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## PROFESSIONAL PAPERS.

NEW SERIES.

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## PAPERS

## ON SUBJECTS CONNECTED WITH

THE DUTIES

of the

## CORPS OF ROYAL ENGINEERS.

CONTRIBUTED BY MEMBERS OF THE ROYAL AND EAST INDIA CONPANY'S ENGINEERS,

AND
EDITED BY A COMMITTEE OF ROYAL ENGINEERS.

VOL. I. NEW SERIES.

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## NOTICE BY THE EDITORS.

The Editors of this work have to explain the circumstances which have led to the new appearance of this volume.

The Subscribers may remember that, in February, 1847, an alteration took place in the mode of publishing the Professional Papers, in consequence of objections made as to the bulk and expense of the volumes in the 4 to shape, and the tenth volume appeared as a separate concern unconnected with the Corps Papers, printed in large 8 vo .

But this separation has been fatal to the 4 to volume, solely on account of the expense, and the Publisher has declined to continue the work.

The Editors found it necessary, therefore, to submit this to the Corps at the General Meeting in February last, when they obtained the following decisions:-

1. That the 4 to form should cease to be published.
2. That the $8 v o$ form should be continued, comprising the objects of both works.
3. That contributors should be confined to the Royal Engineers and the Engineer Departments of the East India Company's Service.
4. That the title of the work should be, under the new form, Volume First, New Series, and termed, Papers on Subjects connected with the Duties of the Corps of Royal Engineers, contributed by Members of the Royal and East India Company's Engineers, and edited by a Committee of Royal Engineers.
5. That the new work under the above title is to be open to the Public, and bound with green, to represent the 4 to volumes in a smaller shape.

The Editors have to state, that this change has created some delay in the publication of the work, in order to extend it to the
size of a volume instead of a few sheets of Corps Papers; and, likewise, to explain the motives which induced the Officers at the meeting to adopt the character of the former volumes in the 8 vo form.

The Professional Papers, although bulky and inconvenient to the Officers of the Corps, when they were extended to ten 4 to volumes, have a value in the profession generally, while their large size rather increased their value; and in other services, the work has been estimated very highly. With these views, it was decided that the character of the work should be maintained, in a more portable form suitable to the wishes of the Corps generally, with the hope, also, that it may be equally esteemed by other services.
G. G. LEWIS,

Colonel Royal Engineers.
J. WILLIAMS,

Captain Royal Engineers.

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## PROFESSIONAL PAPERS.

## NEW SERIES.

## PAPER I.

COAST DEFENCES, chiefly as applicable to the Coast of Great Britain. By Major-General Sir John F. Burgoyne, K.C.B., In-spector-General of Fortifications.

1. The subject of Coast Defences involves a great number of matters that have more or less connection with the general principles of fortification and defence; there are, however, many points that are more peculiarly applicable to that distinet nature of service which may be treated in a desultory manner under their several heads. Some have been already discussed in the "Professional Papers of the Royal Engineers," vol. vii., and in the "Corps Papers," vol. i., pages 101 and 408 ; I wilf avoid, therefore, the precise topics there adverted to as much as possible.

## Towers.

2. The Tower system originated in the Mediterranean, to afford protection against the inroads of Turks and Moors, by placing a few men in posts dispersed along the coast, where they could be secure against a sudden assault; from whence they could give the alarm, and signalise the population to collect and oppose incursions; and from the top of which towers they could perhaps serve a single gun or more to keepvessels at a distance.
3. One of these, a round tower, in Martelln Bay in Corsica, having done very great damage to a British line-of-battle ship and a frigate which opposed it by direet fre, gave a prestige in their favour, even for defence against European powers, that it is conceived was carried too far.
4. Towers may be usefully applied in detached positions, for one, two, or three guns, particularly where the pieces require to be much raised above the natural ground; and in water, or on small rocks or islands affording very little space, and not assailable except from boats.
5. In these latter situations, if of sufficiently substantial construction not to be breached by the fire of shipping, they can hardly be reduced until battered from the shore.
6. The necessary strength to resist the being breached from afloat may be obtained in various ways; in addition to direct thickness throughout, by being circular, or, if quadrangular,
7. By bringing out the arches endways to the fronts liable to be battered (in which case they should be carried through to the face of the escarp), so as to furm a revetment en décharge.
8. If there should be sufficient space, by covering the escarp, or even the lower part of it, by an outer embankment, or counterscarp and glacis, or making the lower part entirely solid, or of increased thickness.
9. As a ship's guns are but little above water, and cannot, particularly when opposed to other fire, be served continuously with the precision necessary for breaching at any peculiar and narrow limit of elevation, the lower 15 or 20 feet of ground or building from the water-level will receive most of the shot, and that being covered, or made peculiarly strong, will give great power to the building to resist the shock of the broadsides of any shipping.
10. If this lower part be even all of it of masonry, and above ground, it can be given much increased solidity without losing the entire of its space, by leaving, in that part of its interior, openings comparatively small, such as only for magazine and tank.
11. An enceinte, however, of detached towers, it is submitted, is faulty.
12. It causes too great a subdivision of the available forces, and is a most expensive mode of procuring an emplacement for guns, and accommodation and space for men and stores.
13. It is considered contrary to sound military principles to attempt to spread your forces along very extended lines of position or frontier: it is, in fact, to be weak everywhere, and, in lieu of the great principle of concentration, to apply them in such manner that only a small portion can be available.
14. Wherever an attack is made, there is a semblance of opposition brought into action, while a great force in the aggregate has no power to co-operate, and remains inactive. This principle will hold good along the coast, as well as in the interior.
15. Under the most favourable circumstances, only three or four towers are likely to be able to co-operate in opposing a landing, and being each of them without any self-protection, and garrisoned with 12 or 20 men only, would be carried in succession without difficulty, by a few hundred men landed for the purpose.
16. If it be said that it was intended that they should be supported by troops, that might or might not be the case ; but if it should be, it is the troops who would make the more effective resistance; and a few moveable field-pieces with them would be more serviceable, at far less expense, and without the great inconvenience of the numerous equipments and garrisons that would be useless in the mass of distant towers not within the sphere of action.
17. Except to protect harbours, bays of limited extent, and other sheltered parts where landing may be particularly favourable, and as places of refuge where occasional protection might be afforded to our trading vessels, the defence of the coasts should be by moveable and not permanent batteries.
18. In construction, every inclosed work, or even building, however small (including towers), meant for defence, should be flanked, either by its exterior form, by counterscarp galleries, by caponnières, or by machicoulis, to give it any chance of resisting a coup-de-main. The want of this precaution is a great defect in the ordinary round tower. If to be at all dispensed with, it is only in case of the tower being closely surrounded by water, so as not to afford footing for ladders.
19. A tower liable to be battered by guns on the land should be covered by a counterscarp, or outer screen of some sort, otherwise it will be breached with little trouble or risk.
20. Generally speaking, the square or rectangular tower has advantages over the round; the construction is more simple and economical, and the interior space more convenient to arrange.
21. The regulation towers of Napolean, described in the "Professional Papers of the Royal Engineers," vol. iii.," afford useful information on this class of defence.
22. One for three guns, with one of its angles presented to the sea, will admit of a good lateral range for all three pieces in that direction, and be favourably placed for resisting the shot from a vessel.
23. In towers, and very small coast forts, the arrangements for accommodation need not be on the ample scale regulated for barracks, but assimilated to what is allowed in a man-of-war, where space requires to be economised. The magazine also may be as in a ship, with the rectangular navy cases for the ammunition; and the space generally for officers and men, with the cooking ranges and stores, as on board, particular care being taken to ensure the building being free from damp, and thoroughly ventilated. These close quarters will be the less inconvenient to the parties in them, because their full occupation will only be in times of threatened attack, and will be subject to frequent reliefs.

## Moveable Batteries.

22. Batteries or brigades of guns to be brought up with troops to parts of a coast attacked or threatened, will be worthy of being organised in time of war in central secure stations.
23. I am not aware of any system having been designed for it, as to the best nature of ordnance, combining the most efficient service against shipping, with sufficient facility of movement, \&cc., \&c., but that is an artillery question $\dagger$.
24. There is one difficulty which may have acted as an impediment to this system, namely, the expense of horsing such a number of pieces of moveable artillery on so remote a chance of being required; but it is submitted that this might be obviated by maintaining the brigade in its station fully equipped in every other respect, and taking up draught horses from the civil employ on periods of emergency. Such a mode of horsing guns for manœuvring in the field would be quite inefficient, and consequently inadmissible; but in this case, the object being chiefly to get the guns to some given ground where they would be served to the last, or perhaps not attacked at all, except by an opposing fire; the advantages to be derived from these batteries would more than compensate for the inconveniences of this mode of moving them.
25. An assortment of intrenching tools, for throwing up epaulements for the guns, should form part of the equipment.

