cupola below the level of the deck are not plated, but the framework is left open; an angle iron is left out at intervals to provide spaces through which access may be had to the interior. The draught of air through these open sides, towards the roof, will clear the turret of smoke.

Motive power. Motion is obtained by travelling winches worked inside the cupola, and by a large stationary winch outside. These also are applicable to turrets on defensive works. On board ship the main deck gives a free passage, so motion can also if necessary be obtained by handspikes or even by a chain or cable, worked round the capstan. The interior winches are to the right and left of the pair of guns and fitted between the angle irons. They act on cog wheels which work in the teeth arranged round the exterior of the iron platform. Three men can work at each winch, but two will generally be found sufficient. The stationary winch is more powerful and arranged for eight men: (vide section to Fig. 3, Pl. V). The cog in this case works along teeth set round the bottom of the framework of the turret. To move the turret, one travelling winch only is absolutely necessary; the second is put for precaution sake. The stationary winch would prove useful in action, for with its superior power the turret can be made to revolve quickly and even pass over small obstructions which would otherwise have to be cleared out; provision, however, need not always be made for it, as full reliance can be placed on the travelling winches, which are perfectly secure. The rate of speed obtainable with the stationary winch is about seventeen seconds for the quarter circle. The laying of the gun is also effected by the machinery, and is done with the greatest nicety, without the least jarring.

The slides. The gun slides are made at present of timber, and fixed at an incline of 4°. They are subject only to vertical motion, which is effected by four powerful screws worked by ratchets and levers (vide Pl. II, fig. 1). In this way the slides are brought to three different levels, the timber supports being made to correspond by means of moveable blocks. Through the use of these different levels a considerable angle of elevation (18°) is secured to the gun, the port not being larger than 30 in. by 20 in.

Gun carriage. The carriage is of wood (metal ones are contemplated), and has trucks in front, but rests on its transom blocks. It has also trucks behind, which are brought into play by working a small lever with tackle. By it the gun and carriage are brought to bear on the trucks alone, and made to run up with surprising velocity, but all the time under the perfect control of the man with the tackle. To prevent accidents from the gun not being checked down the incline, or from any accession of velocity due to the rolling of the vessel, a buffer is placed at the port end of the slide. To check the recoil powerful compressors are used, two on each side. These are in addition to the breeching.

Elevation. The elevation or depression of the gun is effected by working a ratchet and lever at the side, the angles being indicated with tolerable accuracy by an index on a graduated arc engraved on the cheek of the gun carriage.

Laying the gun. In laying the gun two sights on the roof are used (vide Pl. I, fig. 2). The captain of the turret, who performs this service for both guns, stands on the slides and looks through an aperture in the roof; this aperture can be protected, if thought necessary, by a metal casque, but sandbags would probably prove more efficient. With these sights the gun can be laid most accurately and made to bear continuously on objects in motion, *the aim being corrected up to the moment of firing.* The sight nearest the aperture slides up and down, in order that the elevation or depression of the line of sight may be ascertained. The angles so observed have to be added to or subtracted from those due to range before the latter can be applied to the gun, because the angles of elevation or depression imparted to the gun by the ratchet and lever, and indicated by the arc on the cheek, are referable only to the horizontal plane.

I must here observe that this method of proportioning the elevation, though successful on board ship, where the height of the gun is constant, will be found troublesome on land batteries, as different scales for the roof sights will have to be made out according to the height above the sea or the surrounding ground. It is also questionable whether this innovation on the simple method of applying the elevation to the plane of the axis of the gun, will be well received by the Artillery. Laying the gun from the base ring is met with the objection that the port would have to be enlarged considerably to allow of it. This difficulty can be overcome by the adoption of Lieutenant Colonel Shaw's gun carriage, for then the port, even when elongated sufficiently to allow of the gun being laid from the base ring, will not be longer than it is at present. On all occasions recourse must be had to the dispart sight, for the trunnion sight would necessitate the widening of the port, which ought not to be permitted.

Strength of the detachment. The detachment required for the working of two 12-ton guns is 23 men, 15 inside the turret, and 8 outside to carry ammunition and to work the stationary winch if required. This number is small when compared with the great size of the guns.

Weight. The weight of a cupola, including the guns, may be assumed as 140 tons.

Cost. The cost of a turret may be taken at £4,200; a small single gun turret of course costing less. The price tendered by Messrs. Brown and Co. was £4,500, and this included the making of the models; there is no doubt that after one or two have been made they will cost a little less.*

Several modifications of the turret or cupola have, from time to time been thought of; such as, a turret open to the rear; a semi-circular shield on a turn-table; a curved shield moving with the gun and covering the opening of the embrazure; or even a plated cap travelling on the crest of the parapet, and revolving with the gun, and others besides. Most of these have been put forward with the view of getting a lateral range greater than that obtainable with the embrazure shield, but without going so far as the complete circle, which is presumed by some to be in many cases unnecessary and expensive.

The cupola in Captain Coles's hands went through most of the phases above mentioned, before it was brought before the public: the matured shape being in part the result of the conviction that it was the cheapest. In fact the cost is not so much diminished by adopting less than the circle, as would at first thought be imagined. The reason is obvious. In a circular shield immense stability is gained from the form alone, for the parts support each other. But when the circle is incomplete this stability has to be got by means of struts, which add to the expense, and, what is worse, encroach on the internal space. With regard to lateral range, the diminution of power does not follow in the same ratio as the cutting down of the circular form, for a semi-circular shield can turn with its gun through barely 90°, without being liable to be taken in reverse from the right or left. The breaking of the circle is then really attended with a serious diminution of power to the guns, not at all commensurate with the saving effected in the cost of construction.

The American turret.

The American turret is entirely above the level of the deck (vide Pl. I, fig. 1). The pilot-house is fixed on the roof. Both of these revolve round spindles, the spindle of the pilot-house working in that of the turret. The sides are built up of inch-plates bolted together, making a total thickness of iron of 11 inches.† The revolutions are effected by first raising the turret off its bearings by working the screw wedge, and then the whole is turned by applying steam power.

The whole of the turret being above deck must detract from the sea-going qualities of any vessel fitted with it, on account of the leverage the turret must exert in a sea way. The sides from their construction must offer a resistance to shot inferior to that of solid plates of half their thickness when backed with wood, &c. Besides this the American model has many defective details, for instance the slot in which the turret turns is so open and unprotected that the bolt heads dropping down into it have been known to stop the turret altogether. The turret can also be easily jammed by the buckling of a plate near the base, or by the bending of the top spindle, through the heavy blows of shot on the sides of the pilot-house. Any damage to the brass collar in which the pilot-house works, by a shot striking it, will wedge the turret in such a

* The cost of the 2-gun turret of the Royal Sovereign is £4,500 including very expensive brass fittings.

† The sides of the turrets of some of the most recently constructed Monitors are 15 inches thick. The "Onondaga," a two-turret vessel, has 4-inch plates between two series of inch plates, making in all 12 inches as the thickness of the turret's side.

manner that all motion is impossible. Working by steam is rapid and effective, and the celerity with which the guns are turned from the enemy's fire is surprising; but reliance on steam power alone is hazardous, besides it is expensive, for steam has always to be kept up. The Americans are proud of the quick manœuvring of their Monitors, but I believe that after all they will adopt the simple winches and be content with a moderate speed.

The Antwerp Cupola.

The turret about to be used by the Belgians is Coles's, with inclined sides. This shape is used by them as they still continue to employ the breach-loading principle for heavy ordnance. The details are in all respect similar to those of turrets with vertical sides. The gun carriage and slide in use by them is also an invention of Captain Coles (vide Pl. I, fig. 3). It consists of curved slides, arranged so as to gradually check the recoil of the gun and carriage, and cause them to run out again. A buffer is fixed to take off the shock of the return. Great rapidity of fire is obtainable by this method. When tried at Portsmouth it was favourably reported on, but being applicable only to breach-loading guns, its introduction into the naval service has not been taken into consideration.

Application of Turrets to Forts

Before applying the turrets as at present used in the navy to forts, a few slight alterations will have to be made in their detail. For instance, the widened part below the level of the deck will have to be carried equally all round and to project at least one foot, in order to prevent the buckling of the plates affecting the movement of the turret through jamming.* It is also probable that an increased thickness of iron will be necessary, for although 5½ inches may be the limit to which it is advisable to go in the case of a ship, on land we are not so confined. In the application of thicker plates it would be an economy to adopt the polygonal form for the turret, as has been done with those on the Mersey steam rams. Very much greater thickness of iron can be used in this way, and the saving would be considerable, for plates worked flat cost 40 per cent. less than plates bent to a curve.

The requirements of a turret on a work and the constructions necessary for its reception depend entirely on its position. If required for the salient of a fort where it will not be exposed to reverse fire, the winch chamber and communications can be put in rear, opening on the terreplein. (Vide Pl. V, fig. 1.) On the other hand, in the case of a fort liable to an attack on all sides, it would be necessary to leave out the stationary winch altogether, and to provide a communication with a lower level. (Vide Pl. V, fig. 2.)

In the former case arrangements can be made according to Pl. V, fig. 3. Here there is a chamber that takes a winch with a handle 8 ft. 6 in. long. The breadth of this chamber is 7 feet, the passages on either side are 6 feet broad. In each of these there is a large shell recess 5 ft. by 3 ft. 9 in., and 3 ft. 9 in. high. The position of the winch chamber and the level of its floor depend on the position of the cog wheel next to the handle, which can be altered to suit circumstances. In Pl.V, fig. 3, the floors of the winch chamber and communications are 6 inches above the level of the terreplein.

* In a ship the unequal projection of the lower part is done with a view to bringing the centre of gravity in the line of the axis of the turret.

To receive the iron platform, one of granite is necessary. The stone should be at least 2 feet deep, and the centre block which has to take the pivot should be as large as possible. The blocks should be firmly secured together, and the spaces between them filled in with concrete. Between the drum of the platform and the parapet wall it is necessary to leave a space of 2 ft. 6 in., which should be paved and drained for surface water. This space is important, as along it a man has to pass to oil the trucks and to remove obstructions, should there be any. The parapet wall must be strong enough to prevent the possibility of a shot passing through the parapet, and should be capped by a substance that will not be injured by the explosion of the guns. In Pl. V, fig. 3, a 3 ft. 3 in. wall, backed by 4 feet of concrete, is shewn, the crest being formed by a course of granite blocks which brings the parapet up to the height of the ledge of the turret. These blocks are oversailed in order to diminish the distance between the turret and crest to 8 inches. This space is protected by a leather flap which effectively prevents the falling of bolt heads*. The parapet wall extends round two thirds of the circle, the other third being occupied by the passages and winch chamber. Here a free space is necessary for access to the turret. With this object the partition walls are finished 2 ft. 6 in. short of the sides of the turret, the roofing being carried at these points by wrought iron brackets fixed against the ends of the partition walls and secured by iron ties running through to the rear wall. A timber platform is fixed along the open space so obtained, and about one foot lower than the floor of the turret. With this platform the detachment will be able to enter or leave the turret while in any position, without having recourse to the machinery. A set of steps is provided in each passage for descent from the platform. The roofing in of the chamber and passages must be arranged so as to make it a continuation of the superior slope of the parapet round the turret, for it is possible that the guns may be wanted to fire all round the circle. In Pl. V, fig. 3, the roof consists of double ⊢ girders 6 in. by 5 in. by $\frac{1}{2}$ in., bolted down to wall plates 6 in. by 4 in.; the whole covered by $\frac{1}{2}$-in. boiler plate.

In Pl. V, fig. 2, the cupola depends only on its travelling winches. The steps of the communication from below come where the winch chamber is in Pl. V, fig. 3. In this case the platform is the same as before described, and also the parapet wall except towards the rear where it has to be very much oversailed to provide access to the turret, leaving a passage 2 ft. 6 in. wide. For ingress to the cupola, ascent has to be made from the level of the passage to that of the floor of the turret, up small iron ladders which should travel round with the turret. These must be made to unship, to allow of the examination of the trucks and platform. The chambers for powder and shell can be placed at the foot of the communication and under the terreplein.

A parapet, as before described, will be found difficult and expensive in execution, owing to the large size of the blocks of stone necessary for the oversailing portions. To obviate this, and to obtain an homogeneous parapet capable of obstructing shot, I would urge the adoption of concrete made of large sized fragments of stone, as described by Lieut. Colonel Scott, R.E., in Volume XI of the Professional Papers. The case in question is one in which its application would

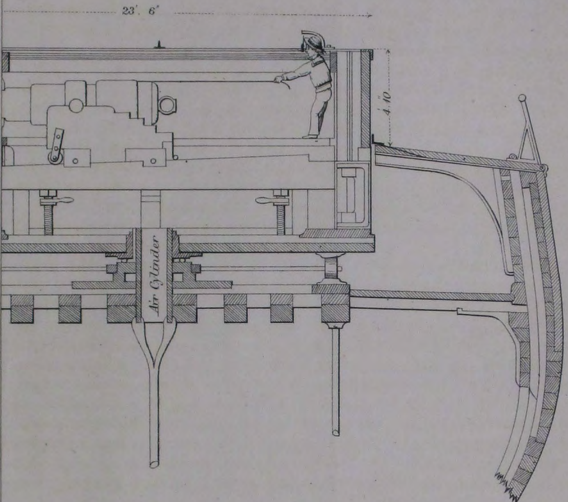
* In a ship the leather is used chiefly to keep the water out.

PLATE 1.

COLES' CUPOLA

"As constructed for the Royal Sovereign."

Fig. 2.



Kell Bros. Lithrs Castle St. Holborn.

ERICSSON'S CUPOLA

As constructed for the Monitors.

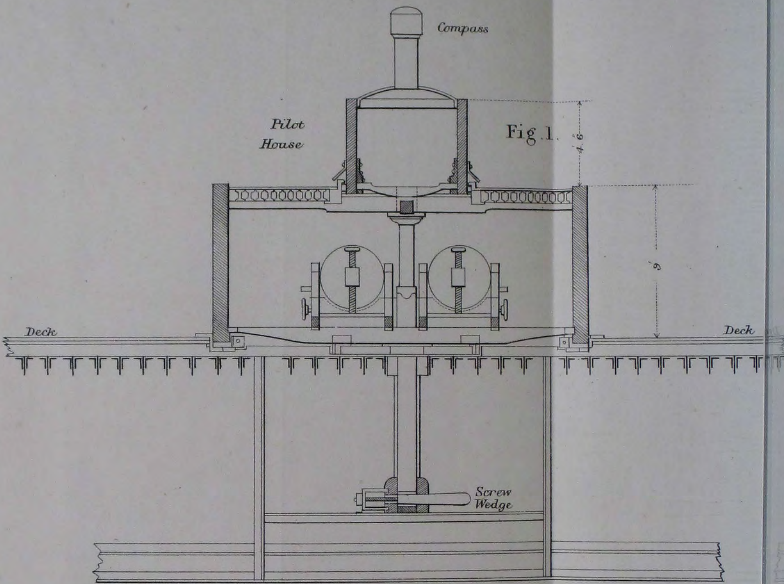


Fig. 1.

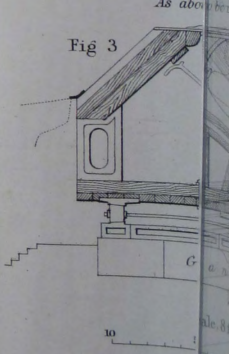
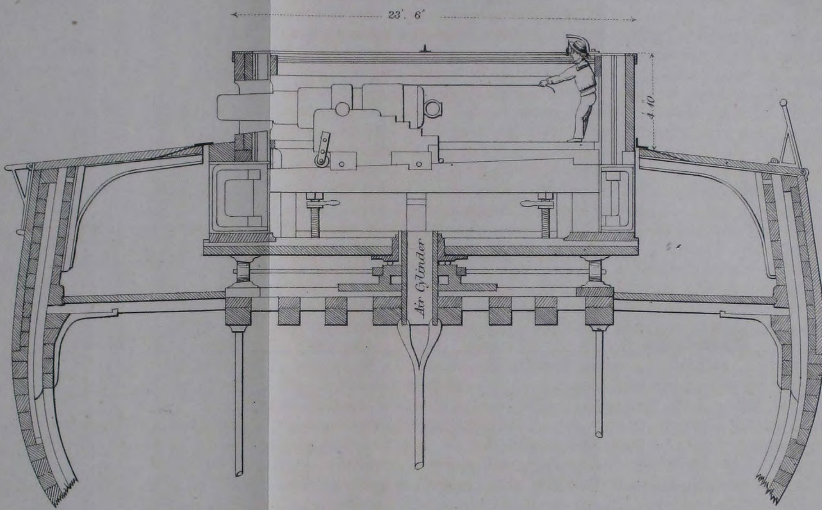


Fig 3

COLES' CUPOLA

As constructed for the "Royal Sovereign".

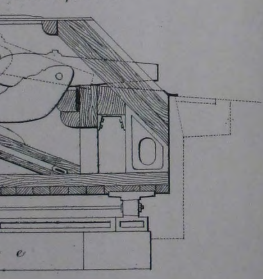
Fig. 2.



POLA.

NG GUNS.)

he Antwerp Forts.



an inch

10 Feet

Kell Bros. Lithrs. Castle

be eminently useful, for with moulds it can be made to take forms most at variance with rules of construction, and which will possess wonderful stability and powers of resistance.

In Pl. V, fig. 2, the work chosen to illustrate the application of turrets is a sea fort of 120 yds. diameter, mounting in all eight turrets. The turrets are 30 yds. apart, with a command over the rest of the work of 9 feet. This arrangement is more effective than that of a larger number of turrets closer together, with no command, for the guns are not restricted in their lateral range, and the command over the rest of the work allows the turrets on one side, when reversed, to fire through the intervals on the other side of the fort.

It will be perceived that the parapets of the turrets act as bonnettes, and protect the terreplein. The casemates below, which look on the channel or area over which the mass of the fire is required, should also have guns mounted in them, protected of course by iron shields.

In conclusion, I have only to repeat that turrets should be adopted for coast defences on the grounds of economy in guns, works, and men, and for the great advantages they offer in the engagement of ships in motion. Their introduction and general use will no doubt follow that of very heavy guns, towards which there is at present a strong leaning. The more monstrous the guns the more apparent will be the merits of an invention that may be regarded as the solution of the barbette gun difficulty, and as one that will allow of real mechanical assistance being given to the gunner.

In compiling the foregoing notes, I have had the advantage of Captain Coles's kind assistance. The drawings on Plates I, II, III and IV, are to a great extent reductions from ones that he has lent me. With regard to the details and the working of the turret, and more particularly the dimensions of the spaces necessary for the stationary winch and the approach, I have to state that they were noted and measured during a special trial, which the inventor caused to be made on board the " Royal Sovereign " for my benefit.

E. HARDING STEWARD,
Captain, Royal Engineers.

Portsmouth,
30th June, 1864.

PAPER XIII.

TEMPORARY BRIDGES

FORMED WITH

JONES'S IRON GABION BANDS,

AT THE

ROYAL ENGINEER ESTABLISHMENT, CHATHAM,

IN 1863 AND 1864.

BY QUARTER-MASTER J. JONES, R.E.

It may be desirable before offering a description of the several iron gabion-band bridges, constructed experimentally at this Establishment, by permission of Colonel Harness, C.B., the Director, to state some particulars with regard to the smaller details of the experiments.

The gabion bands were used as bearers from one to four in thickness (plate I, fig. 3), according to the strength required, and laid on each other, employing as many as were necessary to form the required bridge. To obtain the desired length, the bands were joined together in their lengths by bolts and nuts passing through the small holes *cccc* (Plate I, fig. 6). The bolts were $1\frac{1}{2}$ inches in length, by $\frac{5}{16}$ths of an inch in diameter (Plate I, fig. 4).

The ends of the bearers were held at the banks of the ditch by strong beams passing through loops formed by turning under the end bands, and fastening them with bolts and nuts. On the far end the beam was placed behind stout poles sunk in the ground; the near end of the bridge was similarly fixed, having however, block-tackle connected with it, and a second beam fixed behind other piles for the purpose of hauling on the bridge and bringing it to its proper droop. (Plate I, figs. 1 and 2.)

The distance between the holes *cc* (Plate I, fig. 5) was 5 feet 7 inches, and two extra bands were required at each end to form the connection with the banks.

[As a rule, to find the number of bands in the length of a bearer, divide the span by 5 feet 7 inches, and add 4 to the quotient. In forming bridges exceeding 10 feet in length block-tackle should be used at both ends.]

A description of the Bridges follows :—

No. 1.—A suspension bridge, 128 feet span, 8 feet wide, was constructed over the ditch of a recently-built elevated battery, parallel to the escarp, with 864 gabion bands.

The bands were formed into eight bearers of four bands in thickness; the ends being turned into loops 3 feet long, through which on either bank, straining beams, 13 feet long, and $7\frac{1}{2}$ inches in diameter, were passed. So prepared, the straining beams were placed in rear of four square piles, on each bank, of different dimensions, (such indeed, as could be readily obtained) previously driven into the ground.* Five block-tackles were connected with the straining beams at the near end of the bridge.

On the block-tackle end, short baulks were used between the front straining beam and the front row of piles, to prevent too great a deflection by the stretching of the tackle.

The roadway was formed by covering the bearers with 95 pontoon chesses, which were racked down by passing a rack-lashing between every fourth chess and touching the inside of the outside bearers.

Over the bridge 30 men marched in quick time in single rank; then 40, and 50 two deep; and afterwards 60 four deep, and 70 in the same order.

The deflection before the men passed over was 4 ft. 6 in., after 5 ft. 7 in. The increased deflection was due to the earth, which was very soft, giving way.

Its own weight, and the weight of the load it carried, were as follows:— bearers 2,226 lbs., superstructure 2,565 lbs., 70 men 10,500 lbs. = 6 tons 16 cwt. 2 qrs. 3 lbs.

No. 2.—This was constructed at the same place, in a similar manner, but with only six bearers. Over this a party of 20 recruits, marching in fours, did all they could to make the bridge oscillate and break down. They however got over safely. As no guy ropes were used, and the men were reckless, the oscillation was very great.

A second party of 40, and a third of 60 men, passed over without any difficulty.

An artillery horse was led over several times.

Colonel Collinson, who was present, desired the men to march on the bridge and to halt. Accordingly 60 men were marched over in sections of fours. When the last section had been on some time, seven of the slings connecting the tackle to the straining beams, and two of the hooks of the block-tackle, gave way. On examining the bearers it was found, from the jerk occasioned by the breaking of the slings and hooks, that five of the bands in one of the bearers had snapped at the bridging holes.

The chesses on the bridge were not racked down.

No baulks were used between the straining beam and front piles, consequently the whole weight had to be borne by the block-tackle. To the absence of the baulks is attributable the accident which impaired the bridge.

The bridge was purposely made loose and very temporary, to ascertain if such a structure, constructed in haste, and without the usual safeguards, could, on active service, be depended on, for the rapid movement of troops across rivers.