## Position of Batteries as regards Elevation.

26. The most effective fire against ships would be obtained from guns but little above the level of the water; the shot and shells would then graze over its surface, and bound from it at low angles; but so placed the pieces would be subject to the inconvenience of being most exposed to the fire from the ships, whether clase or distant.
27. In proportion as batteries are elevated, they lose in the best effect of their own fire, but become far less exposed to suffer from that of ships.
28. There is also from elevated direct batteries, if close to the water, a certain space near them which they cannot command at all, and where vessels or boats would consequently be safe from them.
29. It is an object to strike out a medium between these conflicting advantages and disadvantages, by which the battery may be greatly secured from the fire from afloat, without losing very essentially in its own effects.

* The scale to the plate is ineorrectly marked, the figures should be doubled : the 5 feet should be marked 10 , the 10 should be 20 , \&c.
+ Query, 12 -pounder brass guns, medium ; 32-pounder brass howilzers, Dundas.-EDITORS.

30. This may be done by placing the guns at not less than 50 feet above the level of the water (high tides). From that height the shot may be made to strike the water at a distance of 200 yards, and will ricochet * well; at the same time the guns would be but little exposed to the fire from shipping, the loftiest guns on which do not exceed about 24 feet.
31. It has happened, it is said, and perhaps more than once, the shore being very bold, with deep water close to a battery, that its gunners have been driven from their pieces by the fire from a ship's tops.
32. This must have been a very gallant proceeding, but where circumstances admit of such an attempt, and the vessel is observed to be approaching, so as to afford an opportunity for it, a round or two of spherical case directed on the tops, at from 500 to 800 yards' distance, and of grape at from 200 to 400 yards, it is presumed would effectually defeat it.

## Ammunition for Coast Defences.

33. This is chiefly an artillery matter, but it is desirable that officers of engineers should also be able to reason on it.
34. The French regulations, it is believed, give 200 romids per piece for coast batteries of first importance, and 100 rounds for those of least, including shot, shells, and grape.
35. If the pieces are multiplied, so as to have an extra force of them mounted in battery, as suggested in a former paper, vol. i., p. 103, the number of rounds per gun may be reduced.
36. The most destructive fire, and the one of which ressels will naturally have the greatest dread, is that of heavy shells; the large shell guns, therefore, will form a leading armament in coast batteries; ordinary long guns, however (of which the 32 -pounder is perhaps the most efficient), must be employed also, because of their longer accurate ranges, and being less costly in their service.
37. Under many circumstances, red-hot shot may be used to great effect, and therefore the modern moveable shot furnace should be freely provided.
38. The French have rejected the use of red-hot shot from their service, on account of their not being applicable to any sudden call, and that they were never, as they consider, found very effective, while their service is, in their opinion, dangerous, troublesome, and difficult, which caused their artillery usually to have recourse to the cold shot only, even when they had a furnace at hand, and they now think that they have a sufficient substitute in the large shells.
39. We do not agree with them in rejecting the use of red-hot shot, but are still inclined to attach much value to this resource against shipping.
40. Mortars are seldom used, but might be occasionally, to disturb ships that are crowded in distant anchorages, or might even induce a single ship to retire from within their ranges.
41. Rockets, in volleys, may be of great service for close quarters against ships, such as when they attempt to force a narrow entrance, or are very bold in approaching the shore ; also against a number of vessels gathered into a small compass, even at long ranges, as well as to oppose an attempt to force a landing.
[^0]On the Mounting and Covering of Guns for Coast Batteries.
42. The guns in coast batteries may be mounted on the

> Old Traversing Platform,
> Dwarf Traversing Platform,
> Travelling Carriage,
> Garrison Carriage,
and they may be with or without embrasures.
43. It is of consequence not to confound the different circumstances that render each of these the most applicable.
44. The subject chiefly concerns the artillery officers, and therefore very much of what is here submitted must be considered as subject to their superior experience.
45. The high traversing platform, which fires over a 6 -feet parapet, has the advantages of much lateral range or sweep, and of traversing easily. It gives entire cover to all the gunners who are on the terreplein, but it is expensive, occupies a great deal of space in battery, is very cumbrous to store or to move from place to place, presents a large surface to the action of shells and large splinters, and to such a degree to enfilade fire, as to be inapplicable wherever the battery is exposed to it. Thus, in fortresses, a few are occasionally applied to salient angles, to obtain a greater command over the country, but on the distinet understanding that they would be withdrawn from the front of attack as soon as the enemy's batteries were established.
46. They are better adapted to coast batteries, because their advantages are more effective, and their disadvantages less so. Thus, their great lateral range is of peculiar service, while, at the same time, they are seldom, if ever, subject to be enfiladed, and very partially to the effect of vertical shells ; but, again, there is one inconvenience attending their service against shipping in particular, namely, that their firing is not so quick after pointing, nor so well directed by a sight of the object at the time of firing, as to be as well adapted to good practice at a moving object.
47. It has been objected to this argument, that the time occupied in descending and firing is inappreciable, even against a moving object; but though it may be small, it will be variable, and not admit of the most advantageous practice of pointing, and then watching by the eye the most favourable instant for applying the match or pulling the trigger.
48. The dwarf traversing platform has the same facility of traversing with the former, with the same inconveniences of being bulky and expensive, although in a somewhat less degree; but the gunner can see his object when firing.
49. As it is adapted to a lower parapet ( 4 feet 3 inches), the platform is not so well covered, unless protected by merlons, for which this carriage is specially adapted; in that case the gunners, carriages, and guns are well covered from a front fire, and far better from that inclined to the line of parapet; but the merlons reduce the extent of lateral traversing range.
50. The traversing platforms require fewer men to work the guns, than carriages on the ground platforms.
51. Travelling carriages are seldom employed in permanent batteries.

They afford a facility for serving and moving from place to place, but they are expensive (as compared with the garrison carriage), and the carriage and wheels are more exposed than others. They fire over a parapet 3 feet 10 inches high, and would be generally used in embrasures.
52. The garrison carriage is the most simple, cheap, and compact, but its gun fires over an extremely low parapet (only 2 feet 3 inches high), by which much less cover is afforded, especially without embrasures. It is very inconvenient for removal from
place to place, and cannot be transversed quickly for precision, nor so readily as any of the above.
53. The Hon. Captain Fitzmaurice proposed an alteration, by dividing the garrison carriage horizontally, so that the upper part that carried the gun could be traversed by a tangent serew on the lower an extent of about $15^{\circ}$, which seemed to afford much facility for rapid and accurate pointing, but it was not considered worthy of adoption by the Committee of Artillery Officers who examined it.
54. Improvements in the garrison earriages, or rather a substitute for them that should be without their three great defects, would be very desirable, and would seem to be quite practicable, by raising them on front wheels sufficiently to fire over a 4-feet parapet, and substitutiug a block or trail for the hind trucks; in short, to make them assimilate more to the travelling than to the ship carriage, not requiring, however, so high a finish, and the front wheels being only the 4 feet in diameter, to be perfectly covered by the parapet.
55. By this means, the gunners and interior of battery would have much more cover; the guns would be worked easier, though still requiring more men than the traversing platforms, and by a few general limbers they could be conveniently removed from place to place.
56. They would be somewhat more expensive, but far less so than even any kind of traversing platforms, for which they would, in many cases, become sufficient substitutes; nor would the additional cost be unworthily bestowed on their additional advantages.
57. The guns and men on a low barbette battery, when subject to an opposing fire from the same level, or nearly so, are greatly exposed, particularly when the enemy's shot and shells are from a side direction; but they have a greater circle of range than when in embrasures.
58. Those in embrasures afford more shelter, but restrict the lateral range; and the cheeks of the embrasures, besides being difficult to maintain in order, even from the explosion of your own guns, have a tendency to draw the shot by convergence into the battery; and this is more particularly the case with casemated guns, the embrasures of which are arched over.
59. Embrasures, however, are applicable where the line of fire is restricted to a narrow limit, the cover from the merlon being more than equivalent for the disadvantage of the cheeks of the embrasures, particularly if the latter can be given a batter or curve; and the casemated guns may be applied with propriety in positions where the space for the battery is very small, and where, consequently, it is only by different tiers, that the number of pieces can be sufficiently multiplied.
60. Aecording to my view, the ordinary practice is to seek for more front cover in coast batteries than is judicious or necessary, considering that it is always at the sacrifice of some advantage.
61. This has been influenced by theoretical deductions and diagrams, showing the cover necessary to protect the gunners from the course that the enemy's shot may take, rather than from the practicable efficiency of the actual service.
62. In devising protection against batteries on shore, very great consideration must be given to this kind of nice calculation, because of the far greater advantages possessed by the gunners on the land for making accurate practice than they have afloat.
63. The power and the weakness of the fire from shipping might be more duly valued in the construction of the defences.
64. A battery on a level or nearly so with the ship's guns, and especially if the
vessel can approach near it, would be exposed to such an overwhelming mass of point blank fire from its broadsides, as to require the most ample cover, such as can only be afforded by the high traversing platform, and a 6 -feet unbroken parapet.
67. But when the guns in battery are raised so much as 50 * feet or more above the water, the same degree of danger no longer exists, and a dwarf traversing platform, with its 4 feet 2 inches parapet, will be more effective and appropriate.
66. It is not that the enemy's shot may not skim over the crest of the parapet and strike an object between 1 foot 6 inches and 2 feet higher than the parapet (being the height of a man), for some distance in the rear, but the precision required in judging distances regulating the accurate amount of elevation, \&c., may be said to be unattainable afloat, and especially when opposed to other fire; so that, practically, the effective exposure on the battery would be trifling, and the service generally more forwarded by the lesser precautionary provision of the low carriage and parapet, with its advantages in other respects.
67. If the garrison carriage could be adapted as above proposed, by giving it front wheels of 4 feet high and a block trail, so that it might be made to fire over a 4 -feet parapet, the same effect as regards cover would be obtained, and much more simplicity, economy, and general facility in service would be the consequence.
68. In proportion as the distances from the battery are increased will the exposure on its platform be also increased theoretically, but practically, by the greater uncertainty of the fire, it will be reduced to a most remote chance of being productive of evil.

The advantage of having guns in action on a precipice, or on ground so steep as to catch the enemy's shot without their rebounding, even without any front cover, is well known, as there is but one small limit of altitude for the opposing shot to take to attain its object; whereas, when subject to the ricochet, the course that may be effective is greatly prolonged.
69. With reference to this question, the service of steamers against batteries requires especial notice.

It is considered that their power of selecting their own positions and distances, their greater steadiness when lying to, their guns of very heavy calibre on deck, unencumbered by portholes, and with convenient carriages for good practice, added to the degree of skill now given to the naval gunners, will make them much more formidable against batteries than the sailing vessels of the old service; and that, consequently, greater precautions will now be required for the defences on the coast.

Although it would be wrong to despise so powerful an opponent, it is apprehended that effectively the steamers will not be so much to be dreaded as may at first view appear.
70. Two advantages they will decidedly possess : -

1. A superior power of selecting their positions; against which, consequently, the shore batteries must be as much as possible provided.
2. The great rapidity with which they may run over any given distance; thus if the object was to pass a battery, a steamer would be hardly much more than ten minutes exposed to its fire, the best remedy for which would be by constructing the batteries, where practicable, rather in successive distances along the channel to be protected than in mass at one point, so that the vessel as she retires from the fire of one may be caught by that of another.

[^1]71. As regards, however, their direct power of contending with the batteries, it would be small.
72. They can select their distances, it is true, but they have no means of judging them, nor of correcting their practice by observing its effects; in both these particulars the gunners on shore would possess a decided advantage over any kind of ship.
73. Then, like all ships, the steamers are vulnerable everywhere, and, indeed, much more so on account of their machinery, while a very few shots will take any effect on the battery, and any evil from that easy to be repaired.

Their guns are but little raised above the water.
74. But, above all, they will rarely be brought to contend with the batteries.

They will be far too precious to be so risked.
Like the cavalry in an army, they will be carefully reserved for great occasions; like them, they will take outpost and reconnoitring duty; be engaged in maintaining communications and performing rapid detached services; and in influential actions will be freely put forward to aid in striking decisive blows; but, like them, they will be studiously kept from exposure to desultory cannonadings.
75. Viewing the circumstances connected with the service of coast batteries in every light, I apprehend that, excepting in the solitary case of their being liable to be opposed to the broadsides of powerful ships at short ranges and low levels, we should rather in their construction study the means of the greatest possible annoyance to the shipping, than any degree of self-protection that would impede that action.
76. In civil concerns, no prospective advantages will justify a want of precaution to prevent the loss of human life.
77. In war it is very different; success is the primary object to which hundreds and thousands of men's lives are, at the time, necessarily sacrificed,
78. So in engineering and protective works, and in the application of them, we are not solely to consider always what will abstractedly afford the most cover, but what will give most protection consistent with the primary consideration of the purpose for which the work was constructed; thus, by means of the banquette to a parapet, the soldier theoretically may be enabled to retire behind it to load, and mount it again only for the instant necessary to fire, but practically, when the work is stormed, he will never descend, but boldly stand up to the parapet throughout the period of assault, because, although more exposed, there is a much better chance by so doing of beating off his enemy.
79. By the same reasoning, in these coast batteries, if the best cover to be given to the gunners would impede the most efficient service of the guns for opposing their enemy, it should be reduced until not attended with that inconvenience.
80. Where batteries are very much exposed to the most effective fire of ships, the greatest degree of cover must be given to the men and guns, on this very principle, because they would otherwise be silenced, and, consequently, not enabled to give their most efficient service; but when the superior degree of cover would hamper the service of the guns only to save a few casualties, it should be abandoned.
81. In military operations, as said before, the first aim is to obtain success; to save life is a secondary consideration, excepting so far as may not impede the first, when of course it becomes an anxious and imperative duty.
82. We must not be deterred from this kind of reasoning by the outery of its being a barbarous cold-blooded calculation, for war, unfortunately, will admit of no other.

## Iron Gun Carriages.

83. Cast-iron gun carriages were introduced as a measure of economy, on account of the wear and tear of the wooden carriages from decay; on finding, however, by experiment, that they were so brittle as to be completely destroyed on being struck by shot, there has been a great reluctance to use them; it is apprehended, however, that they might be adopted freely for sea batteries, in which service they would not be liable to enfilade, and the carriages little exposed to be struck at all; or perhaps the parts of the carriages most exposed to the direct fire might be of wood.

## Booms.

84. Propositions are frequently made for the application of booms to the protection of narrow entrances to harbours and rivers, but they are subject to so many difficulties and objections, that it is in very rare cases that they can be considered available.
85. The inconveniences attending them are so great, that for very many years we have few, if any, records of their having been employed.
86. Even in the old times they were seldom found effective, but were usually carried away by the first ship that boldly attempted to force them; indeed, when we consider the enormous pressure of heavy ships in motion,-the impression they have been known to make, even on very substantial masonry wharf walls, with only slight way on them, -it is easy to conceive the immense power of strain required to bring them up.
87. If employed, however, at all, they are best placed in a direction not perpendicular, but inclined to the course through the channel, by which the ship would have much less power to force them, while, in case of failing, she would inevitably be glanced off to the shore.
lst. The great labour and expense of their preparation, and to work them, on the chance of a result so precarious as above described.
2nd. The obstacle they present to friendly as well as to the enemy's vessels.
88. Under the head of "Booms," in the Engineer's Aide Memoire, it may be seen how it is attempted, on paper, to remedy these inconveniences, by having a double, or even triple boom; a part across the best channel removable, so as to be opened or closed as required, and other contrivances, so easy to be added by a stroke of the pen, but so difficult in practice.
89. These, like very many other plausible systems that are found in books of Military Engineering, have never been employed, nor probably ever would be, in actual warfare.
90. It is on the whole, therefore, in but few instances that they can be applied, such as under some peculiar circumstance occasionally, for entrances extremely narrow, to protect floating or other bridges liable to injury, or where only to be assailed by boats, \&c.
91. It is considered that a more powerful and less inconvenient substitute might be obtained by floating mines, or catamarans, sustained at the surface of the water so as to be scarcely visible, and prepared for being exploded by galvanic conductors; thus, they might be fired instantaneously from some building on shore, at pleasure, while friendly vessels and the ordinary intercourse might pass them in their full state of preparation, without the slightest danger or impediment.

## On the Manning of Coast Batteries.

92. It is impossible to expect that the extensive defences that could be judiciously applied, and would be even necessary in time of war, could be manned by the regular army and artillery; nor would it be right to lock up in permanent dispersed positions, such numbers of a description of troops that are maintained at a great exvense, and adapted to the most effective manceuvring service.
93. The coast batteries would therefore be manned almost exclusively by local bodies organized for the purpose, who would habitually be engaged in their ordinary pursuits and duties, but always be ready to take their posts in times of need: their service being limited to a few simple operations in one confined position, the instruction necessary to make them very efficient might be readily given to them.
94. In the past French wars, the seafaring population of the coast were embodied into corps of "Sea Fencibles" for this purpose; to these might be added other people of the neighbourhood, and still better, the Coast Guard, who are on the spot, and already under military discipline.
95. The dock-yard men at the great stations also might be made excellent gunners, to aid in the defence of the fortifications immediately connected with their establishments; a more politic arrangement for them, perhaps, than the organization that has been attempted of battalions of infantry.