* If found more convenient the ends might be fastened to trees, rocks, &c.

Its own weight, and the weight of the men it carried, were as follows:—bearers 1,673 lbs., superstructure 2,565 lbs., 60 men 9,000 lbs. = 5 tons 18 cwt. 22 lbs.

No. 3.—A bridge of 100 feet span, 8 feet wide, having 672 bands, formed into eight bearers, of four bands each in thickness, constructed over the wet ditch near the Field-work Depôt. It was of sufficient strength to bear cavalry and artillery.

To pass the bearers over the ditch a 3-inch rope was stretched across and made fast to one of the outside piles on both sides, having on it a grummet 4 inches in diameter.

To this grummet the end of each bearer, in succession, was made fast, and passed over the ditch by a party of men hauling on a rope attached to the grummet from the opposite side; the party on the near side giving their assistance in lifting and moving the bearer towards the ditch.

The eight bearers were passed over and placed in position in sixteen minutes.

To prevent oscillation, guys were used, some of rope and some of gabion bands. To secure the guys to the bridge guy poles were made fast to the bearers on the under side. (Plate II).

The roadway was made by covering the bearers with pontoon chesses which were racked down in the usual manner.

Its weight was:—bearers 1,730 lbs., superstructure 3,337 lbs. = 2 tons 5 cwt. 27 lbs.

No. 4.—A bridge of 65 feet span, 8 feet wide, and made at the same place as No. 1, having 208 bands formed into four bearers of four bands in thickness; one end of the bearers was formed into loops and passed over a straining beam; the other was joined to the block-tackle by four iron clips 10 in. long, $3\frac{1}{4}$ in. wide, $\frac{1}{4}$ in. thick, which were bolted to the bearers.

The straining beam on the far side was resting in a trench cut into the escarp and counterscarp (the bridge being constructed parallel to these faces), supported at the centre by two uprights, and at the back by a baulk 12 in. by 12 in., firmly secured to it by chains.

The bearers were covered with pontoon chesses. Over the bridge 30 men marched in single rank, 30 two deep, then 40 four deep, then 50, and finally 56 in the same order.

With this weight, the straining beam across the ditch broke; there was also a long split in the baulk supporting it at the back.

Its own weight and the weight of the men it carried, were as follows:—bearers 534 lbs, superstructure 2,021 lbs., 56 men 8,460 lbs. = 4 tons 18 cwt. 1 qr. 11 lbs.

No. 5.—This was a prolongation of No. 4, extending it from a span of 65 feet to 130 feet, having 432 bands formed into four bearers, of four bands each in thickness.

With 51 men marching over it in fours, the bearers gave way at the bridging holes, in that portion of the original bridge of 65 feet which had been already experimented on, and probably had suffered in the breaking of the straining beam before spoken of.

Its own weight and the weight of the men, were:—bearers 1,116 lbs., superstructure 3,025 lbs., 51 men 7,650 lbs. = 5 tons 5 cwt. 1 qr. 3 lbs.

No. 6.—A bridge of 132 feet span, 8 feet wide, having 896 bands formed into eight bearers, of four bands in thickness, was constructed at the same place as the preceding one.

In this bridge the chesses were racked down, and there were four guy-ropes on each side fastened to guy-poles.

By permission of Captain MacDougall, R.A., several horses of the battery he commanded passed over with their riders, under the direction of Lieut. Kyle, R.A. A 6-pdr. brass field gun and limber were afterwards drawn over by 22 men.

Lieutenant Sir Arthur Mackworth, R.E., riding a very spirited charger, also crossed.

This was rather a severe trial for the horses, as the chesses being thin, bent to the tread.

No. 7.—A bridge of 100 feet span, 7 ft. 4 in. wide, was thrown over the same place as No. 3, having 546 bands formed into 26 bearers, of one band in thickness. The bands were placed close together; the gabion pickets used in the construction of gabions, 666 in number, were interlaced with the bands to form the roadway of the bridge, and served to steady the foot in passing over, as battens do on gang boards, inclined planes, &c. (Plate II.) The guy-ropes were secured in the same manner as in No. 3.

Its weight was:—bearers 1,516 lbs., pickets 224 lbs. = 15 cwt. 2 qr. 43 lbs., it was of ample strength to bear infantry.

No. 8.—A bridge of 46 feet span, 8 feet wide, was constructed across the ditch of the ravelin, having 264 bands formed into six bearers, of four bands in thickness.

In order to ascertain the time required to form a bridge of this description, having the piles and bearers prepared beforehand, a party of one sergeant and 17 sappers, were directed to form bridge. They commenced at four minutes past 2 o'clock, and at 2.41 the bridge was completed (the time being only 37 minutes).

With a little practise a bridge of this length could be made in 20 minutes.

No. 9.—The following is a description of a bridge constructed with gabion bands by the 1st Devon Volunteer Engineers, under the direction of Lieutenant Edward Appleton, who commanded the company.*

It slightly differs from No. 7. All the purposes Mr. Appleton intended to be served by it, were met effectively.

"The bridge was put up in the month of June, on the occasion of a field-day at Torquay. The spot selected was a chasm between the mainland and a detached headland or rock, distant 65 feet. Jones's iron gabion bands were used as the supports; but as the materials supplied by the government were

* *Builder*, 12th December, 1863.

limited, viz., only 200 bands, without any superstructure, the ***gabion pickets,*** interwoven with the bands, as used in the construction of gabions, were adopted to form the platform of the bridge, and for infantry purposes on a small scale, will be found very efficacious, and possessing this advantage, that nothing but the gabion-bands need be taken to encumber the troops. A sufficient number of gabion-bands to construct a bridge of 50 feet span may be stowed in a space of *four cubic feet.*"

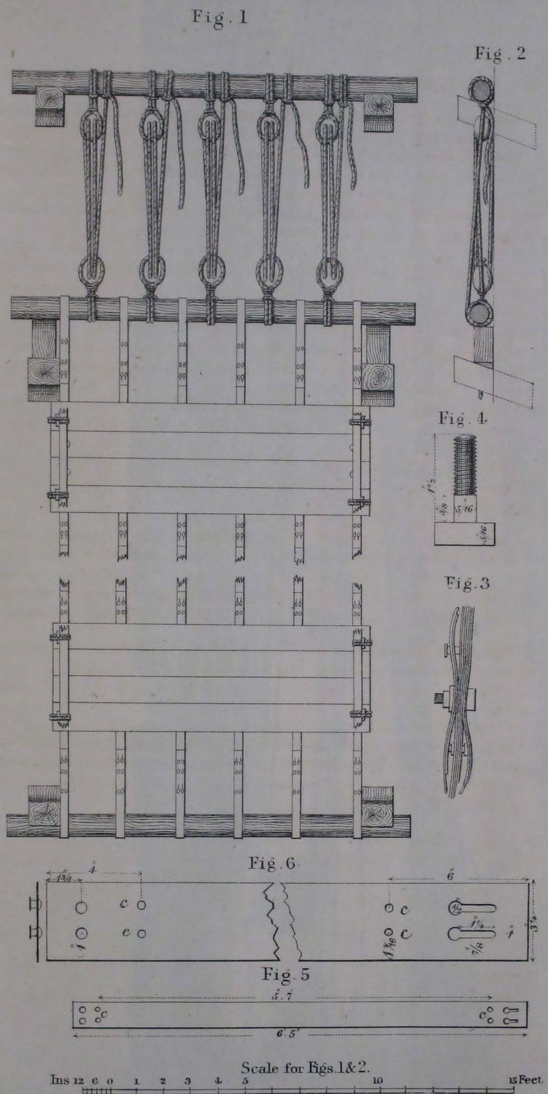
"The bridge consisted of ten lines of gabion bands alternately double and single: each band was united to the adjoining one with the slot and button on the bands themselves, but for additional security the double bands were fastened with the small nuts and screws used for fastening eaves gutters. The end bands formed loops which were passed over straining pieces, and with blocks and tackle were strained and secured to two posts at each end, firmly driven into the ground in a raking position. This bridge was twice erected by about twenty Volunteer Engineers in two hours, and was used by them and the public for approach to the rock for several weeks, with as many as twelve persons at a time upon it, without the least sign of weakness being apparent. The bridge was constructed exactly similar to a ***gabion,*** being 2 ft. 9 in. wide, and a continuous piece of ***basket*** work. With the exception of the gabion-bands and straining tackle, the materials for a bridge of this description may be generally obtained in the field."

It only needs to be observed, that whatever bridge is required, all that is necessary is to augment or decrease the number of bearers to correspond with the utmost load the bridge is intended to carry. The bearers can be increased at pleasure from three to any number. If twelve bearers were used (the breaking weight being about 28 tons), the bridge would safely bear about 9 tons.

The general principles of constructing bridges by means of iron gabion-bands, were approved by the Royal Engineer Permanent Committee, and, on their report, were ordered by the Secretary of State for War to be adopted in the service.

Three tables are added, which shew details of the several structures at a glance, and afford other particular information necessary to be known with respect to the power and capability of the bands, and what stores are required to form 100 feet of bridge.

PLATE 1.



Kell Bros. Lithrs. Castle St. Holborn.

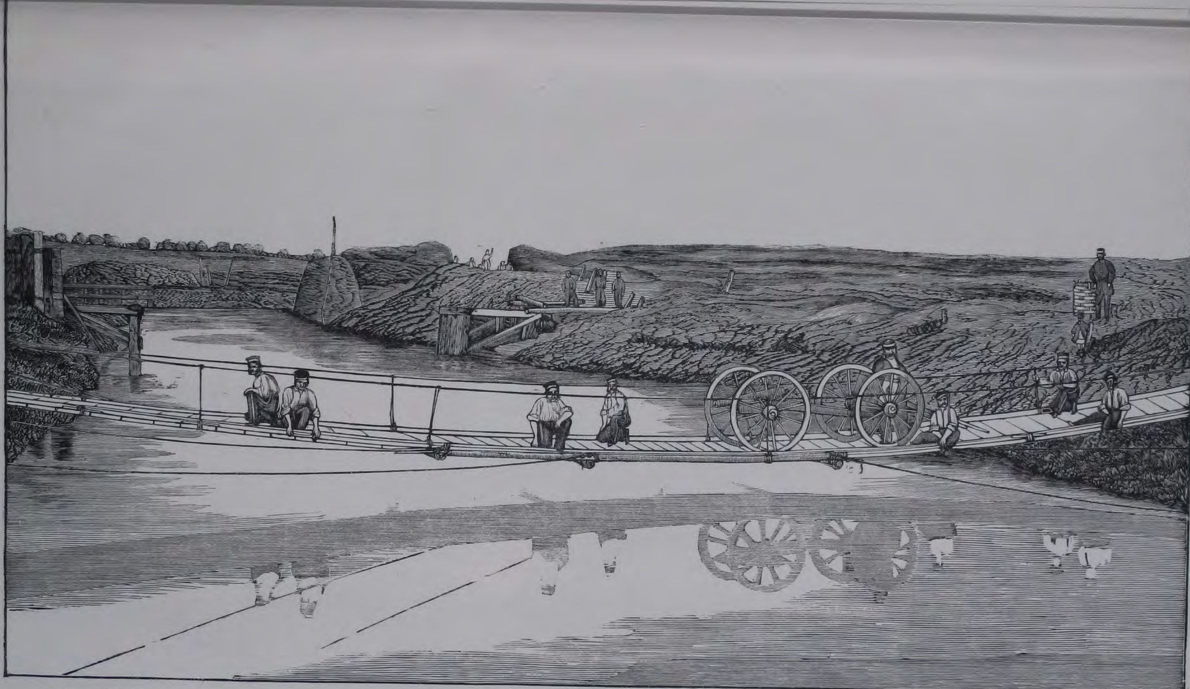


PLATE II.—Bridge for Cavalry and Artillery. Length, 100 feet; width, 8 feet; deflection, 4feet 3 inches; breaking weight, 19 tons.
See description, No. 3.

PLATE III.—Lace Bridge, for Infantry. Length, 100 feet; width, 7 feet 4 inches; deflection, 4 feet 3 inches; breaking weight, $13\frac{1}{2}$ tons.
See descripton, No. 7.

T A B

Detail of eight Suspension Bridges constructed at the Royal Engineer Establishment
and of one by the 1st Devon

Date.	No.	Officers Present.	No. of bearers.	No. of bands.	No. of nuts, bolts, and washers.	Span of bridge.	Width of bridge.	No. of men, and in: Single rank.	Two deep.	Two deep.
1863.						ft. in.	ft. in.			
June 11.	1	Lieut. Colonel Lovell, C.B., R.E......	8	864	448	128 0	8 0	30	40	50
— 14.	2	Lieut. Colonel Collinson and Lieut. Colonel Browne, C.B., R.E.......	6	648	336	128 0	8 0	...	...	20
Aug. 4.	3	Lieut. Colonel Lovell, C.B., R.E....	8	672	352	100 0	8 0	...	...	...
— 27.	4	Lieut. de Vere Brooke, R.E.	4	208	112	65 0	8 0	30	30	40
Sept. 8.	5	Capt. de Montmorency, R.E.	4	432	242	130 0	8 0	...	...	...
Oct. 27.	6	Lt. Cols. Collinson and Lovell, C.B., Cpts. Boileau and Pritchard, R.E., and Lieut. Kyle, R.A................	8	896	468	132 0	8 0	...	...	...
Nov. 5.	7	Lieut. Colonel Lovell, C.B., R.E......	26	564	1,040	100 0	7 4	...	...	...
1864. Jan. 29.	8	Major Fletcher, 1st. L.V.E............	6	264	144	46 0	8 0	...	...	...
1863. June 9.	9	Lieutenant E. Appleton, (F.I.B.A.), 1st Devon Eng. Vol.	10	175	...	65 0	2 9	12	...	...

T A B

Table shewing the result of experiments on Iron Gabion Bands for bridgin

Date.	No.	By whom conducted.	No. of bands.	No. of bearers.	Gauge.	Length of bearers.	Bearers, how suspended.
1863.					BW.	ft. in.	
Nov. 28.	1	Capt. Pritchard, R.E.	40	8	20	21 9	Five bands in leng joined together by r and bolts ; ends doubl over beams.
—	2	Capt. Pritchard, R.E.	40	4	20	22 9	Five bands in length a two in thickness, join together as above.
Dec. 1.	3	Capt. Boileau, R.E...	40	2	20	22 9	Five bands in length a four in thickness, join together as above.

I.

am, 1863-64, the iron gabion bands forming the bearers or supporting chains;
eer Engineers at Truro.

hed over, ler.		Weight in lbs.			Gross Weight.				Deflection.	No. of Non. Com. Officers and men required.	Time.	REMARKS.
Horses.	Guns drawn by men.	Men & guns.	Bearers.	Superstructure.	Tons.	Cwt.	Qrs.	Lbs.				
		lbs.	lbs.	lbs.					ft. in.		hours.	
...	...	10,500	2,226	2,565	6	16	2	3	4 6	1 48	6	
1	...	9,000	1,673	2,565	5	18	...	22	4 6	1 36	6	
...	...	...	1,730	3,337	2	5	...	27	4 3	1 32	6	
...	...	8,460	534	2,021	4	18	1	11	2 0	1 16	6	
...	...	7,650	1,116	3,025	5	5	1	3	4 6	1 24	6	
everal	6-pdr. and 22 men	6,849	2,307	3,868	5	16	1	4	5 0	1 48	6	
...	...	...	1,516	224	...	15	2	4	4 3	1 32	6	
...	...	...	680	1,670	1	0	3	26	1 6	1 17	min. 37	
...	...	...	496	70	1	1	...	14	...	1 20	hours. 2	

II.

ses, carried on at the Royal Engineer Establishment, Chatham, 1863.

Weight, how applied.		Description of strain.	Breaking weight.				Deflection before breaking.	REMARKS.
			tons	cwt.	qrs.	lbs.	in.	
stributed over e whole length three bands, viz., 16 ft. 9 in.		Catenary.	4	2	3	9	12¼	Two bands broke in one bearer, and one in each of the other seven bearers; all gave way at the bridging holes.
Do.	Do.	Do.	3	19	1	15	11⅞	Two bands in three bearers broke at the bridging holes. In the fourth bearer, the inner band, forming the loop, broke near the centre.
Do.	Do.	Do.	4	14	3	14	13¾	Both bearers broke at the bridging holes, in the loop joints, at opposite ends and opposite sides. N.B.—Before the weight was applied, each bearer had a deflection of 6 in.

TABLE III.

Detail of Stores necessary for one hundred Feet of Bridge.

STORES.	No.	Dimensions. Length.		Breadth	Depth.	Weight in lbs.	
		ft.	in.	in.	Gauge.		
Gabion Bands	672	6	5	$3\frac{1}{4}$	20	1,680	These articles are supplied in proportion of one of each for every 20 bands. War Office Circular, No. 842.
Bolts, nuts, and washers,	352	......		......	......	50	
Planking	150	9	0	9	$1\frac{1}{2}$ in.	4,950	
Side pieces	40	10	0	3	$1\frac{1}{2}$ in.	380	
Rack Sticks and Lashings	60	2	0	$1\frac{1}{2}$	$1\frac{1}{2}$ in.	96	
Straining Beams...........	2	13	0	$7\frac{1}{2}$	diam.	380	
Ditto ditto	1	13	0	9	8 in.	270	
Double Blocks	5	0	10	......	......	98	
Single ditto	5	0	10	......	......	82	
Guy Poles.....................	5	12	0	3	diam.	125	
Ditto ditto	2	40	0	3	diam.	167	
Guy Ropes	8	90	0	3	rope	252	
Tackle Fall	5	92	0	3	rope	167	
Slings	10	4	0	3	rope	110	
Spare Lashings	6	6	0	3	rope	60	
Spanners	12	......		......	......	12	
						8,879=	79 cwt. 1 qr. 3 lbs.

J. JONES,

Quarter-Master, R.E.

PAPER XIV.

FORTIFICATION *versus* FORTS,

BEING A SEQUEL TO PAPER XVIII, VOL. XII.

BY COLONEL CUNLIFFE OWEN, C.B., R.E.

[Read at Chatham November 6th, 1863, and reprinted with a few alterations.]

I beg to offer to this meeting some remarks in continuation of those made in this room on the 9th January last, and in reply to Paper XVIII, Vol. XII, read by Captain Wilson on the 20th March last. For the delay which has taken place in making this reply I am not responsible, as these meetings are suspended during the summer months.

The object of my first paper was to shew that a row of forts, such as shewn in Vol. IX of the Corps Papers, was not defensible, except by a large and well trained garrison; and that where no interior enceinte existed, or where it was so distant as not to be able to co-operate with the forts, it was more in accordance with the principles and practice of our profession, and in any case as cheap, to occupy the ground by a continuous line.

I shewed that beyond the paper in question, and the report of a recent American Commission, there was no authority in military literature to support the adoption of these new ideas, and that the opinions of all soldiers whose works I had had an opportunity of consulting appeared to be directly against them.

I especially shewed, and at great length, that it would be impossible to quote even the unsuccessful advocates of the detached system for the Paris Fortifications, in support of the detached system generally, and I expressed a hope that my paper would lead to further research and deliberation.

Of much research I have not heard, but Captain Wilson's paper has been read, objecting to my criticisms on the forts, and endeavouring to show that the line of forts is cheaper and defensible by a smaller garrison than a continuous line of equal length and of the same profile.

A Continuous Line is as cheap as a Detached Line.

I have asserted that a continuous line is as cheap as a detached line, such as is shewn in Vol. IX of the Professional Papers.

1st.—Because the escarps and counterscarps of the latter will cover a great part of the whole space.

2nd.—Because the number of caponiers may be less.

3rd.—Because it will not be necessary to expose faces to direct enfilade and incur the cost of Haxos to cover their armament.

4th.—Because the necessity of an interior enceinte will be saved, or much diminished.

5th.—Because in broken ground much cutting and filling will be saved.

Now, Paper XVIII gives me more than I ask on the first head; it says that continuous scarps and counterscarps will occasion an increased cost of at least one-third, that is making the two systems as 75 to 100. What I said was, that the escarps of the forts would cover nearly half the space, and the counterscarps more than half. I am quite ready to admit that the ditch, rampart, and parapet of a continuous line will cost not one-third more, but as much again, as that of the detached forts proposed, that they will be as 100 to 50 instead of 100 to 75; but let us go a little closer into the question. I have, in a rough, but careful way, made an approximate estimate of the forts before us. I have taken solid revetments, to save my own labour and simplify the question, and I have estimated that they may average 10 feet thick on the escarp, and 7 feet 6 inches on the counterscarp, giving 33 and 25 yards cube, per yard run, of the walls respectively, and I estimate the masonry at 12s. per cubic yard, which gives about £20 as the cost of a yard run of escarp, and £15 for the counterscarp. I estimate the caponiers at £3,000 each; the bombproof accommodation at 1s. per cubic foot measured from out to out; the excavation and disposal, allowing for all turfing, forming, and gravelling, at 1s. 3d. per cubic yard, and I get the following estimate, which is, I believe, not very far from what such a fort would cost:—

Ditches, ramparts, and revetments.	150,000 cubic yards of excavation and disposal, at 1s. 3d.		£9,375
	800 yards escarp, at £20.		16,000
	1,000 yards counterscarp, at £15. ...		15,000
			£40,375
5 caponiers, at £3,000		£15,000	
6 Haxo casemates, at £1,000		6,000	
Mortar battery		1,000	
1,200,000 cubic feet of bombproof, at 1s.		60,000	
Tanks, water supply, drainage, &c.		10,000	
Purchase of land		20,000	
			112,000
	Total for one fort		£152,375
Let us suppose that the ditches of one mile of line are twice as costly, which will add			40,375
	Total for one mile of line... ...		£192,750

But now I must claim some deductions, beginning with the caponiers, which is the second head which I have to consider.

I am told they are three in number, not five, and strictly speaking there are but three caponiers; but there are portions of the keep fitted as such, and which require the same bombproof cover, embrasures, loopholes, magazines, and communications, guns, carriages, and so forth; and, therefore, there are five flanks to the model fort though but three caponiers; and admitting—which I readily do—that each flank should be increased in length if required to flank a greater length of ditch, it is clear that two flanks, even of the increased length recommended, must be cheaper than five. I will estimate the two at £5,000 each, which compared with five at £3,000, will give a saving of £5,000.

3rd.—As to Haxos, the author of Paper XVIII has placed in inverted commas a sentence which is nowhere to be found in my paper*. What I did say was, that "much of the expense of Haxo-casemates may be saved, as it will no longer be necessary to expose faces to direct enfilade." It is assumed that it will be necessary in a continuous line to provide a flanking as well as a direct fire upon the ground in front. I have searched works on fortification in vain to find opinions in support of this assertion. The main objection to the bastioned system is, that the flanks are exposed to enfilade and reverse fire, and the object of the German Engineers has been to reduce the rampart to a line as straight as possible, consistent with the caponiers not firing into one another. All the sinuosities of the bastioned trace arise from the necessity of flanking the ditches, not the glacis. The great saliency given to the ravelins is not to provide a flanking fire, but to delay the enemy in his approaches to the body of the place. I therefore maintain that in a continuous rampart flanked by caponiers, very few, if any, Haxos, will be necessary on the terreplein. Nor is the expense of these Haxos so inconsiderable as it is endeavoured to make out. A casemate cannot be built upon a rampart without its foundations being laid upon the natural soil, and a very sensible economy will be attained by their omission. If I save only half, I save £3,000.