## Steam Power in Coast Defences.

96. The most important consideration that is now required for coast defences (as well as for almost every other circumstance of war) is how to adapt the growing power of steam, in its various applications, to the best service.
97. Since the great development of railways and steam navigation in modern times, there have been no wars of sufficient magnitude to bring out with effect the manner in which they may be fully made to co-operate in military operations.
98. The whole matter is still new to us, and many a mistake has, it is affirmed, been made, and no doubt will continue to be made, before it is brought to something more or less stationary by the successive improvements and devices that will probably rapidly accompany the first few years of a naval war between any great powers.
99. The effect of the railways will be comparatively simple, as they will only act in the one way of facilitating communication. But steam navigation will not only serve to convey military means, but will take a leading part in the contending operations also.
100. The regular men-of-war and armed steamers will form powerful aids in defence of the coasts, whenever they happen to be present at the point attacked; but it would be far too much to suppose that they could be everywhere, and they may not be available on the precise point required at many a critical moment.
101. Very powerful floating batteries, with auxiliary steam power, have been constructed chiefly for coast defence, which will be most valuable wherever present; but the time and expense required for their establishment, the cost of their service, and the difficulty of manning them in time of war, in addition to the other portions of the fleet, will give them only a partial effect.
102. Efforts have been made (with greater success, it is believed, in France and America than with us) to adapt the construction of packets and mercantile steam vessels to carry guns in case of need, and it is of course always in contemplation, on the breaking out of hostilities, to take up a number of the best of them to be armed and converted into men-of-war; this will add greatly to the power of our
fleets, but it will be at a vast expense; considerable time and means will be required for their conversion. The manning of them will present another great difficulty; they will be taken from their mercantile employment, where they would still be wanted, and, after all, cannot be in sufficient numbers to be everywhere for the protection of the coasts.
103. The desideratum, then, is the best mode of rendering available for defence the different classes of harbour, river, and coasting steamers, and this, it is considered, may be done with considerable effect without removing them from their habitual occupation, except very temporarily, and at the last resource, by arming distinct vessels as gun-boats and floating batteries, great or small, and employing the trading and passage steamers exclusively as a moving power for them in times of need, in rivers, harbours, bays, and estuaries.
104. Any barge, lighter, or coaster of 50 tons and upwards, may be at a moderate expense, and rapidly, armed with one or more heavy guns, and prepared for the accommodation of the men to fight them; and any steamer, however small, may be taken up at an hour's warning, and without any specific preparation or alteration, to tow it.
105. In time of war, every man in the country is prepared to take a part in the defence of the nation, and more readily perhaps of his own locality or immediate neighbourhood, and these steamers, with their crews, might be effectively organized for such services of occasional emergency by a few active naval officers.
106. Vessels so taken up would be greatly deficient in power to perform manœeuvres of any refined character, but may be submitted to an occasional exercise in some of the more ordinary operations required of them, and even if not manned and commanded by sufficiently energetic characters to continue much in action (which, however, very many will be), may be of great service in towing the gun-boats into certain anchoring positions, and removing them occasionally from place to place.
107. By enrolling vessels and men, giving liberal allowances for losses and damage, as well as for pensions in case of casualties, the habitual energies of our countrymen would not be wanting in this service.
108. The multitude of small steamers that are working in all our leading rivers, harbours, and other sites along the coast, added to the previous preparation of gun-boats, whether by construction specifically for the purpose, or by the adaptation of existing vessels, would most powerfully augment the available means of defence for the most important situations.
J. F. B.

## PAPER II.

MEMORANDUM transmitted by Colonel R. Jones, Commanding Royal Engineer, Malta, by desire of the Inspector-General of Fortifications, November, 1849 , on Precautions adoptid in Neiv Bulldings in Sicily, with a View to Neutralize the Effects of Shocks of Earthquakes. Collected from the best information he could obtain from some intelligent and experienced Sicilians then at Malta.

IT is evident, by a minute observation of the destructive effects of earthquakes, that it would be impossible for human skill to raise edifices which could defy the power of similar convulsions; but as in countries subject to these phenomena the severer instances are rare, plans of construction might perhaps be devised more or less able to contend against the ordinary shocks frequently felt in countries situated near the Equator, or in southern latitudes generally. The difficulty, however, of successfully combating even minor effects of earthquake, by any one fixed principle of construction, is apparent when the various motions given to the ground so acted upon are taken into consideration, earthquakes being known to act by

Horizontal or undulatory motion;
Perpendicular, saltatory, or vibratory; Vorticose, or whirling motion.

The securest plan for detached buildings is that they should be of wood, and the several pieces of timber composing the roof and sides so united and firmly connected together as to form one mass, which mass should have no foundation inserted in the ground, but be placed either on a prepared surface of the natural rock, or on a paved space of greater extent than the area of the building, having a gentle inclination from the centre outwards. The height of such a building should never exceed its length or breadth, but should rather be under these dimensions. By these precautions the centre of gravity would always remain within the area of the base. The vibrations of an ordinary shock of earthquake might cause a tremulous motion, but could not destroy or overturn a building so constructed.

Buildings on mountains, hills, or elevated grounds have been found less subject to the influence of ordinary shocks than those situated in valleys or low grounds.

In Messina, Catania, and other towns in Sicily which have repeatedly suffered partial destruction from earthquakes, various means have been adopted in the construction of houses, to mitigate the evil effects to which they are subject, and though no precaution has hitherto been found completely successful against the various and uncertain actions of elementary convulsions, yet certain principles
have been found by experience greatly to qualify the destructive effects of an ordinary shock, which are these:-

To give little elevation to a building.
To build substantial walls, with a batter; and, when practicable, to strengthen the angles by pilasters of pyramidal shape.
Cellars, tanks, and excavations round a building have been found advantageous.
When the best cement has been plentifully used, and blocks of stone carefully laid in a rough state and bonded, and all interstices filled in so as to leave no void in any part, walls have been found to stand like monoliths; while the best constructed walls of squared masonry, in the immediate neighbourhood, have been found to separate and fall.
Stone arches or groined roofs are not to be used in upper floors.
The ends of beams are not inserted into the walls, but are left free to oscillate with the oscillatory motion of the earth; they rest on a projecting ledge of the interior wall, and are supported by strong transverse beams similarly laid, the ends of which rest in the strong angular piers.

In some instances, the heads of beams have been passed completely through the walls, and the latter braced together externally by iron braces; but the openings have been found to weaken the masonry, and the practice has not become general.


## PAPER 111.

Discussional Project for an Enceinte. By Capt. Nelson, R.E.

1. Avowedly or tacitly, all combatants bave but one immediate object- "to smite unsmitten, and destroy unscathed: "-this holds good from the dwarfish Bushman with his tiny bow and poisoned arrow, lurking behind a tree, to the treble lines of Torres Vedras, where armies and mountains gave the scale of operation.
2. In fortification, the engineer's version of the task is-

| To Batter, Enfilade, Bombard, Mine, | without being | Battered. <br> Enfiladed. <br> Bombarded. <br> Under-mined |
| :---: | :---: | :---: |

3. And in course of the solution of this problem, from the earliest days of the preceding modes of attack to the present, a series of designs and diagrams-such as is shown very compendiously in Mandar's work, as far as it goes-has been produced, which would be invaluable as a pattern-book to the manufacturers of carpets and counterpanes; the endless combinations, changes, and re-combinations of a few primary forms, reminding one also strongly of those of the kaleidoscope with a few rings, beads, buttons, bits of coloured glass, \&cc.
4. In fortification, the (approximately) "primary forms," or elements, seem to be the tenaille and redan, the caponnière and bastion, whether in the enceinte or the outwork.