4th.—The author of Paper XVIII will not admit that the exterior line being continuous will save the construction of an interior enceinte. Now, the author of the paper in Vol. IX does admit it, for he advocates a continuous line when difficulties occur in forming an interior enceinte. Of course I do not deny that a second enceinte would give additional strength, but it must be clear to all, that when an enceinte exists a second one is much less required. Now, suppose the dockyard we have to protect has an average diameter of 2,000 yards, and this advanced line is 8,000 yards beyond its enclosure, and that the interior enceinte is established only 1,000 yards from the dockyard; we have the exterior line traced on a radius of 9,000 yards, and the interior on one of 2,000; for every mile, therefore, of exterior line, there will be two-ninths of a mile of interior line. Suppose the mile of line to cost what I say it will, about £150,000 per mile, each fort will require £33,000 to be provided for an interior line. It may be said the interior need not be so formidable, but then the cost of land will be incalculably greater; however, I will take only half, say £16,500.

I have stated that in broken ground heavy cuttings and fillings are required to bring the whole of the ground under fire of the forts. It is stated in reply that it would be easy to imagine a site where the cost of excavating the long ditch of the continuous line would render the job impracticable. This is not so easy to me. If the ground is hard, it must be hardest on the eminences which

* By referring to Vol. XII, page 188, it will be seen that the passage alluded to was not intended as a quotation, but simply as an imaginary statement of an advocate of continuous lines.—Ed.

must be chosen for the forts, whereas in carrying a line across valleys you often come to water, and can get rid of your revetments altogether.

It must be borne in mind that the eminence on which the fort is necessarily placed must be reduced to a pyramidal form, and that, if the thing is looked at practically, must be more difficult and more costly than forming the ground into a series of planes passing through the crest of a line which may be bent to any required shape.

To shew that I am not talking at random on this point, I can shew two forts about the prescribed distance apart on ground of no great natural difficulty, one a little larger, and the other a little smaller than that shewn in Vol. IX; and where the excavation has amounted on the average to half a million cubic yards for each fort, 500,000 instead of 150,000; but say they were increased only to 300,000, you must add to the forts, or deduct from the line a sum of £9,375.

I therefore claim saving		on caponiers	£5,000
—	—	on Haxos	3,000
—	—	on interior enceinte...	16,500
—	—	on excavation	9,375
			£33,875

I thus reduce the difference between the two systems to £6,500 a mile, being £158,500, and £152,000 respectively, a difference of 4 per cent., which is not worth talking about, and which, had I been disposed to strain the above figures, I could easily have covered.

The fact is, that the ditch and rampart are but an inconsiderable part of the cost of one of these works, and, when you come to water, it will be less still; while the cost of all casemated buildings will be much increased from the difficulty of getting foundations.

A continuous line can be defended by a smaller Garrison than a detached line.

Then, as to the number of men required. It is made an objection that I speak only of escalade or surprise, a most improbable event in a regular work. This I fully admit; but it must also be admitted that it is upon the facility of surprise that depends the guard that must be kept all round a beleaguered fortress, whether the trenches are opened against it or not. It is only after providing this guard that men can be provided for the actual siege.

What I assert is, that a battalion of infantry and a company of artillery can guard a continuous line $2\frac{1}{4}$ miles in extent, and that the same number of men can do no more than guard the escarps of the three forts.

It is fairly enough remarked that to these forts should be allotted three miles of line, and that I have, therefore, overstated the number of points at which guards would be necessary.

On the other hand, I have given but 600 yards of scarp to each caponier, whereas 1,000 metres* are given at Antwerp; and taking the three miles for a basis of comparison, the forts would require watching at 15 points, and the line at five. I have nowhere stated that the guards should be of the same strength

* 1100 metres. See page 73.—Ed.

in either case, but surely it is easier to control and manage five guards of, say 40 men, than 15 guards of a dozen men each.

And bear in mind that, with these guards on the alert, the continuous line is almost absolutely secure against surprise, the ground inside is absolutely your own, and you may wait in confidence for the attack to declare itself.

It is in the guard of the openings that I claim an economy of men. My openings are all provided for; the author of Paper XVIII postpones his till another part of his paper, and then we shall see that he will have a line of works there, quite as continuous as mine, but, being run up on the spur of the moment, necessarily not so strong in profile; he will have another little intermediate fort or two, improvised, and unless he can show that these lines and forts can be held or guarded without men, he must allow that his works would altogether require many more men than mine; and if he has not these intermediate works, he must then have what French writers call "des courtines de troupes."

To obtain an economy in the garrison of the forts it must first be shewn that fewer men can guard the escarp of the fort than the escarp of the line, and that the balance is more than sufficient to watch the three openings. Besides, if these new views be true, and the enemy cannot really pass through the openings, the artillery fire of the forts must be the preventing cause, and an armament and men to work it must be provided on each fort, whether it be besieged or not.

Imperfectly trained Troops are not suited to the Defence of a Detached Line.

Then, as to the training of the troops. I have stated that the defence of a continuous line is so simple, that it is best suited to young and imperfectly trained forces. The author of Paper XVIII acknowledges that "some authorities lay it down as a rule, that detached works ought to be defended by well-disciplined troops;" but he goes on to explain this altogether away, and talks about patriotic feelings not only converting every man into a finished soldier but enduing him with a spirit of self-sacrifice and resolution, often wanting among the best troops. Now, patriotic feelings are all very well in their way, but they will not, alone, make soldiers; and self-sacrifice is the first of virtues, but it will not, alone, win battles. Both combined will no more make a man a finished soldier, than they will make him a finished swordsman. He may make up his mind to conquer or to die; but, however good his cause, he will most probably die and not conquer, if he does not know how to fence, and if opposed to an adversary who does. Take the siege of Saragossa. I presume there scarcely ever was an instance in which the patriotic feelings of the inhabitants of a beleaguered fortress were wrought to a higher pitch. Historians have told, and poets have sung, how man and woman, priest and layman fought, aye, and died, in its defence; and what was the result? That 35,000 French soldiers invested, besieged and took, with the loss of but 3,000 men, a city defended by 30,000 indifferent troops, commanded by a very brave General, 15,000 armed peasants, answering to our volunteers, and an immense and enthusiastic population; and that the defenders lost the almost incredible number of 54,000 lives.* So unavailing is patriotism and self-sacrifice against military science

* Kausler.

and skill. But, really, this is not the question. It is whether the said patriots or finished soldiers will have a better chance behind a continuous rampart than in and between a chain of detached works. It is admitted that "some authorities" think as I do, that they will. It would have much aided the present discussion had the authorities been quoted which think the contrary. I know of no authority which is stronger in my favour than one which the younger members of this meeting must know very well, the text book on fortification, at Woolwich Academy, in which, p. 126, I read as follows :—

"Detached works require to be defended by the best disciplined troops, who, accustomed to repose unlimited confidence on their officers and on each other, may be depended upon to maintain a steady and resolute defence under circumstances apparently the most discouraging."

The Defence of a Continuous Line is simple and easily understood.

I have objected to the difficulty a governor would find in controlling the actions of the commandants of all the forts, and of those commanding in the intervals. The electric telegraph is put forward as a remedy. It is, I admit, a powerful engine of war, and may lead to very great results. I will go further, it is the only new discovery which, in my opinion, gives the shadow of a support to the total revolution in the art of fortification which has been put forward; and if the confusion of authority were the only objection to the new system, I should be disposed to say, it appears rash to stake so much upon the nimble needles of the telegraph, but it may possibly answer. But the confusion of authority is but one of my objections, and the telegraph would also add to the strength of a continuous line, though we know, from long experience, it can get on very fairly without.

I have advanced that the command of each fort must, in practice, fall to the senior officer present, and that he may not happen to be the fittest person for a situation of such responsibility. I am told that every officer placed in command of a fort "makes it his business to study the course of action he ought to pursue when the hour of trial arrives;" but I must appeal to those who have seen the world, whether we are justified in doing so. Seniority is the rule of promotion in our own corps, and it is the rule of the British army more than, perhaps, of any other; but, even with us, a selection takes place for positions of individual responsibility, for the governors of fortresses, the command of divisions and brigades. Every one is not fit for these positions, though he may do his duty perfectly under the eye of another. To carry out the detached system, with any chance of success, the governor ought to have the power of selecting, as commandants of the forts, the most competent officers in his garrison; and of that the constitution of our, or of any other army, will not admit.

I have objected to the multitudinous covered flanks inseparable from these forts, I should wish them reduced in number and made larger, an advantage which can be attained by the continuous line, and I mentioned, incidentally, some of the advantages of the simplicity of the bastioned trace. It is concluded from this that I object to covered flanks altogether. If those who take this view will read carefully again what I did say, they will come to a different conclusion. What I maintain is, that both covered flanks and open flanks have their advantages and disadvantages, and our preference for one must not blind us to its defects. As French military writers vie with each other in saying, "Il n'y a rien d'absolu à la guerre."

My opponent is indignant at my apprehension of "skulking." Alas all men are not heroes, any more than all officers Bayards. Under the eye of their officers and their comrades few will fail, but many will when isolated. Remember, that to some of these flanks you will scarcely be able to allot a non-commissioned officer.

However, let this point be decided by those who have oftener seen men under fire than either of us. I can but put forward for the consideration of my brother officers, the result of my own observations and reflections. I have seen but few campaigns and have little chance of seeing any more.

Continuous Lines are sanctioned by long experience.

Then, as to the experience of the past, the author of Paper XVIII assents to my opinion, that "continuous lines have been, from the earliest days of fortification, applied to form the main enclosure of a town or military position," he could scarcely do otherwise; but so far as he knows, "this is the first time they have been proposed for application to an extended position some 8,000 yards in advance of the main enclosure." Would it not be the fairer way of putting it, that the occupation of positions so extended in a permanent manner, is now, for the first time, rendered necessary, and we are discussing whether it is necessary in such a case to have two enclosures or one?

I say that if you have already an interior work, you must either throw forward detached works, which will cover, by their fire, the whole or nearly the whole of the ground between that work and the advanced circle, or you must build a second enclosure on the advanced circle. I have acknowledged, and still acknowledge, that when, from the configuration of the ground, the intervening space can be seen from the interior line and from the exterior, then a detached outer line is perfectly admissible, and the forts may be placed even further apart than is now contemplated. So far, I think, we are all agreed; but my opponents seem to wish me to admit, which I cannot, that a considerable space may be left, within the outer line, undefended and unseen. They, in fact, do not consider it necessary that the interior line should support the exterior.

I am all, as I have said, in favour of detached works, when they, by supplementing an existing work, will answer their purpose; but when no interior enceinte exists, I maintain that it is better to build a continuous line on the outer periphery.

At Antwerp, Toulon, and Cherbourg, is there any ground within the exterior line which is unseen?

An enemy can pass between the detached works.

I have asserted that where such unoccupied ground exists, it must be occupied by the besiegers, the outer line of forts remaining intact. The author first doubts whether such ground can, by any possibility, exist. He says, "unoccupied ground is presumed to be safe from the fire of both forts and innerl ine," whereas, "our rifled guns have ranged 9,000 yards." Well, but I presume, neither Whitworth, Armstrong, nor Blakely can fire through the crest of a chalk hill; and that such unseen ground is a very common thing, I trust, this meeting will agree. We all know Woolwich; we will take the Repository as our enceinte, and a chain of works stretching round it at a radius of 8,000 yards—say, round by Deptford, Lewisham, Eltham, Bexley, and Erith—could you not find very fair and abundant cover between? Do bear in mind that 8,000 yards is all but five miles.

Remedies proposed for this defect.

But, though the very existence of such ground is doubtful, and my attack treated as "chimerical," I must be allowed to doubt whether they are really thought so on account of the abundant precautions taken against it, besides the two lines of works.

1st.—Page 196, "Fieldworks might be thrown up, forming a continuous line between the forts," and,

2nd.—"Such" unseen "ground would be defended by some intermediate work."

So, after all the criticism, I would almost say indignation, which has been heaped upon my paper, my very opponents come back to my ideas, they wish for a continuous line though they cannot give up their forts. This is what I have so often found in discussing these new detached systems; they are never complete; some ditch, or work, or battery, or tower, is always wanted to patch up their defects, so that when the hour of danger arrives, when all hands and all thought will be wanted to arm and provision and defend the works, they would have to set to work and do what could have been done as easily, as cheaply, and far more effectually in the first instance.

Where is their assumed economy of men, if, after guarding the forts and the interior enceinte, they have to guard a continuous line on a field profile in the intervals and intermediate works between the outer and inner line; where are their boasted facilities for sorties?

The author, I think, sees the force of this, and towards the end of his paper becomes almost a convert to my views, for he talks of the field profile being turned into a permanent one "as years roll on."

I will put the question before the meeting in another way. Suppose a place had, in spite of all this hostile criticism, been fortified with a permanent continuous line of the same profile as the proposed forts, and the ditches well flanked by caponiers or otherwise; and suppose an Engineer had time and means to strengthen it, would he, at the moment of danger, or, "as years roll on," intrench the salient points inwards? Surely not. Would he not rather make coupures in his rampart and *re*trench against the enemy those points most liable to be breached, or where, from exceptional circumstances, an escalade might be apprehended.

This is not a hypothetical case, it has occurred over and over again in the bastioned trace; and I know no case where the bastion has been turned into an enclosed work.

Had the bastions of Bergen-op-Zoom been treated thus, their successful assaults would not, as they did, have terminated in disaster to the assailants.

their advantages and disadvantages, and our preference for one must not blind us to its defects. As French military writers vie with each other in saying, "Il n'y a rien d'absolu à la guerre."

My opponent is indignant at my apprehension of "skulking." Alas all men are not heroes, any more than all officers Bayards. Under the eye of their officers and their comrades few will fail, but many will when isolated. Remember, that to some of these flanks you will scarcely be able to allot a non-commissioned officer.

However, let this point be decided by those who have oftener seen men under fire than either of us. I can but put forward for the consideration of my brother officers, the result of my own observations and reflections. I have seen but few campaigns and have little chance of seeing any more.

Continuous Lines are sanctioned by long experience.

Then, as to the experience of the past, the author of Paper XVIII assents to my opinion, that "continuous lines have been, from the earliest days of fortification, applied to form the main enclosure of a town or military position," he could scarcely do otherwise; but so far as he knows, "this is the first time they have been proposed for application to an extended position some 8,000 yards in advance of the main enclosure." Would it not be the fairer way of putting it, that the occupation of positions so extended in a permanent manner, is now, for the first time, rendered necessary, and we are discussing whether it is necessary in such a case to have two enclosures or one?

I say that if you have already an interior work, you must either throw forward detached works, which will cover, by their fire, the whole or nearly the whole of the ground between that work and the advanced circle, or you must build a second enclosure on the advanced circle. I have acknowledged, and still acknowledge, that when, from the configuration of the ground, the intervening space can be seen from the interior line and from the exterior, then a detached outer line is perfectly admissible, and the forts may be placed even further apart than is now contemplated. So far, I think, we are all agreed; but my opponents seem to wish me to admit, which I cannot, that a considerable space may be left, within the outer line, undefended and unseen. They, in fact, do not consider it necessary that the interior line should support the exterior.

I am all, as I have said, in favour of detached works, when they, by supplementing an existing work, will answer their purpose; but when no interior enceinte exists, I maintain that it is better to build a continuous line on the outer periphery.

At Antwerp, Toulon, and Cherbourg, is there any ground within the exterior line which is unseen?

An enemy can pass between the detached works.

I have asserted that where such unoccupied ground exists, it must be occupied by the besiegers, the outer line of forts remaining intact. The author first doubts whether such ground can, by any possibility, exist. He says, "unoccupied ground is presumed to be safe from the fire of both forts and innerl ine," whereas, "our rifled guns have ranged 9,000 yards." Well, but I presume, neither Whitworth, Armstrong, nor Blakely can fire through the crest of a chalk hill; and that such unseen ground is a very common thing, I trust, this meeting will agree. We all know Woolwich; we will take the Repository as our enceinte, and a chain of works stretching round it at a radius of 8,000 yards—say, round by Deptford, Lewisham, Eltham, Bexley, and Erith—could you not find very fair and abundant cover between? Do bear in mind that 8,000 yards is all but five miles.

Remedies proposed for this defect.

But, though the very existence of such ground is doubtful, and my attack treated as "chimerical," I must be allowed to doubt whether they are really thought so on account of the abundant precautions taken against it, besides the two lines of works.

1st.—Page 196, "Fieldworks might be thrown up, forming a continuous line between the forts," and,

2nd.—"Such" unseen "ground would be defended by some intermediate work."

So, after all the criticism, I would almost say indignation, which has been heaped upon my paper, my very opponents come back to my ideas, they wish for a continuous line though they cannot give up their forts. This is what I have so often found in discussing these new detached systems; they are never complete; some ditch, or work, or battery, or tower, is always wanted to patch up their defects, so that when the hour of danger arrives, when all hands and all thought will be wanted to arm and provision and defend the works, they would have to set to work and do what could have been done as easily, as cheaply, and far more effectually in the first instance.

Where is their assumed economy of men, if, after guarding the forts and the interior enceinte, they have to guard a continuous line on a field profile in the intervals and intermediate works between the outer and inner line; where are their boasted facilities for sorties?

The author, I think, sees the force of this, and towards the end of his paper becomes almost a convert to my views, for he talks of the field profile being turned into a permanent one "as years roll on."

I will put the question before the meeting in another way. Suppose a place had, in spite of all this hostile criticism, been fortified with a permanent continuous line of the same profile as the proposed forts, and the ditches well flanked by caponiers or otherwise; and suppose an Engineer had time and means to strengthen it, would he, at the moment of danger, or, "as years roll on," intrench the salient points inwards? Surely not. Would he not rather make coupures in his rampart and *re*trench against the enemy those points most liable to be breached, or where, from exceptional circumstances, an escalade might be apprehended.

This is not a hypothetical case, it has occurred over and over again in the bastioned trace; and I know no case where the bastion has been turned into an enclosed work.

Had the bastions of Bergen-op-Zoom been treated thus, their successful assaults would not, as they did, have terminated in disaster to the assailants.

Remarks on discussion of Captain Wilson's paper.

In discussing the paper, it was advanced that because two attempts at escalade succeeded at Badajoz and the enceinte at Badajoz was continuous, therefore, continuous lines are peculiarly subject to escalade. Would it not be thought grossly unfair if I was to retort that because Picurina was carried by escalade, therefore, detached works are peculiarly subject to such a contingency. Detached works are neither more nor less subject to be carried by escalade than a continuous line, if both are equally well or ill guarded; but this I say, that if the keep of one of the proposed detached works be carried by escalade, the whole line falls at once; the occupation of the collateral forts, invested as they might be, in front and rear, is of no use.

And then the distinguished director of this establishment winds up by giving in his opinion, and that of most of the officers present, "that if called upon to prepare a very extensive position, because it might possibly be required, the necessity being doubtful," he would "select such points as would secure the widest command," and "render the capture of those points, by an enemy, as difficult" as possible. "If the defending forces were comparatively weak" he would form some sort of continuous line in rear, but if they were strong he would use those means more sparingly.

With all due respect to him, I venture to observe that the necessity of our works being required is always doubtful, and the better the works the more remote becomes the possibility of their being attacked. But having a position to make defensible, we are bound to make it defensible by the smallest numbers which the resources at our disposal will allow.

The system of forts I have been discussing presupposes that we have money to build them; and if, as I think, I have shown the continuous obstacle, which he admits is wanted where the defenders are inferior in number and training, can be formed in a very superior manner for the same outlay which would be incurred in securing the points; and if, therefore, the position is prepared to be defended by the smallest and least efficient force which is capable of undertaking it at all, he need be under no apprehension of being able to defend it by a stronger force. He is too good a soldier not to know how to dispose of his superfluous forces. A good whist-player is never embarassed by a large hand of trumps. I think he must permit me to welcome him, at all events, as a supporter of my opinion, that the line of detached works requires a stronger and better trained garrison than a continuous line.

Saliency, a new principle in Fortification.

There is another topic treated in the paper before us which merits some attention; at page 196, it is said that "for centuries engineers have concurred in the propriety of thrusting out marked salients for the purpose of reducing the points of attack, and massing upon these points all available means of defence;" and it is claimed that this principle is attained in its fullest extent by the detached line.

Certainly, saliency may be obtained two ways, either by "thrusting out" certain points, or by retiring the intervals, the more the better my opponent seems to think, for he marches the re-entering portion off the field altogether. Think of sponging the curtains out of a drawing of a front of fortification, and exclaiming—see what admirable saliency that gives to the bastions! But is the principle he lays down a true one; has it ever been maintained by any engineers of note, ancient or modern? Examine any system of fortification, or the trace of any existing important fortress. Do you not find that the rampart of the body of the place follows the shortest line consistent with the ditch being flanked; the shortest line, and, therefore, according to Euclid, the straightest. Ravelins are, of course, "thrust out," but they are mere accessories. Their profile is inferior, their armament less heavy, both in number and calibre, than that of the bastions, for the very simple reason that it may have to be withdrawn. Bombproofs are, or ought to be, used sparingly in the ravelins, or they may become useful to the besiegers. In no sense can it be said that "all available means of defence" are massed upon the salients of the ravelins, if the ravelins are meant.

Depend upon it, this principle of saliency rests on no good foundation. It is as modern, and as inconsistent with the true principles of our art, as the saliency of crinoline is inconsistent with the art of the sculptor.

Comparisons between continuous lines on a field and permanent profile.

We are told that continuous lines of field works have almost invariably been broken through with ease. Though this is the opinion of my opponent, the opinion of Vauban* was different, for in talking of lines of contravallation he can only cite one instance, that of Turin, in which they had failed; and Bousmard, writing more recently, says very properly that lines " ont eu un-temps de vogue exagérée pour tomber dans un discrédit plus outré encore."† I think, if the whole subject were carefully gone into, the cases of successful defence would be fully equal to those of successful attack; I, however, admit cheerfully, I have admitted it before, that where there is an equality of forces, where there is even an approach to equality, it is best to strengthen a position by detached works, and to manœuvre between them; but the case is quite different with permanent works. A 30-foot scarp cannot, absolutely cannot, be escaladed

* Défense des Places.

† Bousmard, book V, chap. 8. See also the following translation from book V, chap. 6, cited verbatim in the text books of the Ecole d'Application at Metz. "When the troops occupying an intrenched camp are of equal strength to the assailants, or when the inferiority of the former is not such as to forbid their leaving their intrenchments to take advantage of false manœuvres or disorder among the enemy, it is evident that this camp should be constructed so as to render such an operation practicable at all points where it may be advantageous to attempt it, and must consist of redoubts, or sections of intrenchment separated by intervals sufficient for the passage of large bodies of troops. When, on the contrary, the defenders are so inferior in numbers or quality to the assailants, that they cannot prudently risk themselves beyond the line of works, it is equally evident that no openings whatever must be left through which the enemy could, in spite of the lateral obstacles, come actually hand to hand with the defenders; or through which he could take advantage of the necessary weakness of the defenders at any point; or, again, through which his artillery could breach these curtains of flesh and blood, and drive them so far back that they could no longer support the redoubts which form their bastions. It is useless, therefore, to take all the risk of the openings without any corresponding advantage."

under a flank fire. It has never to my knowledge been done except by surprise, and to that contingency detached works are as liable, every bit, as continuous lines. I do not know what is the height of escarps on which escalade is practised here, but I have seen a letter from the colonel of a regiment of the line remonstrating against his men's lives being risked in the mere practice of escalade against an escarp which turned out on measurement to be 30 feet high.

Again, I suppose I shall be charged with only thinking of escalade, but I am driven to it by the remarks I am replying to. I alluded to certain general actions in which the mere fire of works had not prevented troops passing them, observing that the effects of such fire may be studied as well in the case of field as of permanent works. I am answered that where those works were continuous, that is, where they not only opposed their fire, but a material obstacle to the advance of the attacking force, that obstacle has been "almost invariably" overcome. If for "almost invariably" I am allowed to say "often" overcome, we are agreed; but then, the nature of the obstacle becomes an important question, and I maintain that not only is a 30-foot scarp a greater obstacle than the strongest field work ever built, but that it is incomparably superior; and though, therefore, I have a right to argue that if field works armed with artillery have been passed by, permanent works might be passed in the same manner, except so far as the calibre of the guns affects the question; I cannot, at all, admit that the comparison can be carried on to the *assault* of field and permanent works respectively. The first operation is possible and has been carried out, the second is all but impossible.

Resistance of the two systems to a regular siege.

But now let us go on to the siege. Suppose the trenches opened in due form before a line of detached works and a continuous line, let us consider what would be the state of things within the garrison.

The entire circle must remain guarded in either case, and I will, for the sake of argument, admit that the enemy dare not risk themselves in the intervals between the forts. We will suppose in either case some 5,000 men of the garrison absorbed in the guard of the fronts not attacked, giving some 1,500 men on duty, and we will suppose 5,000 more available on the fronts attacked, giving the same number of duty men. I am taking the proportions usually laid down in works on the defence of fortresses, that one-third should be on the works on duty, one-third bivouacked or ready to turn out, and one-third at rest.

An army to attack the place at all must be able to have a guard of the trenches, besides workmen and artillery, equal to two-thirds of the garrison, say 6,000 men so that you will have 6,000 men always in the trenches, and 1,500 men to conduct the defence, besides a reserve of as many more ready to turn out.

Out of the 1,500 men on the works, perhaps half might be allotted to the guns, and they might manage to work 100 guns. Now, suppose the attack directed upon the capital of one fort, the attack would have to contend with the fire of the faces of that fort and the flanks of the two adjacent forts, measuring on the parapet only about 400 yards, for it is a peculiarity inseparable from forts that they present a minimum of fighting parapet with a maximum of escarp, and at 25 feet a gun—a very small allowance including traverses—you could mount and work 48 guns, and no more; whereas on the line you could mount 100 easily, giving them merlons twice the thickness; and, being further apart, they would be much more efficient.

I may be told of intermediate batteries, but then they are not guarded by an escarp and are liable to capture by a sortie from the trenches. In a sortie from a garrison they very often lose many more than they gain, for the besiegers can afford to lose many men for every one that the garrison loses; but the case is reversed when the garrison venture out of their works and expose themselves to sorties from the besiegers. I cannot, do what I will, discover what advantage this detached line has over a continuous one in any subsequent part of the siege, if siege there must be.

The defenders of the forts will be peculiarly subject to danger from vertical fire, and I would further remark that the great advantage of a long and nearly straight line of defence is lost. The great advantage the attack has always possessed over the defence arises from the converging fire of the former. This advantage becomes less and less as the fronts of attack approach nearer to the straight line, but this gain is at once thrown away by crowding the whole armament on a few points on which the fire of the entrenched lines of the besiegers' trenches may converge as much as in the siege of the smallest fortress.

My opponent is so strong in his condemnation of continuous lines that he seems to think them absolutely incapable of standing a siege, though they have stood thousands of sieges. His expression is worth noting :—"If they are of any use at all, it will be for presenting a continuous obstacle to a sudden assault." How then, may I ask, does he propose to get in? Does he suppose they will fall down flat at the click of the first pickaxe, as the walls of Jericho did at the sound of the trumpets of Joshua? He cannot carry them by assault, he must breach them, and if properly constructed he must patiently sap up to the crest of the covered way, and breach them by mining, or by artillery, or he cannot get in. This he must allow, and he cannot claim more from me for one of his forts.

H. C. O.

Abstract of Discussion.

Colonel Harness—The difference between Colonel Owen and myself is this: we attach different values to the occupation of commanding points of ground. A general officer attacking a position, of which all the commanding points are occupied unassailably, not knowing in what manner the intervals are defended, nor able to guess what preparations have been made to receive him if he should penetrate the first line of defence, would hesitate to throw troops between such points. In preparing a position it would be sufficient in my idea to place commanding points in such a state of defence as would oppose a formidable resistance and leave it to the time of probable attack to perfect the defences between them. Colonel Owen seemed to think that I agree with him as to the nature of the troops required for the defences of the continuous line and detached works; but if detached works are so strong, and the obstacles in rear of them so good, as not to be open to a *coup-de-main*, then I do not think that the troops occupying them need be so good as those required for the defence of a continuous line.

General Sir John Burgoyne—With regard to the question of detached forts and continued lines much is to be said on both sides; either may be right, or either wrong. If it be a case of merely keeping an enemy out of a compact place, as a town, you must do it with a continuous line; but when, as in the case of important arsenals, you come to a great extensive line 20 or 30 miles long, in consequence of its being necessary to keep an enemy at a great distance, a continuous line of ditch, scarp, and counterscarp, however good, running up hill and down hill, would be very weak. A continuous line in such a case would bear resemblance almost to the great wall of China. Under such circumstances, then, we must resort to the occupation of particular points, places which may in case of need be held by a small number of men, and in case of war, would allow of strong defences being created in the intervals. None would attempt to penetrate between such works unless they could at once get at vital parts. If this is not to be done nothing remains but to attack and take two or three of these works.

In extreme cases then, I think we must be all agreed, but others may arise in which we may have doubts as to the plan to adopt. With certain places of intermediate character between the arsenal and little compact town it may become questionable whether Colonel Owen or Captain Wilson is right, and herein all the difference consists. This difference is certainly not so great as is implied by the tenor of these two papers.

Lieut. Colonel Collinson—The tendency of Colonel Owen's paper is undoubtedly to destroy our confidence in the works now being constructed for the defence of England. Does he mean that we are to stop them at once and commence a new system? Since the last large wars of Europe rifled guns have been invented, lines of defence have been greatly extended, and the system of building detached forts in front of existing enceintes entered upon. If we consider the history of the question during the intervening time, we shall see that all the countries of Europe are tending in their fortifications to the principles of occupying important detached points. At all the great fortified places constructed since the last European war, the new and extended lines of defence, taken up in advance of the old works, have been occupied by detached forts. At Antwerp there is also a new interior and continuous line as well, but Antwerp is a special case, and there the outer line of all is composed of detached forts of the Gosport type. In thus determining to use the system of detached forts for these extended lines, the Continental engineers have, I should think, been influenced by two considerations, namely:—first, the extent of line to be defended; second, the nature of the ground to be occupied. With reference to the first point I would remark, that the difficulty of the defence is not in proportion merely to the circumference of the line to be defended. Herein present circumstances differ materially from those of ancient fortresses, where every point was under such close command, that the power could be made to bear at once where wanted. The difficulty of defence increases now in proportion to the area to be defended as well as its circumference. In fact, I would almost say that the difficulty of occupying a continuous line increases as the square of the diameter of the space enclosed. Secondly. With respect to the nature of the ground.—Irregularity of feature obliges us to occupy points with detached forts. It is not within the means of any nation to make a long continuous line over irregular ground, of equal strength throughout, and it is much better to have your separate garrisons included within comparatively small areas, than to have defenders stretched out over a long line of varying powers of resistance. To compare the expense of the two systems by the length of lines of parapet merely is not quite fair. I do not mean that Colonel Owen's estimates are not based on good grounds; as far as I could judge as he went over the items they are so, but his statement does not represent the whole case. I thought from his first paper that he was opposed to the caponier system of procuring flank defence; that he objected to the galleries, communications, and dark passages. It would not appear from his present paper that he is so opposed to it as a system; but if he still advocates the bastioned trace for a continued line, I would remind him that it is now necessary to cover the guns on the rampart to a greater extent than the ordinary bastioned system provides for. Open bastions and open terrepleins are no longer sufficient. Captain Schüman, of the Prussian Engineers, came here a few weeks since to get information on the subject of covering guns and fronts of casemated bastions with iron, with reference to the defence of Mayence. If the caponier system is the better of the two for the object of cover, we should try to improve on the caponier itself rather than resort to the open bastion again. And if we do take the caponier system, there is no reason for such a number of flanking points in it as Colonel Owen attributed to it in his first paper. In fact, the caponier system should have fewer flanking points than the bastioned system. I do not at all agree that the defence of detached forts is opposed to our national character; on the contrary, the Englishman loves best to have some special charge to defend and to occupy—secure and well-defined points—and fight them independently. We prefer independent responsibilities; and, therefore, I think the detached fort system specially suited to the British character. Battalions under their own commanders have that *esprit* which leads to the obstinate defence of the point they are entrusted with, but this is much diminished if they are combined in large bodies spread over large spaces without the feeling of independent command. I should not myself, therefore, advise a general, though he might have the men and opportunity, to throw up elaborate works of defence between forts, for I believe there would be a better defence by preserving the independent character of these forts in its entirety. No foreign general would endeavour to force his way between them without having reduced several of them.

Colonel Owen—I wish to keep clear of every thing like a criticism of the works we are now constructing for the defence of this country, and I have had no hand in putting on the table the models which I see on them. We must not criticise works we have been ordered to construct, and I trust I have always endeavoured to carry out the orders I have received respecting the works under my charge, not in the letter only, but in the spirit. I have discussed the question in the abstract, and I took, for illustration, an imaginary project, published in one of our annual volumes, and therefore a fair subject for professional discussion. There may have been allusions in my first paper seeming to bear on the works in progress, and if they did so, I regret it, and tried to avoid them. I am writing and talking as if no works had been constructed, or were in progress. With reference to the remarks which have fallen from Colonel Harness, while I entertain the greatest respect for his opinion, I must point out that he has not explained why, if it is only necessary to take up these commanding points, soldiers have thought it necessary, for so many thousand years, to oppose a material obstacle between them? It was always open to them to have made use of detached forts only, and to say, as is now said, "can a general come between them?" In no country, that I am aware, have they constructed, or are they constructing, works, used in fortifying a position, which do not cross fire with some interior regularly fortified enceinte. At Cherbourg, they do so; at Antwerp and Toulon they do so. Havre may be an exception; on this place I cannot speak, I have only seen the works there from a distance.

Captain Crossman—At Antwerp the works have only been made to cross fire by two or three months' labour in reducing intervening obstacles.

Colonel Owen—I have conversed with officers who are familiar with Antwerp, and they tell me it would be impossible to encamp anywhere within the outer works without being seen, and I maintain that for efficient defence, nearly, if not quite all, the ground between the two circles, the inner line and outer detached works, must be under fire.

Captain Wilson—Colonel Owen seems to think that in my paper I have denied the possibility of there being unoccupied ground between the two lines of works safe from the fire of both. What I have said is, that it is not fair to presume on such conditions; for if there were such ground it would probably be occupied by an intermediate work. In fact I provide for the contingency, and, in doing so, I manifestly admit the possibility of its existence. I should like to say a few words on the question of authorities, a subject to which Colonel Owen deservedly attaches much importance. He has quoted an opinion of the late Duke of Wellington, apparently condemning the employment of detached works. It is extracted from a work lately published by Sir H. Jones, containing reports and details concerning the fortifications erected in the Netherlands, subsequent to 1815, and gives the substance of the decision arrived at, as to the works to be constructed at Namur, in front of the citadel or castle, that decision being formed in deference to the opinion of the Duke of Wellington. The words quoted are nearly these:—"His Highness (the Duke) disapproving of the detached works proposed by the engineers of the Netherlands, it is settled to adopt the closed line of works proposed by the English engineers for the first line in front of the Chateau de Namur." Here Colonel Owen claims the authority of the Duke in support of his views; but whether he is right or not in drawing such an inference will evidently depend on what this first line in front of the chateau actually was; and in order to examine this point fully we must have recourse to the volume from which the quotation is taken. That book contains in full the reports of the English engineers; then an abstract, giving side by side, in a condensed form, the recommendations of both the English and Dutch engineers; and in a third column those of the Duke himself; and finally, the decisions arrived at concerning each fortress. It is from this last that Colonel Owen has made his quotation, and I think he can scarcely have looked back to the actual reports for full information on the subject, or he would not have drawn the inference which he did. The Chateau de Namur occupies the summit of a high hill, and at the period of 1815 there were in front of it, on the side most susceptible of attack, the remains of some old lines called the Terra Nova Lines, as well as a fort (Fort William) built, I believe, originally, by Coehorn.

These works, which had been allowed to fall into decay, or had been purposely destroyed, the English engineers proposed to reconstruct as a first line in front of the castle—the body of the place, in fact—to which the castle itself was the keep, advising at the same time the construction of two detached works in advance of them, which an enemy would, say the English engineers, be obliged to besiege before he could attack the Terra Nova Lines and Fort William. So we find the case to be actually this, that the English engineers recommended detached works for the outer line, and the duke approved their project, that is, detached works in their proper place. The engineers of the Netherlands had proposed detached works in place of the Terra Nova Line. I was present in January last when Colonel Owen read his paper, and when he referred to the fortress of Namur, I thought he was not quite correctly informed on the subject, for some five or six years ago I visited Namur in company with Capt. Hutchinson, and saw these very detached works, and curiously enough, we observed that the ditches, as recommended by the English engineers, were defended by works of the description which Colonel Owen so strongly condemns, by counterscarp galleries, caponiers, and similar contrivances.

Sir John Jones, whose authority, also, Colonel Owen claims in the advocacy of his views, was a member, and not the least influential one, of the Commission which recommended the detached works I have described. He was the author also, as we all well know, of a very remarkable memoir on the Lines of Torres Vedras, published in the third volume of our "Professional Papers." In that memoir he not only describes the Lines of Torres Vedras, but also discusses freely the merits of lines in general, both detached and continuous, and from it Colonel Owen has given us an extract, to the effect that the defence of such lines as those of Torres Vedras hinges mainly on the activity and foresight of the commander, and the vigour of the defenders. This is perfectly true, but it is also true that, while acknowledging thus freely the fault of a detached line, Sir J. Jones prefers it much to a long continuous line. I know that he refers in each case to field-works; but just hear what he says about continuous lines:—"Nothing can be more vicious than to cover an extensive tract of country with a regular system of bastions and redans, as recommended in most treatises on field fortification. Such long systematic lines of defensive works, besides the great expense, labour, and publicity attending their formation, have the serious defect of being of no strength, unless equally guarded throughout." "Indeed, such long defensive lines, even when most in repute at the end of the 17th and commencement of the 18th century, were invariably forced as often as attacked, and it is difficult to conceive on what foundation their popularity so long sustained itself." And further on he says:—"None of the objections to continuous lines, however, apply to retrenchments formed of enclosed and isolated works, each capable of a good resistance." These quotations, I think, show pretty clearly what were Sir J. Jones's opinions on this subject, and as clearly forbid his being claimed as an authority for condemning the use of detached works.

As to the question of expense, Colonel Owen has given us a carefully drawn estimate of both systems, and has come to the conclusion that there is but little difference between them. That conclusion is very different to mine, and I must confess I am much surprised at it. It is very difficult, if not impossible, to nvestigate *vivâ voce* this branch of the subject so thoroughly as it deserves.

Colonel Owen has, I freely admit, allowed a greater difference than even I made between the length of walls in each case, and yet he arrives at a very different conclusion. I cannot quite see how that is to be accounted for; but I imagine that in making his deductions he has, I will not say got wrong, but proceeded differently, and so arrived at a different result. For the present I will be content with contrasting the cost of the Paris defences with his estimate. In that case there was a very great difference between the cost of the detached works and that of the inner enceinte, the one being 60 and the other 76 million francs, a difference which must be largely increased, when we consider, what I believe to be the fact—that the ground occupied by the detached works is nearly one-half longer than the perimeter of the enceinte. The cost of works actually executed is a better guide than estimates, however carefully made. In considering this subject of expense there is, I think, a point worthy of consideration which is in danger of being lost sight of, and that is, that in building the detached works, it is unlikely that each fort would be as much as 800 yards in perimeter, the length of scarp assumed by Colonel Owen. That, I take it, would be a maximum, and advisable for the most important works; but all points of the line would not be of equal importance, and we should, no doubt, in practice, employ works of more moderate dimensions, perhaps only 400 or 500 yards in perimeter, for the less important forts. This would greatly diminish the total outlay; whereas the continuous line for each mile must be at least a mile long, and generally much more. Again, I think it may be fairly assumed that the existence of a keep in the detached works would justify us in building the scarp walls of the principal ditch of less dimensions than would be necessary for the continuous line, for the keep would probably neutralise any successful escalade on the part of the enemy, by enabling the defenders to rally and eject the intruders. Another consideration, bearing on the question of expense, is that a contractor would much prefer undertaking work concentrated on a given spot than straggling in a long extent over the ground, as would be the case if the line were continuous; and, surely, all will agree in thinking it likely that in cases where great geological difficulties would be met with in excavating the ditch, the long continuous line will prove the more expensive trace.

There is an illustration of the successful employment of detached works in the lines thrown up for the defence of Cadiz in 1810, of which an interesting account is recorded in the volume of our "Professional Papers" which I have already mentioned. The line defended was about $5\frac{1}{2}$ miles long, the defenders about 5,000 in number. The works thrown up were redoubts, 15 in number, and they answered the purpose thoroughly, for though beleaguered for a considerable time, Cadiz was not attacked on that side. It is true that there was in that case a continuous obstacle in front of the redoubts, a creek or river of considerable width and depth, but not of course impassable; and no one can doubt that the position was fortified correctly in that instance by detached works. I certainly think that considerations of site will often dictate to us the correct course to be pursued in fortifying a position—I mean as to whether we should employ continuous or detached works; and such we find has mostly been the case when we examine existing fortresses; but still there are general principles which are fairly open to discussion, and which would apply to many cases that may arise; and I contend that when once you have covered the point to be protected by a continuous enceinte, so as to save it from the effects of a sudden assault, the correct system to adopt for the outer line, subject to considerations of site, is that of detached works, because they fulfil the two main conditions of economy and efficiency. To do more would be to do wrong. For to construct *superfluous* defences, to make a position *superlatively* strong, would be waste.

Colonel Owen.—In conclusion, I can only again repeat my statements concerning the advantages of a continued line, and which I think have not been disproved, though I find myself in a minority on the question amongst my brother officers. These statements are, that "it can be defended by fewer men, and those men far less trained; that its defence is simpler and easier understood by generals, by officers, and men; that it appeals most to the patriotism of citizens; that it has been well and fully tried for thousands of years, and that nothing in the art of war has been discovered to supersede the old fashioned ditch, rampart, and parapet, not only as a battery upon which to mount guns, but as a means of keeping the stronger from closing with the weaker." I know of no military writer of eminence who supports the system of detached forts; and, certainly Capt. Wilson has not fortified his opinions by any testimony of weight. I congratulate him, however, on his now having one eminent authority, that of our distinguished chairman (Gen. Sir John Burgoyne), on his side. Perhaps Sir John will forgive me if I ask him to allow me to say one word upon the subject of the wall of China, that continuous line, 1,500 miles long, which he has ridiculed and which is so often ridiculed. I have the pleasure of the acquaintance of a gentleman who has given much time to the study of Chinese history, and if I am to trust what I have heard, the great wall was not only the most stupendous feat of fortification ever accomplished, but one of the most successful. Within this continued wall, for several centuries, was to be found civilisation—without, barbarism. It did not stop the outer barbarians when the celestials got weak within; then the barbarians got over; but for several centuries that continued wall secured them. Long walls, too, have been built by others than the Chinese in times gone by. We have, in this country, walls of many miles in length, built by a nation which has never been surpassed in military strength or science. The Romans watched such walls; why should we not do so equally well? If permanent fortifications of continued lines have ever fallen, they have fallen from a weakness which would have caused the fall of any works.

APPENDIX.

The long expected work of Brialmont, the Engineer of Antwerp, has recently appeared, and as he is a well known partizan of detached works, which enter so largely into the defence of Antwerp, I was somewhat startled to find how much his ideas coincide with mine.

For instance, Vol. I, p. 82, in talking of the fortifications of Paris, and comparing the opinions of the partizans of the forts and the enceintes, he says:

"The former were altogether right, the latter were only wrong in their strategy, for starting from the supposition that Paris was not to be defended by a large moveable force (but only by a mere garrison), the enceinte was evidently the best."

He even goes further than I can quite follow him: "The only party altogether wrong, both as strategists and engineers, were those who, admitting the above hypothesis of the partizans of the enceinte, proposed forts as well. We shall see further on, that detached works thrown in front of an enceinte offer no security unless protected" (poor forts!) " and completed by a moveable force capable of opposing and repelling every attempt of the enemy."

I should certainly have thought that an enceinte with forts in front, and rendering each other mutual support, could be held by a comparatively small garrison, and even though he thinks the partizans of the forts for Paris altogether right, he maintains, after quoting numerous instances, "that every intrenched camp must have a fortified nucleus;" and at page 92, "that all the ground between the forts and the enceinte must be subject to artillery fire."

It will be seen at p. 102, that he is contemplating a garrison of 100,000 men, of which but 21,000 will be required for the works, so there would not only be artillery fire to act on the whole ground, but an army of 80,000 men!

At p. 114, he recognises the difficulty of finding men capable of commanding a number of forts as a reason for not making them too numerous, "because the increase of number leads to breaking up (morcellement) the defence and to the multiplication of separate commands, and because even in an army well broken to war (aguerrie), few officers are found who know how to defend properly a fortified post."

At p. 128, I find the same estimate I made as to the quality of the troops required to defend a detached fort. They should be, he says, "troops of the line of the best kind in consequence of the isolation of the forts, of the more active watching that such isolation requires, and of the greater dangers and privations to which the garrisons are exposed."

At p. 155, he recognises that a detached fort, garrisoned by even 1,000 or 1,500 men, is not so able to repel an escalade as a great enceinte.