5. No sooner is the "perpendicular defence" of the well-determined tenaille (A) brought forward, than the want of direct fire, the liability to enflade, and the deadness of the re-entering angle in the ditch, oblige the projector "to draw in his horns," and extend laterally into redans and curtains, first, with brisure, B, B, B,then without, $\mathrm{C}, \mathrm{C}, \mathrm{C}$. But, the oblique and imperfect reciprocal support of the flanks and curtains leads to $\mathbf{D}$; the temptation to give, were it only a little flank to the redan being irresistible, "it is very short. and not liable to enfilade;" hence to a certain extent, the "capanati" of Martini and Captain Tylden*, R.E., or caponnière of late days, as the germ of the bastion.
6. But, again, the limited interior space of these caponnièrest, their unsuitability to form capacious retrenchments for the "close defence," drives others to expand this "germ" into the full-blown bastion, with every imaginable proportion between flank and face, according to the value of the engineer for direct or for flanking fire,

[^2]or to his dread of opening the said faces or flanks to enflade; now trusting to outworks, now to defilade in various ways in plan or section for intercepting prolongations, now reckless of that evil, trusting mainly to casemated fires, leaving those of the terreplein to the doubtful protection of traverses; and thus, every diagrammatic contrivance in the way of bastion, from just short of the caponnière (all flank and no face), to just short of the tenaille (all face and no flank), is the labyrinth through which the engineer has hoped to reach the "goal of glory" from the round towers of Nineveh $\ddagger$ to the design of Chasseloup de Laubat, Choumara, \&cc., of the so-called French, or Bastionary School; or to the caponnière and curtain of the so-called Modern or German School-so terrified about enfilade that all the advantages of saliency, and much of those of collateral support, are clipped, cut short, shorn and sacrificed " with all the cruelty of cowardice;" not seeing, perhaps, how nearly related their enceinte is, after all, to that of Vuaban's second and third systems : by and by we shall see their advanced works brought back to the glacis as mere outworks; nor can we promise ourselves that we shall not see them again in the ditch.
7. These remarks might be extended to the innumerable systems of retrenchments, outworks, \&c., in plan; and the same are nearly as applicable to ideas as to sec-tions-now crouching, like Bonsmard, to make his works as cheap as possible, and now heaping Ossa on Pelion, like Choumara in his later and very objectionable system (Figs. 2, 3, Pl, Iv.-Fig. 1, Pl. VII., \&c., 2nd edition); and we shall see everywhere the effects of self-deception in the sacrifice of important points to the especial crotchet of the moment;-a most dangerous remark for one who has himself a "crotchet" to bring forward.
8. Thus there is ever going on the same cycle of endless alternation-a sort of spasmodic expansion and contraction of "Flank," "Face," and "Curtain,"-such as one may observe in the subjects of certain optical toys of Brewster's,-in the transitions and re-transitions from long waists to short waists, and vice versû, in the fashions of the day,-and of late years we still find ourselves, as to fortificational derices, in the last stages of the child's game of "Cat's Cradle"-perpetually producing and reproducing the same forms without hope of relief or release, until some novelty in the weapons used may open a new source of anxiety-a new professional vista-to the enemy, and to the hapless projector*.
9. To add to this confusion, the writer of this paper has thought fit to bring before his brother officers a Project of Enceinte, in-saving his genius-all the spirit of a Montalembert, "et sa manie de stribords." It is more for discussion than anything else, having but little claim to originality, requesting the said brother officers, R.E. or H.E.I.C., to say their say frankly; and in so doing, should the objections raised be not insurmountable, and their suggestions be feasible, we may be able to proceed in the spirit of "hand and glove," not of "gauntlet," to consideration of the best mode of covering the main escarp by the arrangements for the more advanced defences, or such other contrivance as may be forthcoming and available. Bearing in mind, however, the important lesson taught at Ciudad Rodrigo (1812), of what may be done by skill and steady perseverance in the very face of heavy, direct, and vertical fire, untouched by a single enfilading battery-it must not be forgotten in the display of artillery (Table, par. 14), assigned to the tracing proposed, that it is reckoning somewhat without one's host. If these escarps cannot be covered from the enemy's direct batteries, they must fall eventually, if properly attacked, whatever may be their strength of construction.
10. The idea of the trace submitted, originated in a perhaps over-estimation of the enceinte of Vauban's Third System. Not that the tower bastion * alone has any great value ; but that, in combination with Choumara's "monster" traverses, and an extension of the "brisure" principle, we may possibly obtain something valuable.
11. Such as the sketch now offered is, it may be referred to the tenaille, the redan, the caponnière, or the bastion systems, those features being obvious at all points; nay, even to the "circular-are" project, which may be seen in certain French workspossibly Mandar's-where flanks and curtains are comprised in one nearly semicircular curve, so as to obtain concentration on the counter-battery, and avoid enfilade as much as may be; also discernible in the curved flanks of Coehorn and Vauban. If a circle be described from $\mathrm{Z}+100$ yards from C , it will very nearly touch the eight points, $\mathrm{G}, a, c, e, f, h, j, \mathrm{I}$, though quite accidentally so. This accident may perhaps be turned to account by and by, in the arrangement of the outworks.
12. The object of "striking without being struck"-more than can be well helped-is now attempted by-
A. A concentration of fire on the counter-battery.
B. Protection of the ditch, faces, and flanks, by a large amount of flanking and reverse fire, perfectly secure from enfilade and shells, below by casemates, and to a great extent above by shortness of face and defilade in detail, as well as by the huge masses on Choumara's principle, acting either as parados or traverse to each half-front, in gross.
C. Any desirable amount of direct fire, generally perpendicular to the exterior side of the polygon, either from the terreplein, or, if needs be, from casemates below; also by a considerable degree of saliency being given to the tower bastion by the retirement of the curtain, without, it is conceived, any great liability to enfilade.
13. In reference to these three heads, it is premised that the following limits are assumed :-

1st. That G, D, (see Plate, shall not, in the present instance, exceed the pointblank of heavy guns-say 400 yards $\ddagger-$ so that no time may be lost in laying to elevation. This relates chiefly to the terreplein, as it may be advisable to arm some of the casemates with large howitzers, to burst their shells, en forgasse, in the counter-battery; their case-shot, too, must be highly effective in clearing a ditch.
2nd. That the minimum length of curtain shall be such, that round shot fired from a height of 15 feet (i.e. in the casemates of the flank), shall see 4 feet above the bottom of the ditch at D, half way between E and F (see Fig. 2). This renders it doubly safe if case-shot be used, even though the range is too short for it to open with full effect.
3rd. The height of the escarp to be 35 feet, except, perhaps, in the tower bastion, where 40 feet may be allowed for the sake of command of the rest of the work. This, it is presumed, is tolerably secure from escalade.
N.B.-The distance of 45 feet between the lines $1,2,3$, \&.c., will allow amply for 2 guns in casemates, and in the like approximate way during the general study of the subject; 90 feet is allowed for the "facets" $b, f, f g$, sce., should casemated direct fire to the front be desirable.
14. Reverting then to the heads $\mathrm{A}, \mathrm{B}, \mathrm{C}-$
A. - Concentration of Fire upon the Counter-Battery.
relative amounts of fire from one flank of the under mentioned.

| Syetem. | Effective Lengths *. |  |  |  | Remarks, |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{aligned} & \text { 立 } \\ & \text { in } \end{aligned}$ | 㝘 |  |  |
| 1. Cormantaingne | Feet. <br> 121 | $\begin{aligned} & \text { Feet. } \\ & 118 \end{aligned}$ | $\begin{gathered} \text { Feet. } \\ 5 \\ 5 \end{gathered}$ | $\begin{array}{\|c\|} \hline \text { Feet. } \\ 6 \\ 5 \\ \hline \end{array}$ | Terreplein. <br> Flank, if casemated, to place the system |
|  |  |  | 10 | 11 | on a par with the rest, for comparison; suppose with howitzers, so as to clear |
| 2. Bousmard ..... | 173 | 162 | 8 | 7 | Terreplein. |
|  |  |  | 4 | 4 | Casemates in tenaille. |
|  |  |  | 12 | 11 |  |
| 3. Choumara's earlier system. |  |  | . | 8 | Terreplein of flank and tenaille. This system hardly admits of being dealt |
|  | 141 | 141 | 6 | 6 | Terreplein. |
| 4. Chass, de Laubat |  |  | 3 | 3 | Casemated tenaille. |
|  |  |  | 9 | 9 |  |
| 5. System proposedt | 276 | 252 | 14 | $11$ |  |
|  |  |  | 27 | 24 |  |

15. The counter-battery for a 30 -yard ditch and 10 -yard covert-way being, in the octagon, at most 7 pieces, will be here opposed by what may remain at that period of the siege of the 27 guns-say 4 on the terreplein, and 10 in the casemates, total 14 , or double its own strength, to say nothing of the advantage of calibre in both guns and howitzers, which a fortress ought to possess over the besieging train, and the possibility of (practically) eliminating the very ground on which a counter-battery must stand by pre-occupation, \&c.