Elsewhere he estimates that 2,820 artillerymen will be sufficient to secure an enceinte equal in extent to that of Paris, that is 25 miles long, against escalade.

I do not pretend here to give an analysis of Brialmont's work, but merely a few extracts which seem to bear upon the question on which I have been at issue with some of my brother officers. I do not, therefore, allude to the well-merited encomiums he passes upon the works of those very officers, particularly the "camp retranché de Portsmouth."

What I maintain is, that to hold a position with the smallest possible number of men, be that position long or short, you must have a continuous line. With very little, if any, increase to this minimum garrison, you may hold a line of detached works in front of the line and co-operating with it. But if you place the forts so far from the line that they cannot support each other, or if you suppress the line altogether, it becomes an intrenched camp, and not a fortress, and requires to be occupied by an army and not by a mere garrison; and in this I am more than borne out by Brialmont, for his estimate of the force necessary to defend a system of enceinte and forts is much higher than mine.

H. C. O.

June, 1864.

PAPER XV.

NOTES ON THE CHANGES IN THE CONSTRUCTION OF FORTIFICATIONS

WHICH APPEAR LIKELY TO BE REQUIRED IN CONSEQUENCE OF THE GENERAL ADOPTION OF RIFLED GUNS.

BY MAJOR GENERAL BAINBRIGGE,

RETIRED LIST, ROYAL ENGINEERS.

The influence of the increase in the range of guns has been already shewn by the erection of new works around our dockyards at a distance of five miles from them, and the circumference to be occupied is thus so much extended that the construction of *continued* lines of works on such sites has become almost impossible, whilst the accuracy of fire is such that much larger intervals can be commanded by the guns with which they are to be armed than was formerly the case; and it is evident that it has become far more important to destroy all cover, even at great distances, around positions to be defended.

In addition to the remarks contained in the last paper in Vol. XI of this series, it may be observed that since, in *attacking* any position, greater loss will be sustained than was formerly to be expected wherever troops are exposed to the view of the defenders, even at great distances, it becomes more important to have the power of *quickly* overcoming or destroying any obstacles to a rapid advance which are likely to delay them even for only a few minutes under fire; and that, in *defending* a position, the importance of forming such obstacles as would check an enemy, though only momentarily, under fire, (and especially under flank fire) is much increased. It is evident also that in the deliberate attack and defence of a fortified position or fortress the increased accuracy of fire and closer watching of every point within 1,000 yards by selected marksmen, must modify the arrangements made to protect troops and afford them the free use of their weapons: and this has been demonstrated at the siege of Sebastopol, when if a man raised his cap above the parapets of even distant trenches it was certain immediately to receive one or more bullets.

The works undertaken in exposed positions, either by the assailants or defenders, must therefore be *commenced* generally at night or during fogs; far greater quantities of gabions or other building materials will be almost indispensable; and the most perfect organization and direction of the workmen will be needed in order to carry them on with the greatest rapidity possible in the limited time available whilst the ground is not illuminated by light balls.

The paper by Capt. Tyler, R.E., at page 85, Vol. IX, of this series, contains many useful suggestions relative to the construction of works of attack, but we must also consider the means of repairing and maintaining earthen works of every description, whilst crumbling away under the effects of elongated shells containing large charges of powder, and exploded with great accuracy by means of fuses of improved construction; for these will probably be employed in increasing numbers, as their superiority over those of small calibre becomes more evident, and the power of transporting them is augmented by diminishing their weight.

Although *ricochet* fire with rifled guns is not likely to be very effective against works of defence, their *enfilade* fire is so accurate that parapets and traverses covering a rampart against its effects will soon be destroyed; and the explosion of 110-pdr. shells fired from 7-inch rifled guns at low angles directly into earthen parapets, or even with elevation enough to pass over a parapet and lodge in traverses beyond, will produce very large cavities, for they contain 8 lbs. of powder.

The shapes and dimensions of the craters formed by the explosion of such capacious shells, at Chatham in 1853, are shewn at page 80, Vol. IV, of this series; and experiments made lately have given similar results.

The effects of the explosion of 300-pdr. shells, containing 15 lbs. of powder, will probably be such as to make it appear difficult to build any works capable of resisting them long; yet the new 300-pdr. guns are only $10\frac{1}{2}$ inches in diameter, and are portable enough to be employed against any fortress near the sea; and they have been already used at the siege of Charleston with success as regards their range, which was five miles.

When the 300-pdr. guns are perfected they will aid our Navy in proving that "wherever a chip can float" the British flag will have the supremacy, by enabling them to transport those powerful weapons wherever it is required to form batteries *on shore*, although we may admit the inferiority of the fire of even our iron-clad ships when opposed to that of an enemy's guns placed on immoveable platforms. This inferiority, which was partly proved by the failure of the attack on Charleston in April, 1863, appears to arise from the difficulty of aiming accurately with guns mounted on a ship's deck, and, in the case of cupola or turret ships, from the small amount of fire which they can maintain compared with that of batteries on land, and from the liability of the turrets to get jammed or incapable of traversing rapidly.

The 600-pdr. rifled shunt gun, the accuracy of the fire of which, at a range of 7,300 yards, has been lately proved at Shoeburyness, throws a 13-inch shell which holds 29 lbs. of powder; and if circumstances allow such a monster, weighing 24 tons, to be placed in an attacking battery, the effects of the explosion of so large a bursting charge will prove terrific, and its *moral* effect will no doubt be very great, but it is perhaps almost useless to attempt to render our existing works capable of resisting it.

We shall however certainly have to contend against artillery throwing missiles weighing 300 lbs., but as we have as yet very few data for determining their effects, we must for the present be satisfied with analyzing the result of the practice with 110-pdr. guns, and deducing from it the probable effects of the fire of larger pieces.

The following are some of the data which are available, and are taken from the Report of the Ordnance Select Committee on experiments at Newhaven, dated 6th November, 1863:

1st, as regards *penetration*—Practice was carried on at Newhaven at a range of 1,060 yards, firing into a well-rammed parapet of compact loam approaching in stiffness to clay, 25 feet thick at the top; and the *greatest* penetration of the missiles employed is given below:

								ft.	in.
110-pdr.	Armstrong gun,	shot	111 lbs.,	charge	12 lbs.,	penetrated	......	22	0
110-pdr.	—	blind shell	104 lbs.,	—	12 lbs.,	—		18	8
70-pdr.	—	shot	70 lbs.,	—	9 lbs.,	—		17	0
40-pdr.	—	shot	41 lbs.,	—	5 lbs.,	—		16	4
40-pdr.	—	blind shell	40 lbs.,	—	5 lbs.,	—		13	10
20-pdr.	—	shot	20 lbs.,	—	2 lbs. 8 oz.	—		11	9
20-pdr.	—	blind shell	21 lbs.,	—	2 lbs. 8 oz.	—		13	3
68-pdr.	smooth-bore,	shot	66 lbs.,	—	16 lbs.,	—		21	6
68-pdr.	—	blind shell	50 lbs.,	—	16 lbs.,	—		14	10

From this we may conclude that the penetation of the 300-pdr. *shell* into such a solid parapet will be 23 feet at 1,000 yards; and the 300-pdr. gun used at Charleston is stated to have "sent a shot through 26 feet of earth."

At the same time practice was carried on, at a range of 1,060 yards, firing into a hill consisting of stiff gravelly clay with veins of very hard gravel, and the *greatest* penetration of the missiles employed is given below:

								ft.	in.
110-pdr.	Armstrong gun,	shot	111 lbs.,	charge	12 lbs.,	penetrated	....	9	5
110-pdr.	—	blind shell	104 lbs.,	—	12 lbs.,	—		8	3
70-pdr.	—	shot	70 lbs.,	—	9 lbs.,	—		8	6
40-pdr.	—	shot	41 lbs.,	—	5 lbs.,	—		8	4
40-pdr.	—	blind shell	40 lbs.,	—	5 lbs.,	—		8	5
20-pdr.	—	shot	20 lbs.,	—	2 lbs. 8 oz.	—		5	0
20-pdr.	—	blind shell	21 lbs.,	—	2 lbs. 8 oz.	(gravelly clay)		8	0
68-pdr.	smooth-bore,	shot	66 lbs.,	—	16 lbs.,	—		7	0
68-pdr.	—	blind shell	50 lbs.,	—	16 lbs.,	—		4	0

From this practice we see what advantages may be gained by constructing parapets with gravel or rock in the centre, having the interstices well filled up, so as eventually to form a solid mass (similar to the hill referred to above), which would of course be covered with a thick coat of earth. The 110-pdr. shells, at a range of 1,000 yards, would probably not penetrate into such parapets, when made 25 feet thick at the top, more than half-way, if they hit the exterior slope, so that their explosions would not injure the interior slopes; but it is considered most advantageous to fire them into the *superior* slope, so as to penetrate far enough to *blow away* the crest and interior slope, in preference to planting them low down, when the earth thrown up often only fills other craters.

It may here be remarked that these shells did not explode until they had penetrated to a distance equal to two-thirds of that to which they would have attained if blind.

The effect of the artillery defending a fortress having become so great, and the difficulty of forming and arming batteries within musketry range being so much increased, counter-batteries will probably not in general be erected nearer than 500 yards from the works which they are intended to silence; but as the penetration of spherical shot into earth at that distance is about one-fifth more than at 1,000 yards, we may assume that the 110-pdr. *shell* will penetrate 23 feet into a solid parapet at 500 yards, and the 300-pdr. shell about 27 feet into the same, which shews the necessity for increasing their thickness or resistance, if exposed to the effects of the latter at that range.

2nd.—As regards the effects of the *explosion* of shells in earth, it appears that the result of firing 53 rounds from 110-pdr., 70-pdr., and 40-pdr. Armstrong guns, and 68-pdr. smooth-bore guns, against the parapet above described, at a range of 1,060 yards, was that its interior crest was cut down so as to form a hollow $4\frac{1}{2}$ feet deep and 10 feet wide; and that after firing a total of 224 rounds, the breach was enlarged to a depth of 5 feet and width of 33 feet, and the interior laid open.

The total number of shells fired during two days was

110-pdr. shells...	97
70-pdr. —	27
40-pdr. —	67
20-pdr. —	15
10-in. —	6
68-pdr. —	12

The total expenditure of powder for cartridges was 1,975 lbs., and for bursting charges 1,150 lbs.

The weight of iron fired was 15,091 lbs.

The weight of iron which *hit* the parapet was 9,263 lbs., the cartridges propelling it weighed 1,162 lbs., and the bursting charges 714 lbs.

The importance of employing missiles containing large charges is shewn very clearly by comparing these results with those obtained at Berlin, which are described in Vol. V, page 44, of this series, where a very small hollow was produced by firing 170 nine-inch spherical shells into a sandy parapet, whilst the breach above-mentioned was almost entirely due to 69 rounds from one 110-pdr. Armstrong gun; and three such guns would probably have produced the same result in an hour.

It was observed that the mass of earth displaced by the 70-pdr. shell was about 15 times as much as that removed by the 68-pdr. spherical shell; and the latter should therefore not be employed for this purpose in future.

It is not easy to calculate the effects of numerous shells from the dimensions of the craters of two or three lodged in solid earth, and the results must be very different when they are exploded in earth which has been disturbed by other missiles; but it was observed that the 110-pdr. shells, with bursting charges of 8 lbs., exploded in the above-mentioned parapet at a depth of 4 ft. 6 in., produced craters from 11 to 13 feet in diameter, and containing therefore about 170 cubic feet; and the 70-pdr. shells, with bursting charges of $4\frac{3}{4}$ lbs., at a depth of 3 ft. 6 in., produced craters 9 feet in diameter, and containing about 108 cubic feet.

Hence we may conclude that a 300-pdr. shell would displace at least 300 cubic feet of similar earth, and a 600-pdr. shell 600 cubic feet!

3rd.—As regards the *effect on masonry*, the powers of rifled guns in forming a breach in a brick tower, at a range of 1,000 yards, are described in Vol. X, page 5, of this series; and the accuracy of fire and effect of the "Parrott" and other rifled guns employed in breaching Fort Sumpter, near Charleston, must have been very great, for it was a well constructed casemated brick fort, of the same shape as those at Cronstadt, Bomarsund, New York, and Newport, and the reports on the subject state that the ranges of the guns were from 4,245 to 6,330 yards.*

It was reduced to a heap of ruins in seven days by 7,551 missiles, "of which 2,130 struck it inside and 2,495 outside." The guns employed were 200-pdr. rifled guns; and we may observe that the results of the practice with the 600-pdr. gun prove that it would produce the same effect at a range of 7,300 yds. in much less time.

The small effect of the fire of even 11-inch guns at a much shorter range, when placed on board the iron clad ships which attacked Fort Sumpter, shews that such forts may still be able to resist the fire of ships, even in land-locked channels where they are not much affected by the motion of the waves: and it is also stated that the same vessels could not silence the fire of a one-gun earthen battery on the south side of the harbour of Charleston.

The effect of rifled guns against masonry walls covered by a glacis, so as to be unseen from the battery, has been partly tested at Juliers, and is described in Vol. X, page 168, of this series, but it is probable that when the wall is so close to the glacis or covering mass that the terminal angle of the line of flight of the missiles employed is increased to 20°, and their velocity consequently is much diminished, it will prove far more difficult to destroy them, especially when it is considered that as the axes of projectiles remain nearly at the same inclination to the horizon as that which they had on leaving the muzzle, if that inclination is great, as in this case, they must strike a vertical surface so obliquely as to diminish their penetration very much; and we require further experiments on this subject.†

4th.—As regards the *effect on iron*, the article on this subject by Captain Inglis, R.E., in Vol. XII of this series, gives much information. There seems to be no doubt that wrought iron may be formed into shields or parapets so as to afford a great amount of protection against direct fire, and we may therefore expect to see guns covered by iron parapets, or by iron walls extending into the merlons on each side of them; and if they are placed in contact with earth they will probably be formed in general of iron alone, and not of iron and timber: thus they will be very expensive, and so heavy as to be very difficult to apply to attacking batteries; and though the Americans carry on their civil war

* See also page 18.—ED.

† In Major Brialmont's new work on Fortification, Vol. III, page 379, it is stated as a result of experiments carried on at Verona, in January, 1862, that "In order that a wall may be screened by a glacis from the pitching fire of rifled guns, the crest of the glacis must be raised above the top of the wall $\frac{29}{100}$ of the horizontal distance between the crest of the glacis and the wall." These experiments were carried on against a detached wall 4 feet thick and built three years, from a battery of 12 and 24-pdr. rifled guns, distant 1,740 paces from the wall.—ED.

"regardless of expense" they do not yet appear to have employed them in any such works.

Flanking works of small dimensions will often require to be constructed entirely of iron, or of iron backed by timber, for there is great difficulty in connecting iron and masonry properly, as the concussion and vibration affect the latter very much; but existing flanking buildings must soon be covered with iron, at least at the parts most exposed to fire, and experiments are required to prove which is the best mode of effecting this object.

If iron parapets are constructed 12 inches thick they will be secure against the effects of 110-pdrs. at 500 yards, and as it will be very difficult to form iron shields of that thickness in the batteries built for the attack of a fortress, the guns in the latter must have the superiority under a direct fire; and they can also be rendered much more secure against vertical fire.

They must likewise have a great advantage over guns placed on board ship, for, in addition to the greater accuracy of their fire, before mentioned, it will be nearly impossible to case the ships with iron 12 inches thick: indeed a very solid target representing part of a ship's side, consisting of 5 inches of iron and 18 inches of teak (and therefore stronger than the side of H.M.S. Warrior) has been penetrated by missiles fired from the 110-pdr. at 800 yards; a target, representing the side of the "Lord Warden," consisting of iron and timber weighing 400 *lbs.* per square foot, has been much injured even by a spherical steel 100-pdr. shot, and was quite penetrated by a single 300-pdr. steel shot fired from the $10\frac{1}{2}$-inch Armstrong gun, both at a range of 200 yards: and another target, representing the side of the "Gloire," consisting of small $4\frac{3}{4}$-inch plates screwed to a mass of timber 27 inches thick, was much injured, though not quite penetrated, by 68-pdr. steel shot, and Armstrong 110-pdr. steel shot; but was quite perforated by steel shot, weighing 168 lbs. and 220 lbs., fired from the Armstrong 9·22 and $10\frac{1}{2}$-inch muzzle loaders, all at a range of 200 yards; and it must not be forgotten that unless ships come to close quarters, their fire will have very little effect against forts.

Iron may probably be employed with advantage in the construction of cupolas or turrets at the salients of fortifications or on towers, to enable a powerful gun placed in each to command all the approaches; and the traversing apparatus can, in such positions, be protected by the parapet, so that the risk of their getting jammed, and unable to traverse, would be much less than in those on board ship.

It may also be desirable in some cases to use iron for strengthening the keeps of fortresses; although the *first* expenditure of money available would of course be applied to the protection of the guns and of the flanking works.

Finally we arrive at the conclusion that the introduction of rifled guns will give us a great advantage in attacking existing works, but that guns can be more effectually protected in forts constructed so as to resist the new missiles than any placed in attacking batteries or in ships; and there seems no reason to doubt that we can keep in advance of other nations in manufacturing guns and muskets as well as in using them effectually, and also in building iron walls, as well as in destroying them by operations carried on either underground or in the open air.

P. J. B.

PAPER XVI.

GUNNERY EXPERIMENTS UPON IRON ARMOUR.

By CAPTAIN INGLIS, R.E.

The following contains an abridged account of the experiments with guns against iron armour which have taken place since the period of my writing Paper XV in last year's volume.

It will be remembered that as I then left the question an important inquiry had commenced as to the best form and material for shot and shell intended to be used against iron armour, and that already results were greatly in favour of steel projectiles.

It was also thought at that time that a conical-headed shot had some advantage over flat-headed or other shaped shot as regards penetration into iron.

Recent experiments have placed beyond all doubt the superiority of steel over any other material for these purposes, and this has led some of our principal iron masters and inventors to look more closely into its manufacture; the precise degree of tempering required is of course the main point to be considered, and some highly successful results have been obtained in this respect.

Various processes of manufacturing steel have been brought into work in recent years, and some of these promise, if not a superiority in the metal itself, at any rate increased facilities in its manufacture and consequent reduction in price.

Most of these different descriptions of steel have been tried in projectiles against iron armour with interesting results.

The first of these trials in order of date was the following:

Trial of 40 pdr. and 12-pdr. projectile. Shoeburyness, 12th and 13th Nov., 1863.

This experiment was intended to test the character of certain steel-case hardened wrought iron and chilled cast iron projectiles.

The guns used were the Armstrong breech-loading 40-pdr., the Armstrong breech-loading 12-pdr., and the Whitworth breech-loading 12-pdr.

The charge of the 12-pdrs. was $1\frac{3}{4}$ lbs., that of the 40-pdr., 5 lbs. of powder.

The range was 200 yards.

The plates fired at by the 12-pdr. solid shot were of $2\frac{1}{2}$-inch rolled iron without any backing; the 12-pdr. shells were fired at 2-inch plates backed by 12 inches of oak; and the 40-pdr. shot were fired at a "Warrior" target.

The $2\frac{1}{2}$-inch and 2-inch plates were all 6 ft. × 3 ft., and having no bolt holes they were secured at their edges to strong timber uprights by means of railway rails placed vertically.

The projectiles were of the following description :—

1st. Homogeneous metal—Mr. Whitworth.

2nd. Steel—Sir W. Armstrong.

3rd. Bessemer's steel—Messrs. Brown and Co.

4th. Cast steel (unforged)—Mr. Attwood, Tow Law Iron Works.

5th. Homogeneous metal and case-hardened wrought iron—Messrs. Shortridge and Howell, Sheffield.

6th. Chilled cast iron—Captain Palliser, 18th Hussars.

7th. Steel—Royal Laboratory Department, Woolwich.

8th. Cast iron re-melted—Ditto, ditto.

The results may be given as follows :

Of six Whitworth 12-pdr. solid flat-headed shot fired at the $2\frac{1}{2}$-inch plates, only one was found unbroken in the earthen butt in rear of the plates.—Their average velocity on impact was 1,274 feet a second.

On a subsequent occasion some steel shots of the same quality were fired from the same gun under similar conditions, except as to velocity, which was reduced to 1,120 ft. a second, and then the shot passed through the $2\frac{1}{2}$-inch plates without breaking up.

Two Whitworth 12-pdr. shells were fired at the 2-inch plates backed with wood; they both passed through ; one penetrated 5 feet into the earthen butt without bursting, and the other passed out to sea.

Twelve steel 12-pdr. shot of Sir W. Armstrong were tested. Six of these were round-headed, and six flat-headed.

All the latter and four of the former were fired at the 2-inch plates, and in every instance passed through without breaking up. The flat-headed shot were found to be shortened 0·39 inch with an increase in diameter of 0·26 inch, the round-headed 0·14 inch, with an increase in diameter of ·005 inch.—Their average velocity on impact was, for the flat-headed, 1,116 ft., and for the round-headed, 1,150 feet per second.

The remaining two round-headed shot were fired at a $3\frac{3}{4}$-inch unbacked plate, but only one struck fairly—it made an indent 2·75 inch deep and cracked the plate front and rear—it rebounded 17 yards, was shortened ·86 inch, and increased in diameter ·08 inch.

Five Armstrong shells were fired at the 2-inch plates, and, with one exception, burst in passing through the backing.

Two round-headed 12-pounder shot of Bessemer's steel, manufactured by Messrs. John Brown and Co., of Sheffield, struck the $2\frac{1}{2}$-inch plates.—One broke through the plate but did not itself penetrate; the other made an indent of 1·35 inches, was shortened $1\frac{1}{2}$-inch, and increased in diameter ·47 inch.

Mr. Attwood's cast steel 12-pdr. shot penetrated the $2\frac{1}{2}$-inch plates, were shortened about 1 inch, and increased in diameter ·15 inch.

Messrs. Shortridge and Howell's shot did not penetrate and were much altered in form.

The chilled cast iron shot all broke up on impact, but they showed a marked improvement on the common cast iron shot of the service, the indents being in the proportion of 2 inches to $\frac{3}{4}$ inch.

The shot of cast iron, remelted 4, 8, and 12 times, fired from the 40-pdr., did not show any material advantage over the service shot; the iron melted twelve times seemed to have lost cohesion in a very large degree.

The principal feature of the experiment was the excellent quality of the steel supplied by Sir W. Armstrong. This was really all that could be desired, and it only now remains to simplify and cheapen the manufacture of this material as much as possible. The cost of such metal must necessarily be high compared with cast iron; but as recent inventions become more fully developed, and its manufacture is more universally practiced, we may anticipate a great reduction in price.

Soon after this, sundry trials were made of shot composed of refined cast iron of various mixtures. These all tended to show that at a very slight additional cost a metal greatly superior to ordinary cast iron can be produced, and this at any rate encourages further efforts in this direction.

Bellerophon Target. Shoeburyness, 8th Dec., 1863.

The object of this experiment was to test the principles of construction adopted by the Admiralty in the iron-cased frigate "Bellerophon."

The target, 20 ft. 9 in. × by 8 ft. 6 in., represented that part of the ship which is situated between the main and lower decks, and not that in the line of ports.

The method of construction was this:

The inner frame work of the target consisted of eleven vertical ribs placed 3 feet apart. Each rib was composed of an angle iron 10 in. × $3\frac{1}{2}$ in. × $\frac{1}{2}$ in., and two angle irons $3\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{5}{8}$ in. riveted on it.

Every alternate rib was secured to the beams representing the upper deck beams by a very strong wrought iron knee, and the end ribs had knees connecting them with both upper and lower deck beams.

To the double angle irons of the ribs the skin, which is composed of two thicknesses of $\frac{3}{4}$-inch plate, with a layer of painted canvass between, was secured by rivets.

On the outside of the skin four horizontal angle iron stringers were attached, two behind the upper armour plate, $9\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{1}{2}$ in., and two behind the lower plate, 10 in. × $3\frac{1}{2}$ in. × $\frac{1}{2}$ in.; these stringers were riveted to the skin by their shorter arms, and thus projected $9\frac{1}{2}$ inches and 10 inches respectively; between them came the horizontal timbers, forming a wood backing, 10 inches thick, to the armour plates; it will thus be seen that in one case the stringers projected to the face of the timber backing, and therefore came in contact with the armour; in the other they were buried $\frac{1}{2}$ inch below the surface. In addition to these stringers there were two horizontal flat irons 6 in. × $\frac{3}{4}$ in. riveted on to the face of the skin, to form covering pieces to the joints.

The armour consisted of two rolled iron plates 6 inches thick (made by the Millwall Company); each plate measured therefore 20 ft. 9 in. × 4 ft. 3 in. wide, and weighed upwards of 9 tons.

The upper plate was held by 22 bolts $2\frac{1}{2}$ inches in diameter, and the lower plate by an equal number of $2\frac{3}{4}$-inch bolts.

In one half of the target, divided vertically, the armour bolts had elastic washers under single nuts, and were clenched after the nuts were on. In the other half, common washers and double nuts were used.

The target was erected in front of a strong timber frame which gave it support at the levels of the decks only, and therefore in this respect it approached the condition of the actual ship's side.

It was the heaviest ship's target ever tried at Shoeburyness. It weighed 393 lbs. per square foot, excluding all knees and strengthening pieces behind the ribs, which, together, weighed some $51\frac{1}{2}$ lbs., against 335 lbs. of the original Warrior.

The range was 200 yards, and the following guns were in battery:—

The $10\frac{1}{2}$-inch Armstrong muzzle-loading rifled (12-ton) gun.

The 7·1-inch muzzle-loading gun of the Ordnance Select Committee.

The Whitworth 7-inch rifled gun.

The Whitworth $5\frac{1}{2}$-inch rifled gun.

The 110-pdr. breech-loader Armstrong gun and the 68-pdr. service gun.

A round from the 68-pdr. and 110-pdr., the latter throwing a shot cylinder of $66\frac{1}{4}$ lbs. with the same charge as the 68-pdr. (both shot of cast iron), had little effect beyond the usual indents of $1\frac{1}{2}$ in. and $1\frac{1}{4}$ in. The striking velocity of the latter shot was 1,468 ft. per second against 1,405 ft. of the 68-pdr.

A salvo of two 68-pdrs. and two 110-pdrs., with shortened cylindrical shot of $66\frac{1}{2}$ lbs., was next fired, but of these four shots, two only, one from each gun, gave fair hits, and they produced little more than indents of $1\frac{1}{4}$ in. or $1\frac{3}{4}$ in. deep.

A cylinder of 60 lbs., cast iron, from the 110-pdr., fired with a charge of 16 lbs., and attaining at 120 ft. distance a velocity of 1,630 ft. per second, made an indent in the armour plate 1·8 in. deep and broke one bolt situated at a distance of 4 ft. 6 in. from the point of impact.

A steel shell, weighing 69 lbs., from the Whitworth $5\frac{1}{2}$-in. gun, fired with a charge of 12 lbs., the bursting charge being 2 lbs. 6 ozs., and striking with a velocity of 1,220 ft. per second, made an indent of merely 1·3 in. This shell struck on the head of a bolt which had an elastic washer; the nut was slightly loosened, but otherwise the bolt was left as good as ever.

A steel shell, weighing 119 lbs., fired from the 7·1-in. gun, with a charge of 16 lbs., the bursting charge being 2 lbs. 4 oz., and striking with a velocity of 1,270 ft. per second, made an indent of only 1 inch, and did very little more damage.

A shell from the Whitworth 7-inch gun burst at the muzzle.

A solid cast iron spherical shot, weighing 150 lbs., fired from the $10\frac{1}{2}$-in. gun, with a charge of 35 lbs., next struck the target, 6 in. from the edge of a plate, on a bolt, with a velocity of 1,567 ft. per second. The work in this shot was equal to 5,719,307 lbs., raised 1 ft. high. It made an indent of 5 in., and drove the plate in some $3\frac{1}{2}$ in. The plate was cracked in several places and the skin of the target slightly bulged. Altogether the effect was not great.

A solid steel spherical shot, of 165 lbs. weight, fired from the same gun, with the same charge, struck at the junction of the plates with a velocity of 1,492 ft. per second. The work in this shot was equal to 5,703,429 lbs., raised 1 ft. high. It passed through the armour and buried itself in the wood backing. The shot, when afterwards taken out, was found to be a good deal cracked and distorted. Two armour bolts, without elastic washers, were broken, and the skin was cracked as well as bulged; one rib was broken, and one or two rivets.

A solid cast iron cylindrical shot, weighing 308 lbs., was next fired from the same gun, also with a charge of 35 lbs., and struck on a bolt with a velocity of 1,096 ft. per second. It made an indent of 1·6 in., and bent back the plate some 2 in.; the armour was cracked; the bolt struck was driven in about 2 in. (this bolt had an elastic washer); some rivets and three backing bolts were broken; the skin was slightly bulged. The work in this shot was equal to 5,744,946 lbs., raised 1 ft. high.

Lastly, a steel shell, weighing $149\frac{1}{2}$ lbs., fired from the Whitworth 7-in. gun, with a charge of 27 lbs., and a bursting charge of 5 lbs. 8 ozs., struck the lower armour-plate with a velocity of 1,283 ft. per second. The armour-plate was penetrated and the shell burst in the backing; the head of the shell remained in; the depth to the nearest point of the shell was $9\frac{1}{2}$ in. At the back of the target the skin was found to be bulged, one rib bent, two deck knees slightly displaced, one armour bolt and three bolts, used to secure the backing, were broken. When the armour-plate was afterwards removed, a large piece of its rear side, measuring 1 ft. 5 in. by 1 ft. 3 in., was found to be carried away round the shot-hole and forced into the backing.

The general result of the experiment was considered to be favourable to the target, although, as I have said before, there was so much more iron used in its construction than in any previous ship's target, that a comparison with former trials can scarcely be instituted.

As might have been expected, the indents of a given gun, say the 68-pdr., were less than on other targets in about the proportion of 1·75 to 2·05 on the "Warrior," and 3·5 on the Chalmer's target.

Again no comparison can be instituted between the effects of the $10\frac{1}{2}$-in. gun on this and other targets, for, in this experiment, it was fired with a charge of only 35 lbs., whereas the "Warrior" was fired at with charges of 40 lbs. and 50 lbs., and Chalmer's target with charges of 45 lbs. and 50 lbs.

In general it may be said that this experiment shows in a striking manner the advantages gained by the use of steel projectiles; secondly, it shows the great increase of support given to the armour by the stringers or layers of iron plates between the timbers of the backing. It may be remembered that when writing the account of the trial of Mr. Chalmer's target in last year's volume, I noticed the superiority of the *compound* backing over the *simple* backing of timber, and I then urged the desirability of constructing a target on the Warrior model, only giving it a compound backing of timber and iron. The experiment upon the Bellerophon target confirms this opinion, and I still believe that with a weight of ship's side exceeding by a very little, if at all, the weight of the "Warrior," a structure as strong as the "Bellerophon" might be obtained.

Lastly, a great advantage was gained in this experiment, by overcoming the prejudice which has hitherto existed against the use of large armour bolts in ship's targets. For some reason or other it had been thought necessary to confine the bolts to a diameter of $1\frac{1}{2}$ in.; it was considered, I suppose, wrong to wound the armour to a greater extent than for the head of a $1\frac{1}{2}$-in. bolt. This has long appeared a fallacy to all practical men; it is now found, as was fully expected, that the injury done to the armour by a hole for a $2\frac{3}{4}$-in. bolt, is little, if at all, greater than that caused by the hole for the $1\frac{1}{2}$-in. bolt, whereas there can be no question as to the assistance rendered by the stronger bolt in preventing buckling and general distortion, and displacement of the armour.

Description, &c., of the 600-pdr. rifled gun.

The next event of importance was the trial of Sir William Armstrong's 600-pdr., or, more accurately speaking, his 13·3-in. muzzle-loading wrought iron 10-grooved shunt rifled gun, weighing 22 tons 18 cwt.

As the appearance of this gun is an event which cannot but be regarded with great interest by all professional men, it may perhaps be permitted me to depart from my general rule and devote a short space to what is more strictly speaking an artillery subject, namely, a general description of the gun and its mode of manufacture. First, its principal dimensions are as follows :—

	ft.	in.
Extreme length	15	3
Length behind centre of trunnions	6	2·5
Length of bore	12	1·25
Calibre	1	1·3
External diameter over breech	4	3·5
Ditto ditto over trunnion hoop ...	4	5·5
Ditto ditto at muzzle	1	9·5
Width over trunnion ends	6	2·5
Rifling, one turn in 65 calibres.		

The gun was commenced in May, 1862, and delivered in March, 1863.

It is composed of eight layers of coiled cylinders, including the barrel; these vary in thickness from 2 in. to 2·8 in.

The breech piece is 6 ft. $8\frac{1}{4}$ in. long, has an outside diameter of 2 ft. 6·3 in., and a sectional area of 458 square inches.

The barrel was made an open tube, and the breech end closed by a wrought iron cylindrical plug fitted into the bore and backed by a forged wrought iron piece screwed into the breech piece and faced with a disc of steel.

The trunnion hoop was made from scrap iron forged under the hammer.

The outer breech coil was made from a bar 5 in. by 4 in., and 124 ft. long, weighing 71 cwt. It was heated in one length, coiled on a drum as usual and afterwards welded under a 15-ton hammer. This is by far the largest coil yet made. After the fifth layer of coils had been put on, the usual process of turning the gun in a lathe after each course was abandoned and the remaining courses were fitted on by accurate turning and boring to dimensions previously taken, without moving the gun from the shrinking pit in which it stood. This was done partly to save the frequent removal of such a heavy mass and partly on account of its being too large and heavy to put into a boring machine. This point becomes important as removing one of the difficulties which stood in the way of the manufacturer in building up guns of these vast dimensions.

The gun being rifled with ten grooves, the projectiles are provided with that number of rows of brass studs, each row being composed of six studs; the studs are fixed to the projectiles by being stamped into shallow undercut holes.

The common shell is $30\frac{1}{2}$ in. long, weighs $556\frac{1}{4}$ lbs., and carries a bursting charge of $42\frac{1}{2}$ lbs. of powder.

The steel shell for piercing the sides of iron-clad ships carries a bursting charge of 24 lbs., and is of the form designed by Sir William Armstrong for directing the force of the explosion forward; this is effected by making the shell open in front and merely closing it with a light cast iron head when it is loaded; this head of course gives way the instant an object is struck, and the walls of the steel shell being very strong, the powder cannot fail to explode in a forward direction.

The gun also carries a segment shell composed of 510 segments, of about 6 oz.

each, packed in two rows or layers; the bursting charge of this shell is 15 lbs.

There are also spherical cast iron and steel shot, diameter 13·235, weighing respectively 304 and 342 lbs.

The garrison sliding carriage, on which the gun is mounted, is of timber, and weighs 54 cwt.

The timber traversing platform is 20 ft. long, weighs 75 cwt., is attached to a pivot near the front, has a slope of $3\frac{1}{2}°$, and is mounted on six wrought iron trucks running on three iron racers.

The recoil, when compression is used, is not more than 10 or 11 feet.

One non-commissioned officer and 20 men work the gun.

It is traversed with treble and double block-tackle, and six men on tackle on either side of the gun can run it up after firing.

One man carries the cartridge, four the shot; a gyn, with luff tackle, is used to raise the shot and its iron bearer to the height required to hook the latter on to the muzzle, and four men ram the shot home.

Trial of 600-pdr. November and December, 1863.

A preliminary trial of this gun took place at Shoeburyness in November, 1863, on which occasion elongated projectiles, weighing from 507 to 516 lbs., were fired with charges of 70 lbs. of powder at various elevations.

With 1° of elevation the mean range was 771 yds. (740 to 789 yds.), and the deviation only 2 ft.

With 2° of elevation the mean range was 1,164 yds. (1,148 to 1,184 yds.), and the deviation not more than 4 ft.

With 5° of elevation the mean range was 2,349 yds. (2,308 to 2,400 yds.), and maximum deviation 12 ft.

With 10° of elevation the mean range was 4,148 yds. (4,080 to 4,187 yds.), and maximum deviation 12 ft.

The average velocity of the above at 30 yds. from the muzzle was 1,250 feet per second.

A cast iron spherical shot, weighing 304·75 lbs., fired with a 70-lb. charge, at 1° of elevation, ranged about 960 yds., and at 30 yds. from the muzzle had a velocity of 1,576 ft. per second, being about the same as that of the 68-pdr. service shot.

The result of this day's firing being considered exceedingly favourable to the gun as to accuracy, it was shortly afterwards, namely on 11th December, 1863, tried against a floating target of the "Warrior" construction moored at a range of 970 yds.

A trial shot was first fired with a cast iron shell weighing 612 lbs. and 70-lb. charge, at a common wooden target at 1,000 yds. distance, using an elevation of 2° 5′; this mark was hit the first time.

Three steel shells, weighing 612 lbs. each, were next fired at the real target with charges of 70 lbs., and bursting charges of 24 lbs., the first two, owing to a slight increase of elevation having been erroneously given, passed just over the target; the third, fired at 2° elevation, retained a velocity of 1,143 ft. per second, at 40 yds. from the muzzle, struck the target near the centre and produced wholesale destruction.

The shell appeared to burst as it passed through the wood backing, and it is almost impossible to describe the havoc made.

A large irregular hole, measuring some 2 ft. by 2 ft. 6 in , was pierced through and through armour, backing, and inner structure of the ship; ribs in the neighbourhood were smashed and supports carried away, fastenings broken, and the whole mass so shaken and twisted from end to end, that on subsequent examination, when brought to shore, it was found useless to attempt anything like a repair.

Subsequent trials of 600-pdr.

This gun was subsequently used against iron on three other occasions, which, although not according to date, had better be mentioned here. The first of these was on the 10th March, 1864, when a steel spherical shot of 344 lbs. was fired with a charge of 90 lbs. of powder against a piece of 11-in. rolled iron plate at 200 yards.

The plate measured only 3 ft. 8 in. by 3 ft. 4 in , weighed about 2 tons 8 cwt., and was supported (without any bolts) at two of its edges by timbers resting against the face of an old ship's target; the greater part of the plate was consequently unbacked.

The shot had an initial velocity of 1,708 ft., and struck with a velocity of 1,574 ft. full in the centre, made an impression 4·9 in. deep, broke the plate completely in two from top to bottom, throwing the two halves some feet asunder, and afterwards fell back itself considerably flattened on one side, and set up and cracked, but still holding together.

It is much to be regretted that the value of this experiment was in a great measure lost through the dimensions of the plate being so small, and this seems the more unfortunate since it was a piece cut off the monster plate rolled by Messrs. J. Brown and Co., of Sheffield, in the presence of the Lords of the Admiralty, in 1863, to which I alluded in the latter part of my paper in last year's volume. The quality of the metal of the plate was all that could be desired, but it was too much laminated, that is to say, the several piles of iron of which it was composed were not perfectly welded together throughout: and this points to one of the difficulties met with in the manufacture of these large armour plates. For if, through insufficient means or want of skill, any time be lost in bringing the hot metal from the furnace to the rolls or hammer, or if delays take place in either of these operations, the necessary heat is lost and the welding cannot be perfect. A plate thus constituted, instead of being one solid mass, is made up of so many laminæ, which although not absolutely distinct the one from the other, are very imperfectly connected, and thus it cannot be much superior to an equal thickness made up of a number of distinct sheets.

The second additional occasion of the 600-pdr. being fired against iron armour, was on a visit of H.R.H. the Commander-in-Chief and the Secretary of State for War to Shoeburyness on the 8th April last.

The target fired at was composed as follows :—A structure, consisting of ribs and skin exactly resembling those of the "Warrior," was protected by two thicknesses of timber, namely, 12 inches of oak placed horizontally, and 6 inches of teak vertically, which again formed the backing to armour plates 6½ inches thick; there was thus in this target an excess of strength upon the "Warrior" equal to about 2 inches of armour plate. After the experience with this gun against the "Warrior" at nearly 1,000 yds., it was easy to predict the effect upon this target at 200 yds.

The shot was of steel, it weighed 612 lbs., was fired with a charge of 70 lbs.

of powder, and of course passed completely through and through the target. This experiment, really unnecessary to those who had studied the previous achievements of this 22-ton gun, may nevertheless perform an important part in persuading others of its complete superiority over any naval structure yet afloat.

The other occasion of the 22-ton gun being used against iron armour took place at Shoeburyness on the 13th May last. It was this time tried to ascertain what its effect would be upon a strong iron clad ship at about two miles distance.

The target made use of was the same as that at which it was last fired: the armour being $6\frac{1}{2}$ in. thick, backed by 18 in. of timber, on framework and ribs the same as in the Warrior.

The gun was placed at 200 yds., the steel shot weighed 603 lbs, and was fired with a charge of 40 lbs. of powder.

This charge gave a velocity on striking of about 860 ft. per second, which is very nearly equal to the velocity which it would have at 3,300 yds., if fired with a charge of 70 lbs.

It struck rather nearer the edge of the target that it should have done, but the structure was well supported at this point by the timbers forming the roof of the box or cell of which the target formed the front. It is sufficient to say that a large piece of the armour, some 18 in. by 17 in., was completely smashed in, the backing crushed and destroyed over a large area, the inner skin very much bulged and ripped open in a joint, two ribs completely broken in two, others crippled, and several bolts and rivets broken. The shot did not completely penetrate the target, but this seemed principally to be owing to the support given by the roof of the box, otherwise the injury done was very nearly equal to that when the gun was fired on the former occasion with 70 lbs. of powder; and I think it may be safely assumed that a steel shot fired from this gun, with the full charge of 90 lbs., would break in the side of any ship in our navy at a distance of 4,500 yds., or about $2\frac{1}{2}$ miles.

[Experiment to test fastenings of various sorts. 22nd Dec., 1863.

One of the evils arising from the desultory and disconnected character of the early experiments upon iron armour showed itself in the confused and contradictory data afforded as to the matter of fastenings. This fundamental point, instead of forming the groundwork of the investigation, received so little consideration that it was never made the subject of any special experiment, and was merely treated in common with all the other matters involved in the use of armour for war purposes. Scarcely anything was tried beyond the ordinary screw-bolt with the universal thread; whether these broke or held fast in any particular target was of course noticed and recorded, but nothing was done to ascertain whether an improved system could not be devised, or at any rate whether some modifications were not necessary under certain circumstances.

At last it became apparent that the matter could not so rest, and an experiment was arranged to set the investigation on foot; of the ill success that attended it I will shortly speak, but a description of the preparations must first be given. The following bolts were selected for trial:—

1st. The ordinary screw-bolt with universal thread.

2nd. The ordinary screw-bolt with a thread of modified form proposed by myself.

3rd. The ordinary screw-bolt with elastic washers of two descriptions, namely, one a simple india-rubber washer 3 in. thick, the other an elastic washer confined in a strong wrought iron cup and resembling a railway buffer in principle.

4th. A rivet, or more accurately speaking, a bolt with a conical head at either end.

5th. A screw-bolt cut with a very fine thread and reduced for a certain part of its length to the lesser diameter of the screw part, proposed by Captain Palliser, 18th Hussars.

To obtain as even and as satisfactory a comparison as possible between these several fastenings it was determined to try them when used in securing iron armour to some substance having very little elasticity. It was feared that otherwise it would be impossible to make sure that all underwent a like amount of strain. It was further decided that bolts of $1\frac{1}{2}$ in. diameter were to be used, that the armour plates were to be 4 inches thick, and that they were to be secured to granite blocks.

Accordingly four plates, each measuring 4 ft. 6 in. by 2 ft. 6 in. by 4 in. thick, were made of very uniform quality; the wrought iron for the bolts was carefully selected, and four granite blocks were provided measuring 5 ft. 6 in. by 3 ft. 6 in. by 3 ft. thick, and weighing therefore upwards of 4 tons each. To obtain great accuracy of fire a range of 100 yds. was chosen. But unfortunately a 68-pdr. was used for the experiment.

As was fully expected by many, the blow of the 68-lb. shot (cast iron), fired with the full service charge of 16 lbs., proved altogether too much for the targets provided; as each shot struck the armour, the granite block in rear gave way under the blow and split from end to end in all directions, and thus no strain whatever was brought upon the bolts. In fact the experiment failed altogether and nothing was gained but another warning against the brittleness of granite.

[While upon this subject I must not omit to mention a chance shot (cast iron spherical), fired the same day from the 68-pdr. at the 100 yds. range, and which struck full in the centre of a granite block forming part of an old masonry wall. The stone hit measured 4 ft. 3 in. by 2 ft. 3 in. on its face, and was 3 ft. deep; its weight was therefore about two tons. This single shot was enough to effect the complete destruction of the granite block. It was shattered into a thousand pieces. At the point of impact the material was crushed and driven in to a depth of rather more than a foot, and from thence cracks radiated in all directions. A more complete demolition could hardly have been effected. The stone was a fair specimen of Devonshire granite. The shot broke up.]

This experiment having failed to give any test of the relative value of the different sorts of fastenings, it was subsequently continued upon a target differently constructed. This time the same 4-in. plates were backed by a thickness of 3 feet of oak.

The gun used was the 68-pdr., throwing cast iron shot with a reduced charge of 10 lbs. of powder, at 100 yds., this being as nearly as may be equivalent to the range being increased to 700 yds., with a full service charge of 16 lbs.

The result of two rounds with the reduced charge and one with the service charge, at each plate, was that one rivet or double-headed bolt was broken, and also one screw-bolt with the universal thread; but not one of the bolts with the modified thread, or with either of the elastic washers, or with the shank reduced on Captain Palliser's principle, gave way, although all underwent severe direct and cross strains; which is the best therefore of these three latter descriptions must be decided by further trial and by considerations of their respective values in a practical point of view.