> B.-Protection of Ditch, Faces, and Flanks of the Enceinte.
16. The whole space in the ditch opposite the curtain, as well as the salient of each tower bastion (or bastion in cases $1,2,3,4$ ), receives the cross-fire of the two collateral half-fronts. In case 5 , it will be $2 \times 24=48$ guns, \&c., if with earth para-

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pets; or $2 \times 27=54$, if with masonry parapets; or more than double the strongest, and nearly treble the weakest, armament brought into comparison therewith in the preceding table.
17. The guns of the terreplein, at $6 \frac{1}{2}^{\circ}$ depression, strike the 4 -feet level above the bottom of the ditch at 92 yards (see Fig. 2), and those of the casemates at 30 yards. The numerous re-entering angles, which would be dead in the tenaille system, are here (as in the angle of the flank of all bastions) seen into by at least the short opposing flank of 3 guns. There is, however, but little of the whole escarp seen by less than 6 guns, and usually more, independently of the protection given by the flanks $\mathbf{E}, e, \mathbf{F}, f$, sweeping the front generally.
18. In the present instance, the height of the "monster" traverse is assumed* on that given by Choumara for the masses at his bastion salients, i. e., about 12 feet above the crest of the parapet at that point. These traverses will of course be made available for casemated mortar batteries $\dagger$, magazines, stores, \&z., or even barracks. In the tower bastion they will be supported on arches across the hollow interior. The communication between the tower and the place is, for obvious reasons, maintained only by a foot-bridge at H . The interior end of the traverse thus cut off, gives a loopholed musquetry fire, rasant, taking the terreplein in flank and reverse. See Fig. 4.

## C.-Direct Fire.

19. This would naturally refer mainly to the outworks. Until these are arranged, it would be idle to speculate as to the quantity, quality, or position of the artillery, observing, once for all, that the number of embrasures may far exceed even that of the guns, \&c., these last being moved as required.
20. Should masonry parapets be preferred, the expense of the work, as to length of casemate, will be much reduced, as shown in the tower bastion at 39 feet instead of 55 feet. As before shown, also, masonry admits of a much larger armament.
21. Should musketry fire be desired for the ditch, the points $\mathrm{G} e$ and $\mathrm{I} f$ being joined by a half-sunken gallery, not high enough to interfere with the casemates, would give a considerable quantity, the gallery itself being a serious impediment to surprise by escalade. The tracing would then become purely bastionary, and all my "crotehets" sink into sheer retrenchments.

## R. J. NELSON,

> Capt. R. E.

Nassau, 23rd Feb., 1850.
N.B.-It is requested that, with reserve and exception of the editorial privilege, all comments may bear the name of their writers; and it is recommended, at least to my juniors, previous to entering on this and like subjects, to prepare a syllabus of the peculiar merits and defects of each of the more modern systems, say from Coehorn, inclusive-a considerable task; but what is "a difficulty?"-something TO BE surmounted.
R. J. N.

[^4]
## NOTES TO THE PRECEDING.

22. No. 1 (p. 14). The caponnière (or tower) has, however, peculiar advantages, whatever may be its defects.
23. If in permanent fortification, the defence, to a certain extent, may become effective at a far earlier period during the construction of the work, than in the bastionary systems, inasmuch as the caponuières themselves, if finished first, and their lines of fire right and left kept tolerably clear, sketch out as it were the general tracing whilst the remainder of the work is going on. Not so with bastions; no space is in anywise inclosed until the enceinte is complete; and "nothing is stronger than its weakest point," whether we speak of a fortress or a chain-cable.

N. B. - If liable to enfilade from field-guns, $a, b, c, d$ can be covered.
24. In field fortification, if, where there is no ditch, or at most a shallow one, the caponniéres are on the salients as long stockade tambours, one-half of the fire intended for flanking defence can be concentrated on any front, by the parties taking two or three steps, so as to cross the caponniére and look on another front.
Thus, if A be a field-work for 200 men, of whom 100 are told off for flanking fires; if each of $a . b . c . d$ be made long enough for 25 muskets on each side, the fire of 50 men can be changed and crossed in a few seconds from any one front of attack to any other, by facing the party about and changing sides of the caponniére. Here, also, these tambours are virtually bastions, without the loss of collateral support, occasioned by placing them on the centres of the faces, as is necessarily done when they defend ditches only, to prevent their firing upon one another.
25. No. 2 (p. 14). Dr. Layard's recent and most remarkable discoveries at Nineveh, give evidence of how little advance the art of war had made in many respects, until the introduction of gunpowder, since the days which Xenophon in his retreat mentioned as long past and obscure matters of history. In the plates of this work we have the tower, curtain and diteh; the sword, the spear, the javelin, the bow and arrow, at least two varieties of the battering-ram and tortoise, the escalade, and rudiment of the pontoon. Let any one compare Lieut.-Col. Jebb's "hieroglyphic" plate of the Attack on Dendermonde, with the representations of an escalade by Dr. Layard, and he will see how nearly matters remained in statu quo "until some novelty in the weapons used opened a new source of anxiety, a new professional vista to the enemy and to the hapless projector."
26. No. 3 (p. 15). The tower bastion seems referable to the objectionable system of "many keeps," and very small ones too, necessarily producing the feebleness of
dispersion at the very moment when the strength of concentration is most needed. A botanist would call this the "polychotomous" system.
27. But for the difficulty of covering the enceinte, it is difficult to understand why even the bastionary system is so generally fettered with GD (Figs. 1 and 3 of the present design), averaging about 400 yards; can no mode of preserving the body of the place to the last be devised, without being cramped by single central ravelins or like works, so as to admit of reducing the expense of fortifications by placing the bastion, tower, or caponnière at good artillery ranges apart, without even the limit above assumed of "point-blank?" Vauban's 180 toises, or about 384 yards, gives in the heptagon (Bousmard, Pl. 21.), about 346 yards for GD. Some artillerists will think this a better point-blank than 400 , but assuming 400 or more, we have a larger amount of blank fire; besides, this point-blank principle (possibly that of Vauban) is not indispensable. Were it necessary to quote precedent, I think I remember much longer lines on the second enceinte of Coblentz.
28. No. 4 (p. 16). To assist in the consideration of this subject, the following table is subjoined; the dimensions given are sufficiently accurate for the purpose :-

|  |  | AB |  | GD | Coehorn finally reduces his dimen- |
| :---: | :---: | :---: | :---: | :---: | :---: |
| *Coehorn's | 1st system | 495 |  | 495 |  |
|  | 2 nd | 400 |  | 555 | sions, if his three systems are to be |
|  | 3 rd | 320 |  | 490 | considered as progressive. |
| *Vauban's | 1st | 384 | (180 toises) | 346 |  |
|  | 2nd | 352 |  | 303 | mensions. |
|  | 3 rd | 395 |  | 335 |  |
| *Cormontaingne |  | 384 |  | 316 | The systems marked * are from |
| *Bousmard |  | 378 |  | 314 | Bousmard's edition of 1814; the |
| Carnot's lst system |  | 550 |  | 523 | rest are from their respective authors. |
| Chp. de Laubat |  | 418 |  | 316 |  |
| Choumara (1st edit.) |  | 484 |  | 394 | he |
| System proposed |  | 400 |  | 400 | the counter-battery on the glac |
| Average of all but $\}$ the last |  | 415 |  | 399 | firing over any counterguards other work interposed. |

If AB or GD be 1000 yards, then the amount of fire will be 50 guns, \&c., instead of the 24 with earthen parapets (see table, par. 20 ); and 62 guns \&c., instead of 27 , with masonry parapets. Beyond this limit, the ranges would probably be too uncertain, or require too much time in nice adjustment of the artillery.
29. No. 5 (p. 18). Perhaps the simplest conception of a casemated mortar battery is, that of a bomb-proof piazza, groined on massive pillars; such, on the whole, are those in Fort Alexander, Coblentz. This opportunity is taken of recommending Lieut. Col. Humfrey's fragmentary work on the fortifications at that place, the chief value of which lies in the plates; the text, perhaps, owes its present unsatisfactory character to the original design of the book (such at least as the title would imply) never having been carried out. Unfortunately for the corps, there was no vacancy when this officer was gazetted to the artillery.
30. It is conceived that the three mortars in such casemates at the salient of the tower bastion will be more than equivalent for the 32 -pounder on traversing platform, which would have otherwise occupied that spot during the distant defence.

## PAPER IV.

## NOTE on the Equilibrium of Roors. By Lieut. St. John, R E.

In the year 1687, Lami published, in a treatise entitled "Nouvelle manière de demontrer les principaux Theorèmes des élémens de Mécaniques," a theorem, in which it is asserted, that if three forces are in equilibrium, or if $\mathrm{P}, \mathrm{Q}, \mathrm{R}$, are three forces, and keep a particle at rest, then

$$
P: Q: R:: \sin (Q, R): \sin (P, R): \sin (P, Q) ;
$$

where $(\mathrm{Q}, \mathrm{R}),(\mathrm{P}, \mathrm{R})$, and $(\mathrm{P}, \mathrm{Q})$ denote the angles between the directions of Q and $R, P$ and $R, P$ and $Q$ respectively; or, in other words, if three forces act at a point, and are in equilibrium, the magnitude of each force can be represented by the sine of the angle contained between the other two. This elegant and useful theorem is demonstrated by Poisson in his "Traité de Mécanique," vol. i., pp. 52, 53.