Steel shot from the 68-pdr. against the "Warrior." 8th Jan., 1864.

The next shot of any importance fired at Shoeburyness were some spherical 68-pdrs. of toughened steel made by Messrs. Brown, of Sheffield.

The charge used was 16 lbs., the range 200 yds., the gun the service 95-cwt. gun, and the target of the Warrior build.

This was an interesting experiment as showing in a marked manner the advantage gained by using projectiles of steel instead of common cast iron.

The ordinary 68-pdr., it will be remembered, at 200 yds. range, does little or no injury to the Warrior beyond indenting the armour to a depth of about 2 in. On this occasion a blow from the service cast iron shot was first given to enable a comparison to be drawn between the quality of armour used in this and the previous Warrior targets, and the indent made was as nearly as possible 2 inches deep. Two steel shot were then fired with the same charge of 16 lbs. each, and they both penetrated the $4\frac{1}{2}$-in. armour and drove pieces of it into the teak backing. Here then the difference was very marked as to injury of armour; the steel shot broke through the $4\frac{1}{2}$-in. plate, when the cast iron only indented 2 inches. But on the other hand the latter did more injury to the fastenings than the steel: 9 bolts altogether gave way, and 4 rivets, and it is believed that all, or at any rate nearly every one of these, gave way under the blow from the cast iron shot; one of the bolts was distant 5 ft. 9 in. from the point of impact and passed through some 3 ft. 6 in. of timber in addition to the target. It is right that I should mention here that a severe frost occurred at the time of this experiment, and the fracture of such an unusual number of bolts was generally attributed to this fact. This is an interesting point to observe, although the importance of this injury to the bolts is lessened by the fact of recent experiments proving that elastic washers relieve the fastenings from almost all their liability to fracture.

13-in. mortars at iron armour. 10th March, 1864.

The next experiment tried at Shoeburyness was of a somewhat novel character. It was instituted with the view of ascertaining what would be the effect of the direct fire of solid shot from 13-in. mortars upon iron armour.

The shot used were of cast iron, weighing 280 lbs., the charge was 20 lbs., the range 200 yds., and the mortar was laid at 2° elevation. The initial velocity of the shot was about 798 ft. per second, and the velocity on impact 763 ft.

The target fired at was that on the principle designed for iron clad ships by Mr. Scott Russell, and described in Vol. XI, page 203.

The mortar was mounted in its ordinary bed and placed on a slide.

By singular good luck the first shot fired struck close to the mark aimed at and did considerable injury to the target. A large piece of the armour was broken away and forced in some 6 inches, one rib was quite broken and another cracked, and the skin was a good deal bulged. Altogether the damage done exceeded by a good deal that which was caused by a 68-pdr. on the same target.

The mortar recoiled the whole length of the slide.

The next shot fired at the same range missed the target (30 ft. long and 10 ft. high) altogether.

The next struck about 6 feet from the mark aimed at and did much the same injury as the first shot.

Mr. Nasmyth's experiment upon wool. 17th March, 1864.

As indicating the endless variety of theories entertained by scientific men on this great question of stopping cannon shot, I must not omit a trial instituted this year at Shoeburyness, at the suggestion of Mr. Nasmyth, where compressed wool formed the resisting medium.

So far as I could understand that gentleman's views, they were much to this effect. A blow delivered upon any substance is directly conveyed to the particles which are in its path, and not only to those immediately in front, but also to those situated obliquely to the direction of the blow, and hence the force of the blow is borne by a cone of which the apex is the point struck. According to the structural composition of the mass, the base of the cone will bear a greater or less proportion to its axis, or, in other words, the blow will be more or less distributed, and in a fibrous material the base of the cone would be more extended than in one of a granular or crystallized composition; hence, therefore, his selection of wool.

The experiment was arranged as follows:

A tube of boiler plate 18 ft. long, 8 ft. in diameter, and closed at one end, was filled for a depth of 11 feet with wool packed as closely as could be done by manual labour and the use of ordinary screws and levers; it was then laid on its side, presenting its open end to the gun and its other end resting against a bank of earth.

The first shot from an Armstrong 110-pdr., with a 12-lb. charge, at 100 yds., passed through the 11 ft. of wool, the ⅜-in. iron forming the end of the tube, and penetrated afterwards 14 feet into loosely packed earth. A second shot from the 68-pdr., at the same range, with the service charge, had about the same effect; and so palpable was the failure of the material in resistance, either by forming itself into a cone, or by any other means, that even Mr. Nasmyth himself concurred in the uselessness of firing another shot.

Steel shot against 5½-in. plates. 24th March, 1864.

An experiment, very different in character from the last one, was next set on foot at Shoeburyness. It may be regarded as in continuation of that on page 127 of this paper. On that occasion steel projectiles from 12-pdrs. were used against 2 and 2½-in. plates. On this occasion plates 5½ in. thick were struck by shot from the 110-pdr. breech-loading Armstrong guns.

The object of both experiments was to put to competition the various descriptions of steel recommended by the principal manufacturers in this country for projectiles. It was wise to make trial first of the smaller natures, and having gained so much in their trial it would have been folly not to extend it to the larger natures of projectiles.

With this preface I will proceed to a description of the experiment.

The plates forming the targets were of rolled iron, each 7 ft. by 3 ft. 6 in., and 5½ in. thick, manufactured at the Millwall Iron Works, and although somewhat laminated in texture, the metal of which they were composed was of good quality, and they may be taken as a fair specimen of heavy armour plates as now manufactured.

Ten plates were set up on this occasion. In their erection two conditions had to be fulfilled, one was that each plate should form a separate target, and another that the plates were to be left entire without any bolt holes.

A framework, consisting of two whole timber piles, driven about 6 ft. into the ground, and standing 9 ft. out, and 2 ft. 1 in. apart, well strutted behind, was provided for each plate.

The plates, standing on end, were blocked out about 4 in. from these uprights, and were held back by means of a common railway rail laying flatways against the face of the plate close to each of its side edges. Each of these vertical rails was held at top and bottom by a shackle embracing the timber upright behind the plate, and the railway rail in front of it, thus forming a secure fastening.

Each shackle was made up of two side pieces of railway rail placed horizontally and on edge, about 3 ft. 6 in. long; each side piece was perforated by two slots to receive cross pieces of $2\frac{3}{4}$-in. by $1\frac{1}{2}$-in. iron; one of these cross pieces passed in front of the railway rail laying on the face of the plate, the other passed behind the timber uprights.

This mode of erection, somewhat difficult to contrive at first, proved very successful in the trial, and will hold good in all future similar cases.

Passing now to the practice against these plates, the following may be taken as a general description:

The range was 200 yds., the shot weighed 110 lbs., and with one exception were hemispherical headed; the charge, except when specially mentioned to the contrary, was 12 lbs., and the initial velocity would be about 1,125 feet a second, or, $\frac{Wv^2}{2g} = 965$ tons raised 1 ft. high.

The performance of each manufacturer's shot is given in the order of merit, beginning with the best.

Messrs. Brown's shot passed clean through the plate and penetrated afterwards some 6 ft. into an earthen bank; the shot were but little altered in form. The same shot, fired with a reduced charge of 10 lbs., produced an indent of about 2·5 to 2·7 inches in the face of the plate, with a bulge and crack in rear, and were themselves much more injured than when fired with the 12-lb. charge; the shot were completely broken up.

Messrs. Attwood's shot stuck in the hole they made through the plate, one of them with a conical head only indented the plate to a depth of 4 in., and the conical head was crushed into a form very nearly approaching the hemisphere.

The shot made by Messrs. Sanderson did not quite make a hole through the plate; the depth of indent was 4 inches in the face of the plate with a bulge and piece scaled off in rear.

The shot of Messrs. Butcher and the Bolton Company made indents of about 3·5 and 3·6 in., and caused injury in the rear but did not quite penetrate.

Those of the Mersey Company and from Messrs. Bessemer made a slightly less deep indent with about the same injury in rear.

The other shot fired broke up under the blow without doing quite so much injury as the last described.

From a careful consideration of these results it appears that all depends upon the precise amount of tempering given to the steel of shot intended to be used against iron armour. A shot may be too highly tempered and become too brittle to bear the first shock of collision, while on the other hand if not sufficiently tempered it changes form and "sets up," and so also defeats the object. The difference lies in an extremely narrow compass, and it is therefore not surprising that so much care and skill are required to insure the exact condition of metal most favourable for this purpose.

On a subsequent occasion, a shot made by Mr. Krupp, fired from the same gun, passed through these 5½-in. plates without breaking up, and two others of the same maker pierced the plates but did not themselves quite pass through.

12-ton gun against Chalmers's target. 5th May, 1864.

In order to institute something like a comparison between the resistance offered by Mr. Chalmers's target and the Bellerophon to the 12-ton (10½-in.) gun, shot were fired from it on this occasion under the following circumstances:

In the trial last year of the Chalmers's target, three shots were fired from the gun alluded to at 200 yds. range, namely, one steel elongated shot with a charge of 45 lbs., and two cast iron spherical shot of 150 lbs., each with a charge of 50 lbs.; the former went completely through the target; the two latter penetrated the armour and buried themselves about 1 foot deep in the backing.

Against the Bellerophon target three shots also were fired from this gun, namely, one spherical cast iron, one spherical steel, and one elongated cast iron, but all with the reduced charge of 35 lbs. of powder. The spherical cast iron shot made an indent of about 3½ inches, and a bulge some 5 inches deep in the armour and caused some cracks in it. The spherical steel shot struck on the joint of two plates, pierced the armour and penetrated 7 inches into the backing. The elongated cast iron shot made an indent in the armour 1·6 inches deep and cracked it.

In order therefore to get something like a fair comparison between the two targets, a spherical cast iron shot was now fired from the same gun at the Chalmers's target with the reduced charge of 35 lbs. of powder at 200 yds. range, and the result was as follows:

The first shot struck too near the edge of the target to give any result. The next struck near the joint of two plates and made an indent 3·3 inches deep, with a crack across and around the indent; the armour was bulged in some 7 inches, 3 bolts and 2 rivets gave way, and other slight injuries were done.

Altogether it may be said that the effect of this shot upon the Chalmers's target was very nearly equal to that on the Bellerophon.

A spherical steel shot should now be fired at Chalmers's target with 35 lbs. of powder, in order to make the comparison more complete.

Steel shot from 68-pdr. against armour. 5th May, 1864.

Some spherical steel shot, made by Messrs. Brown and Co., of Sheffield, all tempered in different degrees, were next fired from the 68-pdr., at 200 yds., with the service charge of 16 lbs. of powder. The shot weighed 71·4 lbs. The target used was that consisting of 5½-in. armour, backed by 18 inches of timber, and the skin and framework of the Warrior.

Service cast iron shot from this gun make an indent from 1·6 in. to 1·8 in. deep, and of course break themselves up.

The steel shot made indents varying in depth from 2·6 in. to 3·8 in., or seven of these shot gave 3·2 in. for a mean depth of indent; this is just double that made by the cast iron shot.

The steel shot were slightly flattened on the striking side and set up, their original diameter of 7·94 in. being reduced in one direction to about 7 or 7·5 in., and increased in the other to 8·5 and 9 in.; the shot were in some instances slightly cracked but in no case did they break up.

Lord Warden target, Shoeburyness. 17th June, 1864.

This experiment was intended to test the principle of construction adopted in the "Lord Warden" ship which is building at Chatham.

It may be described in a general way as a wooden ship, armour-plated, with the addition of an iron skin $1\frac{1}{2}$ in. thick, worked outside the vertical frame timbers of the ship, and between them and the outside planking. The frame timbers were $12\frac{1}{2}$ in. square, and placed continuously, *i.e.* without intervals or spaces; these timbers were braced together by means of diagonal riders or bands of iron 6 in. by $1\frac{1}{4}$ in., and were connected with the five-deck beams (upper deck-beams 16 in. by 16 in., lower 15 in. by 12 in.), by means of strong knees of timber and iron; the weight of iron in each knee was $3\frac{1}{2}$ cwt. On one side of the frame timbers came the inner timber planking 8 in. thick, and on the outside the wrought iron skin before mentioned $1\frac{1}{2}$ in. thick; outside this skin came the outer timber planking 10 in. thick; and outside this again the $4\frac{1}{2}$ in. rolled armour plates secured through the whole structure by means of 2-in. screw-bolts having heads increasing to $2\frac{7}{8}$ in. Iron washers resting on india-rubber washers were used under the nuts of all the armour-plate bolts.

The target presented a front 20 ft. long by 9 ft. high, and consisted of two armour plates made by the Millwall Company, each 20 ft. by 4 ft. 6 in. Each plate was held on by 22 bolts; there was therefore a bolt to every 4 feet superficial of target.

The total weight of the target was 38 tons 16 cwt.; it was secured to a strong timber framework in rear similar to those used on former occasions, and which gave support only at the levels of the decks. The range was 200 yds.

The guns used were as follows:

One 68-pdr. 95 cwt. service gun; one light 9·22 in. muzzle-loading rifled gun 11 ft. long, 6 grooves, weighing 6 tons 11 cwt. 2 qrs.; one heavy 9·22-in. muzzle-loading rifled gun 13 ft. 3 in. long, 6 grooves, weighing 12 tons 2 cwt. 2 qrs.; one 10·5-in. muzzle-loading rifled gun 11 ft. 7 in. long, 10 grooves, weighing 11 tons 15 cwt. 2 qrs.; one 7-in. muzzle-loading rifled gun 10 ft. 9 in. long, 6 grooves, weighing 6 tons 13 cwt. 3 qrs.

The first shot was of steel, spherical, 7·94 in. diameter, weighing 71·4 lbs., and was fired from the 68-pdr. service gun with a charge of 16 lbs. of powder. Its striking velocity would be about 1,400 ft. a second. It made an indent 3·6 in. deep, and nearly broke through the armour; the shot rebounded some 15 yds. and broke into two large and several small pieces.

The second was a spherical steel shot 9·14 in. diameter, weighing 114·25 lbs., fired from the light 9·22-in. gun, with a charge of 25 lbs. of powder. This shot had a velocity, at 40 yds. from the muzzle, of 1,541 ft., at 170 yds. of 1,444 ft., and on striking, of about 1,424 ft. It penetrated the armour and buried itself unbroken in the backing, its nearest point being some 5 inches in from the face of the armour. The planking in rear was slightly started, the main deck waterway (timber 15 in. by 15 in.) broken across, and two armour-bolts started.

The third was a steel elongated shell, weighing 174·5 lbs., empty, with a bursting charge of 7½ lbs., from the same gun. It was fired with a charge of 20 lbs. of powder, and had a velocity of 1,028 ft. per second at 40 yds. from the muzzle, 1,006 ft. at 170 yds., and on striking of about 1,002 ft. It struck the upper plate of the target close to its edge and on a bolt, and broke in a piece of it 12½ in. by 11½ in., forcing it in to a depth of 6½ in. Two bolts were started and the plate struck was slightly displaced. The inner planking was slightly splintered and torn and one shelf piece was sprung. The shell broke in two pieces.

The fourth was a cylindrical steel shot, weighing 100 lbs., 10·54 in. long, and 6·91 in. diameter, fired from the 7-in. gun with a charge of 25 lbs. It had a velocity at 40 yds. of 1,565 ft., at 170 yds. of 1,507 ft., and on striking its velocity was about 1,497 ft. It struck on a bolt, near the left hand top corner of the target. It penetrated to the skin, indenting it 1 in. and buckling it 3½ in., and forcing away the timber passed out at the top of the target unbroken. Its diameter after the blow was 7·34 in. A couple of bolts were started, but the shot struck too near the edge of the target to give a very satisfactory result.

The fifth was a spherical steel shot, 10·43 in. diameter, weighing 168¼ lbs., fired from the 10½-in. gun, with a charge of 50 lbs. of powder. Its velocity at 40 yds. was 1,683 ft., at 170 yards 1,594 ft., and on striking 1,576 ft. It struck the upper plate on a bolt 10 in. from bottom and penetrated the armour, breaking a hole 11½ in. by 11 in. through it, and remained itself in the backing unbroken, its nearest point being 12 in. from the face of the armour. At the back of the target two inner timbers were broken and thrust out, a shelf piece broken half through, an iron knee cracked and bent out; the bolt struck was driven back some 10 in., and other damage was done.

The sixth was an elongated steel shot, weighing 221 lbs., diameter 9·14 in., length 13·42 in., fired from the heavy 9·22-in. gun, with a charge of 44 lbs. Its velocity at 40 yds. was 1,507 feet, at 170 yds. 1,461 feet, and on striking about 1,450 feet. It struck the upper plate and completely penetrated everything, passing 500 yds. out to sea. When picked up its length was reduced to 11·8 inches, and its diameter enlarged to 10·005 inches. The hole formed in the armour was about 11 inches one way and 10½ inches the other. At the rear everything met with was carried away with apparent ease.

The seventh round was from the light 9·22-inch gun, firing a spherical shot 9·17 inches diameter of chilled cast iron weighing 103¾ lbs., with a charge of 25 lbs. of powder. The shot had a velocity at 40 yds. of 1,654 feet, at 170 yds. 1,532 feet, and on striking of 1,507 feet. It struck on the junction of the two plates and broke up. It forced in the armour over an area of about 13 inches one way and 11 inches the other, and buried some of it in the backing at a depth of 6·8 inches from the surface; very slight injury was done to the rear of the target.

The eighth round was from the heavy 9·22-inch gun, firing an elongated steel shot 9·14 inches diameter, weighing 221 lbs., length 13·38 inches, with a charge of 30 lbs. of powder. The velocity of the shot at 40 yds. was 1,239 feet, that at 170 yds. was not taken, and that on striking would be about 1,200 feet. This shot grazed a plate lying at the foot of the target, and then struck the lower plate very near its edge; part of the armour, measuring 14 inches by 10 inches, was broken away, exposing the inner skin, and the shot passed under the target; when got out it was 12·93 inches long, and its diameter at the head was 9·56 inches.

The ninth round was from the $10\frac{1}{2}$-inch gun, firing an elongated steel shot of 10·46 inches in diameter, weighing 301 lbs., 14·07 in. long, with a charge of 45 lbs. of powder. Its velocity at 40 yds. was not taken, at 170 yds. it was 1,255 feet, and on striking 1,248 feet. It struck on the junction of the two plates and completely penetrated the target. The hole formed in the armour measured about 11 inches by 12 inches; several bolts were broken; at the back an iron knee was carried away 50 feet to the rear and the timbers torn to pieces. The shot afterwards struck a granite block and broke itself up.

The tenth round was from the heavy 9·22-inch gun, firing an elongated steel shot, the same as in the eighth round, but with 35 lbs. of powder. Its velocity at 40 yds. was 1,326 feet, at 170 yds. 1,293 feet, and on striking about 1,282 feet. Unfortunately it struck close to the hole made by a similar shot in the sixth round, and of course passed through the target, only adding to the injury of the former shot; the hole now formed was about 18 inches across.

The eleventh round was from the light 9·22-inch gun, firing a steel elongated shell 9·14 inches in diameter, 12·46 inches long, weighing, empty, 175 lbs., and with its bursting charge $182\frac{1}{2}$ lbs.; charge of powder 25 lbs. Its velocity at 40 yds. was 1,183 feet, at 170 yds. 1,146 feet, and on striking 1,139 feet. This shot struck close to the hole made in the fifth round, increasing it to an area of about 16 inches in diameter. It penetrated the target but did not burst, the bursting charge being merely blown out. Altogether it did considerable injury to the back of the target, but as it was so close to a former shot-hole the result obtained was unsatisfactory.

The twelfth round was from the heavy 9·22-inch gun, firing a solid steel elongated shot similar in every respect to that in the 10th round. Its velocity at 40 yds. was 1,385 feet, at 170 yds. 1,352 feet, and on striking about 1,341 feet. It struck close to the hole made in the 6th and 10th rounds, the three holes now forming a large triangular aperture. The shot was picked up 500 yds. to the rear of the target, unbroken, and measuring $11\frac{1}{2}$ inches in length and 10·18 inches diameter at its head.

The thirteenth and last round was from the light 9·22-gun, firing a spherical shot of chilled cast iron 9·18 inches diameter, weighing 105·44 lbs, with a charge of 20 lbs. of powder. Its velocity at 40 yds. was 1,566 feet, at 170 yds. 1,507 feet, and on striking about 1,497 feet. It struck close to the junction of the two plates, pierced the armour, and buried itself in the backing at a depth of 10 inches from the surface. The shot broke up. The timber between the armour and skin was much crushed and displaced, and other injury was done.

Altogether then, it may be said that this target bore tolerably well the heavy battering it got, and yet it cannot be regarded as a good model for a ship's side or for any other purpose.

The division of the armour into two independent thicknesses in the manner here adopted cannot be an advantageous distribution of the material. Armour in two thicknesses, of $4\frac{1}{2}$ inches and $1\frac{1}{2}$ inches, placed a few inches apart, would offer considerably less resistance to the passage of a shot than would the same armour collected in one thickness of 6 inches, and the mere presence of 10 inches of timber in the interval cannot materially affect the question either way.

On the other hand I am not prepared to say that the greatest resistance is to be obtained by massing the armour into one thickness. I believe our experiments go to prove the contrary, but the essential condition of strength in any plan involving a division of the armour, is that the two or more plates shall be intimately connected and brought into one girder-like structure.

The top and bottom flange of a wrought iron beam, if separated from the web or rib forming the depth of the girder, will offer a poor resistance to statical pressure, and it is scarcely to be expected that dynamical forces governed by the same laws, under somewhat different conditions, will fail to be influenced by the defect. My argument, then, is that if in this "Lord Warden" target the outer and inner armour had been reduced by about half an inch each, and this weight of metal had been employed in the shape of webs or ribs strongly riveted to the inner, and supporting the outer armour, a largely increased resistance would have been obtained with equal weight of material; the filling of the spaces between these ribs with timber would be a consideration of secondary importance, but if it would give stiffness to the structure, with a less expenditure of weight than other material, it should be added.

Small plate target, Shoeburyness. 4th August, 1864.

The last experiment which I can record this year is one made to test the value of a method, adopted on the continent, of armour plating on ordinary timber ships. It may be generally described as merely securing a number of small sized plates to the outside of a timber ship by means of a great number of wood screws, and the target used in the experiment may be more particularly described as follows:

It presented a front of 17 feet 3 inches by 10 feet in height.

The frame timbers of the ship were 11 inches, the inner planking 6 inches, and the outer planking 10 inches thick. The timber side therefore was 2 feet 3 inches through.

The deck beams, 14 inches by 14 inches, were 3 feet apart, and securely fastened to the side by very massive timber, knees, and ordinary bolts and straps.

The upper half of the target was plated with armour $4\frac{3}{4}$ inches thick; the lower half had armour $5\frac{7}{8}$ inches thick.

The upper plates were 5 feet 9 inches long and 2 feet 7 inches wide; the lower the same length but 2 feet 5 inches wide.