We now proceed to show how Lami's theorem may be applied to determine the conditions of equilibrium of any number of beams forming a roof in a vertical plane, and symmetrically arranged with respect to a vertical line drawn through the highest point, and having weights, arising either from lateral beams or otherwise, acting on the ridge and shoulders.
Let ABCD * .... be one-half of a roof in equilibrium, and symmetrically arranged with respect to the vertical line AK passing through the highest point A.


W
Let the length of the beams A B, B C, C D $\ldots$, be represented by $b, b_{1}, b_{2}, b_{3} \ldots$. The angles which these beams make with the horizon by $\alpha, \alpha_{1}, \alpha_{v}, \alpha_{3} \ldots$
The weights of the several beams by $\mathrm{W}, \mathrm{W}_{1}, \mathrm{~W}_{2}, \mathrm{~W}_{3} \ldots$
The weights on the ridge and shoulders by $A, A_{1}, A_{2}, A_{3} \ldots$ and
H , the horizontal thrust, which is the same throughout the roof, or an equilibrium could not exist.
The several beams being uniform, their weights, $\mathrm{W}, \mathrm{W}_{1}, \mathrm{~W}, \mathrm{~W}_{3} \ldots$ may be taken as weights applied at the middle points of the several beams, and therefore the
vertical pressure arising from the beam AB may be divided into two equal vertical pressures collected at the extremities $\mathrm{A}, \mathrm{B}$, and hence the vertical pressure at A , arising from the beam AB , is equal to $\frac{1}{2} \mathrm{~W}$. For the same reason, the vertical pres. sure at $A$, arising from the upper beam $A B_{1}$ on the opposite side of the roof, is also equal to $\frac{1}{2} \mathrm{~W}$., therefore the whole vertical pressure at A is equal to $\mathrm{A}+\frac{1}{2} \mathrm{~W}+\frac{1}{2} \mathrm{~W}$ $=\mathrm{A}+\mathrm{W}$.
Now if P be the pressure in the direction B A, then the horizontal resolvent is $\mathrm{P} \cos \alpha$, which being equated equal to H gives $\mathrm{P} \cos \alpha=\mathrm{H}$, or $\mathrm{P}=\mathrm{H} \sec \alpha$ the pressure at $A$ in the direction $B A$, consequently the three pressures at $A$ are $H$ sec $\alpha$ in the direction $\mathrm{BA}, \mathrm{H} \sec \alpha$ in the direction $\mathrm{B}_{1} \mathrm{~A}$, and $\mathrm{A}+\mathrm{W}$ in the direction of gravity.

Hence, by Lami's theorem,
or,

$$
\mathrm{A}+\mathrm{W}: \mathrm{H} \sec \alpha:: \sin (\pi-2 a): \sin \left(\frac{1}{2} \pi+a\right),
$$

$$
\frac{\mathrm{A}+\mathrm{W}}{\mathrm{H} \sec \alpha}=\frac{\sin (\pi-2 \alpha)^{*}}{\sin \left(\frac{1}{2} \pi+\alpha\right)^{*}}=\frac{\sin 2 \alpha}{\cos \alpha}=\frac{2 \sin \alpha \cdot \cos \alpha}{\cos \alpha}=2 \sin \alpha ;
$$

therefore,

$$
\frac{A+W}{2 H}=\sin \alpha \cdot \sec \alpha=\tan \alpha
$$

We have, therefore,

$$
\begin{equation*}
\tan \alpha=\frac{\mathrm{A}+\mathrm{W}}{2 \mathrm{H}} \tag{1}
\end{equation*}
$$

Again, at the point B , the three pressures are $\mathrm{H} \sec \alpha$ in the direction $\mathrm{AB}, \mathrm{H} \sec \alpha_{1}$ in the direction CB , and $\mathrm{A}_{1}+\frac{1}{2}\left(\mathrm{~W}+\mathrm{W}_{1}\right)$ in a vertical direction. Hence, by Lami's theorem,

$$
\begin{aligned}
& \frac{A_{1}+\frac{1}{2}\left(W+W_{1}\right)}{H \cdot \sec \alpha_{2}}=\frac{\sin \left\{\pi-\left(\alpha_{1}-\alpha\right)\right\}^{*}}{\sin \left(\frac{1}{2} \pi-\alpha\right)^{*}} \\
& =\frac{\sin (\alpha-\alpha)}{\cos \alpha}=\sin \alpha_{1}-\cos \alpha_{1} \cdot \tan \alpha
\end{aligned}
$$

$$
\begin{equation*}
\text { or, } \frac{A_{1}+\frac{1}{2}\left(W+W_{1}\right)}{H}=\tan \alpha_{1}-\tan \alpha \text {. } \tag{2}
\end{equation*}
$$

Adding equations (1) and (2) together, we obtain

$$
\begin{equation*}
\frac{A+2\left(A_{1}+W\right)+W_{1}}{2 H}=\tan \alpha_{1} \tag{3}
\end{equation*}
$$

Similarly, for the point C, we find

$$
\frac{2 \mathrm{~A}_{2}+\left(\mathrm{W}_{1}+\mathrm{W}_{2}\right)}{2 \mathrm{H}}=\tan \alpha_{2}-\tan \alpha_{1},
$$

which being added to equation (3) gives

$$
\begin{equation*}
\frac{A+2\left(A_{1}+A_{2}+W+W_{1}\right)+W_{2}}{2 H}=\tan \sigma_{2} . \tag{4}
\end{equation*}
$$

The same principle is applicable throughout the entire roof; we have, therefore, the following equations:-

$$
\left.\begin{array}{l}
\tan \alpha=\frac{A+W}{2 H} \\
\tan \alpha_{1}=\frac{A+2\left(A_{1}+W\right)+W_{1}}{2 H}  \tag{5}\\
\tan \alpha_{2}=\frac{A+2\left(A_{1}+A_{2}+W+W_{1}\right)+W_{2}}{2 H}
\end{array}\right\}
$$

If s represent DK , the half span of the roof, and $h$ equal the height, AK , then from the geometry of the figure we obtain

$$
\begin{align*}
& b \cdot \cos \alpha+b_{1} \cdot \cos \alpha_{1}+b_{2} \cdot \cos \alpha_{2}+\ldots \ldots=s  \tag{6}\\
& b \cdot \sin \alpha+b_{1} \cdot \sin \alpha_{1}+b_{2} \cdot \sin \alpha_{2}+\ldots \ldots=h \tag{7}
\end{align*}
$$

Equations (5), (6), (7) are the equations of equilibrium: they are somewhat remarkable, especially (5); by a careful inspection it may be observed that they successively follow a regular law, so that having obtained $\tan \alpha, \tan \alpha_{1}$, and $\tan \alpha_{2}$; $\tan \alpha_{3}, \tan \alpha_{4}$. . . . can be written down without the necessity of investigation.

A knowledge of the first principles of plane trigonometry is necessary in order to fully understand how the several angles marked * have been reduced to their simplest forms.

The Greek letter $\pi$ represents, as usual, $180^{\circ}$, so that $\sin (\pi-2 \alpha)=$ $\sin \left(180^{\circ}-2 \alpha\right)=\sin 180^{\circ} \cdot \cos 2 \alpha-\cos 180^{\circ} \cdot \sin 2 \alpha=0 \cdot \cos 2 \alpha-(-1) \cdot \sin 2 \alpha$ $=\sin 2 \alpha$.

Similarly, it is shown that

$$
\begin{aligned}
& \sin \left(\frac{1}{2} \pi+\alpha\right)=\sin (90+\alpha)=\cos \alpha, \\
& \sin \left\{\pi-\left(\alpha_{1}-\alpha\right)\right\}=\sin \left\{180_{1}-\left(\alpha_{1}-\alpha\right)\right\}=\sin \left(\alpha_{2}-\alpha\right), \\
& \sin \left(\frac{1}{2} \pi-\alpha\right)=\sin (90-\alpha)=\cos \alpha .
\end{aligned}
$$

In the simple isosceles truss roof,

$$
\mathrm{H}=\frac{\mathrm{A}+\mathrm{W}}{2 \tan \alpha}
$$

This measures the horizontal thrust of the roofing against the supporting wall, supposing the tie-beams to give way; and from the above equation we learn that this will be less the larger $\alpha$ is, or the steeper the roof is, the ather quantities remaining the same; also, the nearer the roof approaches to a flat one, the greater will be the horizontal thrust, and when the roof actually becomes flat, this thrust will be a maximum.