Each plate was held on by three rows of screws, the rows being 10 inches apart measuring vertically, and the screws 1 foot 2 inches from centre to centre horizontally; thus there were as many as 14 or 15 screws to plates of only 14 or 15 feet superficial, *i.e.*, as nearly as possible one $1\frac{1}{2}$-inch screw to every square foot of surface. In the "Warrior" there is one $1\frac{1}{2}$-inch bolt to every $3\frac{1}{4}$ feet superficial of armour.

The screws being quite a novelty in ship building may be more fully described. They consist of a spindle or stem 19 inches long and $1\frac{1}{2}$ inches in diameter, tapering down to 1 inch, with a thread wrapped round it at a pitch of $1\frac{1}{2}$ inches, and standing up about $\frac{1}{4}$ inch. The head of the screw swelled in a conical form out to a diameter of $2\frac{3}{8}$ inches, and in order to allow the use of a spanner or key a short piece of the head was cut square ($1\frac{3}{8}$ inch side).

The hole in the armour was of course countersunk to suit the head, and the thread did not extend to that part of the head which was in the armour.

The whole length of the screw being 19 inches it passed entirely through the outer timber planking, and about $\frac{1}{3}$rd through the main timbers. The quality of the iron of which they were made was the most remarkable I have ever seen; for toughness nothing before tried in this country can be compared with it. In some cases they were nearly bent double or twisted and almost tied in knots without showing the slightest symptom of a crack. They were made in France by Messrs. Petin, Gaudet, and Co., of Rive de Gier, and were said to be of a very superior description of charcoal iron from *Elba*, and have been extensively used in the "Frégates cuirassées."

The total weight of the target was 28 tons 3 cwt., and it was supported in rear in the usual manner by a massive timber framework.

This being a sufficient description of the target I shall proceed with a short account of the experiment.

The range was 200 yds., and the guns used, &c., were as follows:

On account of an accident to the wires leading from the electro-ballistic instrument, no velocities were taken on this occasion.

A 68-pdr. service cast iron shot, fired with service charge, striking close to the corner of a $4\frac{3}{4}$-inch plate, bent it in about 6 inches and formed a crack; also a bolt, about 5 feet away from the spot struck, started out very slightly.

A 110-pdr. cast iron shot, with service charge, striking near the edge of a $4\frac{3}{4}$-inch plate, made an indent 1·7 inches deep, and buckled the plate 2·9 inches.

A spherical steel shot, weighing 70 lbs., fired from the 68-pdr., with a 16-lb. charge, struck on the joint of two $4\frac{3}{4}$-inch plates, and made a hole 8·5 inches by 8·7 inches, and 5·7 inches deep. The piece was very nearly broken away from the plate, and therefore it may be said to be almost, if not quite, penetrated. The shot rebounded some 10 yds. and was set up but did not break.

An elongated steel 110-lb. shot, fired with 12 lbs. of powder, struck a $4\frac{3}{4}$-inch plate and stuck in it, leaving about $5\frac{1}{2}$ inches of its length outside. The shot was a little cracked and set up but did not break, some bolts showed symptoms of being very slightly drawn out, and the corner of the plate was cracked and driven in.

After these a steel elongated shot, weighing 220 lbs., was fired with a 30-lb. charge from the 9·22-inch heavy shunt gun. By calculation this charge gave a velocity equal to that which the same shot would have at about 1,500 yds. if fired with a full charge of 44 lbs.

It struck near the edge of a $4\frac{3}{4}$-inch plate and went clean through the target, making an indent of ·3 inch deep on another target in rear. The armour-plate struck was a good deal displaced and the timbers of the ship in its neighbourhood were very severely injured. The shot set up to a length of 12 inches and increased somewhat in diameter.

The next shot was of chilled cast iron, on Captain Palliser's principle. It was cylindrical and hollow, 20 inches long, weighing 258 lbs. 12 oz., and was fired from the 9·22-inch gun, with a charge of 44 lbs. of powder. It struck a small $4\frac{3}{4}$-inch plate 2 feet $10\frac{1}{2}$ inches by 2 feet 7 inches, and went completely through everything, producing great havoc inboard. The hole made in the armour measured 10 inches by $11\frac{1}{2}$ inches. The timber backing was so much injured that the bolts had nothing to hold on by, and the plate was much displaced and very nearly detached altogether from the target. One of the large timber knees of the ship was carried away and thrown down some 15 feet to the rear. The ground was strewn with splinters of timber and fragments of the shot which broke up in passing through the armour; a large piece of it buried itself in the timber of a target in rear. The armour-bolts, although twisted into all manner of forms, did not break.

Next, a spherical steel shot, weighing 168 lbs., fired with a 50-lb. charge from the 10·5-inch gun, struck partly on a $4\frac{3}{4}$-inch and partly on a $5\frac{7}{8}$-inch plate. It went completely through the target, making a hole 13 inches by 11 inches in the armour, smashing the timbers and displacing a large knee. It broke up into several pieces.

After this a 70-lb. steel shot, from the 68-pdr., struck a $5\frac{7}{8}$-inch plate, and made an indent 3·9 inches deep, cracking the plate slightly about the indent and buckling it about 4 inches. The shot was set up but did not crack much.

Also a 110-lb. steel shot, from the 7-inch gun, struck a $5\frac{7}{8}$-inch plate and made an indent 2·8 inches deep with a buckle of about 3 inches; the indent was cracked round the bottom and the shot set up and slightly split.

After this a steel elongated 220-lb. shot, fired from the 9·22-in. gun, with a 30-lb. charge as before, was aimed at a $5\frac{7}{8}$-inch plate, but struck a $4\frac{3}{4}$-inch one, and of course as before, went completely through everything, making a considerable indent on an iron plate in rear.

Also a 168-lb. spherical steel shot from the 10·5-inch gun, fired with a $22\frac{1}{2}$-lb. charge (in order to give a velocity equal to that of a similar shot at 1,000 yds. if fired with a 50-lb. charge), missed a $5\frac{7}{8}$-inch plate, and hit a $4\frac{3}{4}$-inch one near the hole made by the former 168-lb. shot, and went completely through the target.

The next shot fired was intended to be a steel elongated shot, from the 10·5-inch gun, with a 35-lb. charge, and when everyone looked for complete penetration, the shot, striking partly on a $4\frac{3}{4}$-inch and partly on a $5\frac{7}{8}$-inch plate, and on the corner of one of them, did no more injury than merely driving in a piece (16 inches by 8 inches) of one plate, with the backing, to a depth of 9 inches, and doubling back the corner of the other. The shot itself broke up, and on examination of the fragments it at once appeared that a cast iron shot had been used by mistake.

The next shot fired was a steel elongated shot weighing 220 lbs., from the 9·22-inch gun, with a 30-lb. charge. It struck a $5\frac{7}{8}$-inch plate, and making a hole $11\frac{1}{2}$ inches by 11 inches, passed completely through the target, striking an iron plate in rear and glancing off 44 yds. to the left. It was set up a little, but did not break.

Another elongated steel shot from the 10·5-inch gun, striking on a $5\frac{7}{8}$-inch plate, went through and through the target, causing fearful havoc in board; and after a steel shell, weighing 217 lbs., with a burster of 11 lbs., which was fired with a charge of 30 lbs. from the 9·22-inch gun, had also passed through bursting in its passage, and one or two more shot of Captain Palliser's chilled cast iron from the 9·22-inch gun, the state of wreck to which the whole structure was reduced can scarcely be described. If a body of shipwrights had been employed for weeks in taking the timber framework to pieces and splitting it up into firewood they could scarcely have effected what was now done.

On the whole it is evident that this target cannot be compared with some of our own. As a cheap and ready expedient for armour-plating a timber ship, this method is ingenious and much to be admired, but beyond this nothing can be said.

Small plates are much inferior to large, as offering so many more joints and weak points to be struck, and as otherwise being capable of less resistance; and this was apparent in this experiment, in spite of the excellent quality of the plates used, better plates having never been put into a target at Shoeburyness. The wood screws did their duty remarkably well; the quality of the iron in them was the most extraordinary perhaps ever produced, although not subjected to the same sort of strains as our bolts are, which secure armour to iron framed ships, yet the cross-strains and torsion which they bore without the least appearance of fracture told their quality in unmistakeable terms; some were bent nearly double and others almost tied into knots and twisted like rams' horns without any apparent rupture of the material.

The absence also in this target of an inner structure of iron and of something that can give better support to the armour than simple timber planking, told very much against it.

This closes my account of the experiments for this year's volume. In the next I hope to publish a statement which may be useful in giving an outline of the principal effects produced upon iron armour by most of the guns hitherto tried or brought into the service.

T. INGLIS.

PAPER XVII.

EXTRACTS*

FROM THE

REPORT OF THE SIEGE OF FORT PULASKI, GEORGIA,

IN 1862.

BY BRIGADIER GENERAL Q. A. GILLMORE,

CAPTAIN OF ENGINEERS, U.S.A.

Fort Pulaski is situated on Cockspur Island, Georgia, latitude 32° 2′ N., and longitude 3° 51′ W. from Washington, at the head of Tybee Roads, commanding both channels of the Savannah River. The position is a very strong one. Cockspur Island is wholly marsh, and is about one mile long and half a mile wide.

It is a brick work of five sides, or faces, including the gorge; casemated on all sides; walls 7½ feet thick, and 25 feet high above high water; mounting one tier of guns in embrasures, and one *en barbette*. The gorge is covered by an earthen outwork (demi-lune) of bold relief.

The main work and demi-lune are both surrounded and divided by a wet ditch. Around the main work, the ditch is 48 feet wide; around the demi-lune, 32 feet.

* Made by the Editor from the official report procured by Lieut. Innes, R.E.

The communication with the exterior is through the gorge into the demi-lune over a drawbridge, and then through one face of the demi-lune, over the demi-lune ditch, by another drawbridge. The scarp of the demi-lune, and the entire counterscarp of main work and demi-lune, are revetted with good brick masonry.

At the time of the siege, it contained 48 guns, of which 20 bore upon the batteries on Tybee, viz.: five 10-inch columbiads, five 8-inch columbiads, four 32-pdrs., one 24-pdr. Blakely rifle, two 12-inch, and three 10-inch sea-coast mortars. A full armament for the work would be 140 guns.

On the 29th of November, I was directed by General Sherman to make an examination of Tybee Island and Fort Pulaski, and to report upon the propriety of occupying and holding that island, and upon the practicability (and, if deemed practicable, the best method) of reducing Fort Pulaski. I reported, on December 1st, that I deemed "the reduction of that work practicable, by batteries of mortars and rifled guns established on Tybee Island;" and entered into some details as regards the position of the batteries, the precautions to be observed in their construction, and the intensity of the fire that should be maintained against the work. The immediate occupation of Big Tybee Island by at least one regiment was also recommended.

The armament (for the siege) comprised thirty-six pieces, distributed in eleven batteries, at various distances from the fort, as shown in the following table:

1.	Battery,	Stanton,	3	heavy 13-inch Mortars	at 3,400 yds.
2.	"	Grant,	3	- - -	- 3,200 -
3.	"	Lyon,	3	- 10 - Columbiads	- 3,100 -
4.	"	Lincoln,	3	- 8 - -	- 3,045 -
5.	"	Burnside,	1	- 13 - Mortar	- 2,750 -
6.	"	Sherman,	3	- - -	- 2,650 -
7.	"	Halleck,	2	- - -	- 2,400 -
8.	"	Scott,	3 1	10 - } Columbiads 8 - }	- 1,740 -
9.	"	Sigel,	5 1	30-pdr. Parrott 48 - James's (old 24-pdr.)	- 1,670 -
10.	"	McClellan,	2 2	84 - - (- 42 -) 64 - - (- 32 -)	- 1,650 -
11.	"	Totten,	4	10-inch Siege Mortars	- 1,650 -
			36		

Each battery had a service magazine capable of containing a supply of powder for about two days' firing. A depôt powder magazine, of 3,600 barrels capacity, was constructed near the Martello Tower, which was the landing-place for all the supplies.

Serious difficulties were encountered in making a road sufficiently firm to serve for this heavy transportation.

Tybee Island is mostly a mud marsh, like other marsh islands on this coast. Several ridges and hummocks of firm ground, however, exist upon it, and the shore of Tybee Roads, where the batteries were located, is partially skirted by low sand-banks, formed by the gradual and protracted action of the wind and tides. The distance along this shore, from the landing-place to the advanced batteries, is about two and a half miles. The last mile of this route, on which the seven most advanced batteries were placed, is low and marshy, lies in full view of Fort Pulaski, and is within effective range of its guns. The construction of a causeway, resting on fascines and brushwood, over this swampy portion of the line; the erection of the several batteries, with the magazines, gun platforms, and splinter-proof shelters; the transportation of the heaviest ordnance in our service by the labour of men alone; the hauling of ordnance stores and engineer supplies, and the mounting of the guns and mortars on their carriages and beds, had to be done almost exclusively at night, alike regardless of the inclemency of the weather and of the miasma from the swamps.

The positions selected for the five most advanced batteries, were artificially screened from view from the fort, by a gradual and almost imperceptible change, made little by little every night, in the condition and appearance of the brushwood and bushes in front of them. No sudden alteration of the outline of the landscape was permitted. After the concealment was once perfected to such a degree as to afford a good and safe parapet behind it, less care was taken; and some of the work in the batteries, requiring mechanical skill, was done in the daytime, the fatigue parties going to their labour before break of day, and returning in the evening after dark.

In all the batteries, traverses were placed between the pieces.

With two exceptions (batteries Lincoln and Totten), the magazines were placed in or near the centre of the battery, against the epaulment, with the opening in the rear. An ante-room for filling cartridge-bags was attached to each. The magazines for the batteries Lincoln and Totten were located in the rear of the platforms.

For revetting the sides of traverses and epaulments, fascines, hurdles, brush, and marsh sods were used. Marsh sods form the best revetment for sandy soil. All the others allow the sand to sift through them to such an extent as to become a serious annoyance to the men serving the pieces.

In order to diminish, as much as possible, the labour of forming the parapets in front of the pieces, the foundation timbers of all the gun and mortar platforms were sunk to high-water mark. This brought them, in many cases, to within six or eight inches of the substratum of soft clay. To secure them against settlement, the lateral as well as vertical dimensions usually adopted for platforms were considerably enlarged.

The first shell was fired at a quarter past eight o'clock, A.M. (April 10th), from battery Halleck. The other mortar batteries opened one after the other, as rapidly in succession as it was found practicable to determine the approximate ranges, by the use of signals. The guns and columbiads soon followed, so that before half-past nine, A.M., all the batteries were in operation; it having been deemed expedient not to wait for the barbette fire of the work to be silenced, before opening with breaching-batteries Scott and McClellan.

The three 10-inch columbiads in battery Scott were dismounted by their own recoil, at the first discharge; and one of those in battery Lyon, from the same cause, at the third discharge. They were all, except one in battery Scott, subsequently remounted and served.

As the several batteries along our line, which was 2,550 yards in length, opened fire one after another, the enemy followed them up successively, with a vigorous, though not at first very accurate fire, from his barbette and casemate guns. Subsequent inquiry showed that he knew the exact position of only two of our batteries (Sherman and Burnside). These were established just above high-water mark, on low ground, void of bushes or undergrowth of any kind. During their construction, no special attempt at concealment had been made, after once securing good parapet cover by night-work.

Great disappointment was expressed, by all experienced officers present, at the unsatisfactory results obtained with the 13-inch mortars. Although the platforms were excellent, and remained, for all useful purposes, intact—and although the pieces were served with a very fair degree of care and skill—not one-tenth of the shells thrown appeared to fall within the work; an estimate that was afterwards found to be rather over than under the correct proportion. Whether this inaccuracy is due to the fact that no cartridge-bags were furnished for the mortars, to inequalities in the strength of the powder, to defects in the piece itself, or to these several causes combined, remains yet to be ascertained.

By one o'clock in the afternoon (April 10th), it became evident that the work would be breached, provided our breaching batteries did not become seriously disabled by the enemy's fire. By the aid of a powerful telescope, it could be observed that the rifled projectiles were doing excellent service; that their penetration was deep and effective; and that the portion of the wall where the breach had been ordered, was becoming rapidly "honey-combed."

It also became evident before night, on account of the inefficiency of the mortar firing, that upon breaching alone—ending, perhaps, in an assault—we must depend for the reduction of the work.

I extract as follows, from my preliminary report to Brigadier-General Benham, dated April 12th, 1862:

"The only plainly perceptible result of this cannonade of ten and a half hours' duration (on the 10th), the breaching batteries having been served but nine and a half hours, was the commencement of a breach in the easterly half of the pan-coupé, connecting the south and south-east faces, and in that portion of the south-east face spanned by two casemates adjacent to the pan-coupé.

"The breach had been ordered in this portion of the scarp, so as to take in reverse, through the opening formed, the powder magazine, located in the angle formed by the gorge and the north face.

"Two of the barbette guns of the fort had been disabled, and three casemate guns silenced.

"The enemy served both tiers of guns briskly throughout the day, but without injury to the *matériel* or *personnel* of our batteries.

* * * * * * *

"On the morning of the 11th, a little after sunrise, our batteries again opened fire with decided effect, the fort returning a heavy and well directed fire from its casemate and barbette guns. The breach was rapidly enlarged. After the expiration of three hours, the entire casemate next the pan-coupé had been opened, and by twelve o'clock, the one adjacent to it was in a similar condition.

"Directions were then given to train the guns upon the third embrasure, upon which the breaching batteries were operating with effect, when the fort hoisted the white flag. This occurred at two o'clock."

During the 11th, about one-tenth of the projectiles from the three breaching batteries were directed against the barbette guns of the fort. Eleven of its guns were dismounted, or otherwise rendered temporarily unserviceable.

The garrison of the fort was found to consist of 385 men, including a full complement of officers. Several of them were severely, and one fatally wounded.

Our total loss was one man killed. None of our pieces were struck.

General Observations.

The three breaching batteries, Sigel, Scott, and McClellan, were established at a mean distance of 1,700 yards from the scarp walls of Fort Pulaski.

The circumstance, altogether new in the annals of sieges, that a practicable breach was made at that distance, in a wall 7½ feet thick, standing obliquely to the line of fire*, and backed by heavy casemate piers and arches, cannot be ignored by a simple reference to the time-honoured military maxims, that "*Forts cannot sustain a vigorous land attack,*" and that "*all masonry should be covered from land batteries.*

At Fort Pulaski an excellent opportunity was afforded on the scarp wall near the breach for obtaining the actual penetration of the several kinds of projectiles.

An average of three or more shots for each calibre was taken, giving the following results, which may be relied upon as correct:

Table of penetrations in a brick wall, as determined at the Siege of Fort Pulaski, Georgia, April, 1862.

Kind of Gun.	Distance from wall.	Kind and weight of projectile.	Elevation.	Charge.	Penetration.
Old 42-pdr. rifled.	1,650 yards	James's 84-lb. solid	4¼ deg.	8 lbs.	26 in.
- 32 - -	1,650 -	- 64 - -	4 -	6 -	20 -
- 24 - -	1,670 -	- 48 - -	4½ -	5 -	19 -
Parrott rifled guns.	1,670 -	Parrott 30 - -	4½ -	3½ -	18 -
10-in. Columbiad, smooth bore.	1,740 -	128-lb. solid, round	4½ -	20 -	13 -
8-in. Columbiad, smooth bore.	1,740 -	68 - - -	5 -	10 -	11 -

The above table indicates very prominently, although it affords no exact means of measuring, the great superiority of rifled over smooth-bored guns, for purposes requiring great penetrating power.

Against brick walls the breaching effect of percussion shells is certainly as great as that of solid shot of the same calibre. They do not penetrate as far by twenty to twenty-five per cent., but by bursting they make a much broader crater. Such shells would doubtless break against granite walls, without inflicting much injury.

Sir W. Denison, from a comparison of the several sieges in Spain during the Peninsular War, estimates that a practicable breach at 500 yards could be made in a rubble wall, backed by earth, by an average expenditure of 254,400 lbs. o metal, fired from smooth-bore 24-pdrs. for every 100 feet in width of breach: equal to 2,544 lbs. of metal for every lineal foot in width of breach.

* Mean angle of line of fire with wall 67°.—Ed.

Before we can draw any comparison, however imperfect, between this estimate and the results obtained at Fort Pulaski, it is necessary to make certain deductions from the amount of metal thrown from the breaching batteries used against that work, as follows:—

1st. For the shot expended upon the barbette guns of the fort in silencing their fire.

2nd. For ten per cent. of Parrott's projectiles which upset, from some defect which, I know from personal observations, has been entirely removed by the recent improvements of the manufacturer.

3rd. For nearly fifty per cent. of the 64-lb. James's shot, due to the fact that one of the two pieces from which they were thrown, had, by some unaccountable oversight, been bored nearly one-fourth of an inch too large in diameter, and gave no good firing whatever. Making these deductions, it results that 110,643 lbs. of metal were fired at the breach.

The really practicable portion of the breach was of course only the two casemates that were fully opened, say 30 feet in aggregate width, but the scarp wall was battered down in front of three casemate piers besides; and had these piers not been there, or had the scarp been backed by earth alone, as was generally the case in Spain, the practicable portion of the opening would have been from 45 to 50 feet wide. Calling it 45 feet, the weight of metal thrown per lineal foot of breach was 2,458 lbs., against 2,544 per lineal foot in the Peninsular sieges. Had the fort held out a few hours longer this difference would have been much greater, for the wall was so badly shattered to the distance of 25 or 30 feet each side of the breach, that the opening could have been extended either way with a comparatively trifling expenditure of metal. On repairing the work one hundred lineal feet of the scarp wall had to be rebuilt.

It must be borne in mind that at Fort Pulaski only fifty-eight per cent of the breaching metal was fired from rifled guns, the balance being from the smooth-bored 8-inch and 10-inch columbiads (68 and 128-pdrs.) of battery Scott.

It may therefore be briefly and safely announced that *the breaching of Fort Pulaski at* 1,700 *yards, did not require as great an expenditure of metal, although but fifty-eight per cent. of it was thrown from rifled guns, as the breaches made in Spain with smooth-bore exclusively, at* 500 *yards.* In the former case the wall was good brick masonry, laid in lime mortar, and backed by heavy piers and arches; in the latter, rubble masonry backed by earth.

The inaccuracy of the fire of the 13-inch mortars has already been adverted to. Not one-tenth of the shells dropped inside of the fort. A few struck the terre-plein over the casemate arches, but so far as could be observed by subsequent inspection from below, without producing any effect upon the masonry. Whether they penetrated the earth-work to the roofing of the arches, was not ascertained.

We may therefore assume, that *mortars are unreliable for the reduction of a good casemated work of small area, like most of our sea-coast fortifications.*

To the splinter-proof shelters, constructed for the seven advanced batteries, I attribute our almost entire exemption from loss of life. We had one man killed by a shell from one of the mortar batteries outside the fort, which was the only casualty.

(Signed) Q. A. GILLMORE,
Brig. Gen. Vols.

Printed by W. P. Jackson, "Journal" Office, Woolwich.