From equation (5) we learn that the beams must be less and less inclined to the horizon as we ascend, since $\tan \alpha_{2}$ is greater than $\tan \alpha_{1}$, and $\tan \alpha_{1}$ greater than $\tan \alpha$; and, also, that every one of the angles $\alpha_{0}, \alpha_{1}, \alpha_{2}, \alpha_{3} \ldots$ is greater, or every one less than $90^{\circ}$; and the equation (6) shows that they must be all less than $90^{\circ}$, otherwise we should have $s=w$, a sum of negative quantities, which would be absurd.

## S. A. St. JOHN,

Lieut. R. E.

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## PAPER V.

Some REMARKS explanatory of a Plan and Sections of the Sikh Intrbnchments at Sobraon. By Brevet-Major W. E. Baker, Bengal Engineers.

Or all the enemies whom we have encountered in India, the Sikhs have shown the greatest aptitude in the construction of field-works. Possessed of a powerful artillery, they have placed their chief dependance on that arm, and have laboured to give it greater effect by protecting their guns and gunners with batteries and intrenchments. Undeterred by examples of caste, all hands join in the work; and the celerity with which they occasionally throw up their intrenchments is very remarkable.

The works at Sobraon were not perhaps the strongest constructed by the Sikhs, nor are they the latest with which we have had to do; but they were formed, as it were, under our own eyes-were put to the test of an attack by our troops-were carefully examined after they had been evacuated by the enemy, and it is therefore supposed that a brief notice of their form and construction may not be without interest.

It would be foreign to the purpose of the present paper to enter into the history of the first Sikh war (of 1845-46), which has already formed the subject of an article in Vol. X. of the Professional Papers of the Royal Engineers, but it is necessary to allude to such of the circumstances of that campaign as conduced to give to the intrenchments at Sobraon the form and development in which we found them in the beginning of February, 1846.

After the Sikh army had been defeated at Ferozshah, they retired across the Sutlej with such of their guns and camp equipage as they could remove. The British forces, however, having been summoned hastily to repel an unlooked-for invasion, were not in a condition to follow up their advantage; and it was determined by their leaders to await the arrival of reinforcements of men, heavy artillery, and military stores, before crossing the river, and carrying the war into the enemy's country.

This forced inaction of the British army not only arrested the flight of the Sikhs, but encouraged them to resume the aggressive ; and about the beginning of January, 1846, they commenced the construction of a bridge of boats, near the village of Sobraon, covering it by a small tête-de-pont. The position of the bridge was well chosen, at a slight bend of the river, and at a point where the high land approached the right bank, and completely commanded the low sandy tract over which the bridge must necessarily be approached from the British side. The early establishment of heavy batteries on the elevated ground, proved that the Sikhs had at that time understood and appreciated the strong point of their position, though they subsequently transferred most of their guns from these batteries to their exterior line of intrenchment.

The commencement of the Sikh bridge was observed by the British leader, who, however, did not think proper to prevent its completion, but contented himself with moving his troops into the position shown in Plate 4, where they were ready to repel the enemy should they attempt to penetrate in force into our territory. The Sikhs availed themselves of the opportunity thus afforded them to strengthen their position, and threw up the line marked in Plate 1, as the "First Interior Line," whose trace, like that of the other lines of intrenchment, appears not to have been regulated by

any scientific principle, but to have followed the banks of one or other of the dry channels which intersect the lower levels of the Sutlej valley. In this "First Interior Line," which was thrown up in one night, probably in anticipation of an attack on the bridge head, there were no batteries.

They next proceeded to the construction of the "Second and Third Interior Lines," which they armed with several batteries ; and finding themselves still unmolested, they undertook, and found time to complete, the "Exterior Line," embracing, with the river, an area of about one square mile, of a stronger section than the rest, and fortified with 27 batteries, many of which were closed to the rear, so as to form little redoubts, and projected sufficiently to give a considerable amount of flanking defence along the front of the exterior line. To arm their new batteries, they withdrew their guns from the interior defences, and in a great measure, also, from their positions on the right bank of the river. It might; by some be supposed, that the interior lines of entrenchment were formed in subordination to the main line, and intended to enable the Sikhs to hold their position, or secure their retreat, after the outer defences should have been carried. But though these works might doubtless have been used for that purpose, and though such an object might have entered into their calculations, yet there is reason to believe that each line, as it was formed, was intended to be final, and to supersede those in its rear. The bateries in the interior lines were found in all cases disarmed, and in many dismantled.

The position thus fortified by the Sikhs was a very strong one for defence, but afforded few facilities for retreat. Their bridge, formed of flat shallow boats, was rickety, and, in fact, broke down as soon as a crowd of men began to push over it in disorder. The ford, by which the remnant of the Sikh army eventually escaped, was at the best an indifferent one. It crossed the river in a winding course, over sandbanks liable to shift when disturbed by the feet of many passengers, the depth of water being already so great, that even a slight rise in the level of the river would greatly increase the difficulties of the passage. Powerful batteries on the high bank, rising immediately from the river, might indeed have been very effectual in covering a retreat, or checking the pursuit of an enemy; and such had been formed, but, as before stated, they were in a great measure disarmed previous to the attack on the 10th February.
The period of inaction which circumstances had rendered imperative on the British army, was, under Providence, the means of bringing the campaign to a conclusion more quickly than would probably have occurred, had it been possible to adopt the more obvious plan of following the Sikhs across the Sutlej after the battle of Ferozshah. They were thus induced to place themselves in a position where indeed they could not be attacked without considerable loss, but whence retreat was difficult, and where defeat was therefore ruin. So complete was the overthrow of the Sikh forces at Sobraon, and so great their loss in men and guns, that their army may be said to have been, for the time, annihilated; and the few leaders that remained with any semblance of followers, were only anxious to secure better terms for themselves, by an early surrender.
In referring the reader to Plates 1 and 2 for the trace and profiles of the works, I would offer a few remarks under these heads respectively.

It has been already observed, that the trace of the Sikh lines followed the banks of dry channels which abounded in front of the bridge of boats, but that the exterior line possessed an imperfect flanking defence from several salient batteries. The most remarkable of these were, Nos. 5, 6, 8, and 11, of which the last two had embrasures in their flank, so as to rake the trenches right and left. The two Zumboor batteries, armed with swivel guns dismounted from camels, whose pack-

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saddles were piled up like sand-bags, on the parapet, were particularly adapted for flanking defence. Being closed to the rear, they enabled the enemy to maintain a destructive fire upon our troops, not only during the advance, but after we had gained an entrance into the entrenchment. It will be observed, that while the front and left flanks of the position were protected by double and triple lines of trench, the extreme right flank was comparatively open, being covered merely by two detached portions of single trench. This omission was attributed by us at the time to the reliance of the Sikhs on their batteries on the right bank, but it was more probably to be accounted for by the nature of the soil near the river, which, having been lately covered with water, was wet and swampy, in many places a mere quicksand, almost impassable for troops.
The profiles of the Sikh entrenchments were generally imperfect, and calculated in many places to afford as much advantage to the attacking as to the defending troops, after the former had gained the foot of the outer trench. The parapets were deficient in thickness, and in height nowhere exceeded $6 \frac{1}{2}$ feet, but were more generally from 4 to 5 feet high, and without banquettes. The earth was obtained from shallow trenches excavated either in front or rear, or both. The slopes were made as steep as the nature of the soil would permit; they were in some instances faced with sods, but near the river, where the soil was muddy, they were much inclined, presented little obstruction to the advance of infantry, and were not insurmountable even by cavalry. Almost throughout the circuit of the outer works, there were two or more parallel lines of parapet, with a narrow interval between, the interior having little or no command over the exterior. A reference to the sheet of sections, Plate B., will show that the profiles were strongest on the south and south-west faces, which were attacked respectively by Gilbert's and Smith's divisions.
The batteries had apparently been the principal object of attention with the Sikhs, and evidenced more pains and labour than had been bestowed on any other of their works. The parapets, however, which nowhere exceeded 10 feet in thickness, were insufficient to withstand our artillery, while the frequent omission of epaulements exposed their guns to an enfilade fire, and gave us a great advantage in the cannonade which preceded the attack. The interior slopes of the batteries and the cheeks of the embrasures were all reverted, some with fascines made and picketed similar to those in use with the British army; others, as in batteries Nos. 5 and 6, Plate 3, with straight round piles 8 to 10 inches diameter driven close together, with a batter corresponding to the interior slope; others with 4 to 5 inch planks supported by posts, as in battery No. 19, Plate 3, or driven close together like sheet piling, as in battery No. 22, in the same plate. In nearly all the batteries great pains were bestowed in protecting the gunners, by blocking up with baulks as much as possible the gorge of the embrasures. This arrangement is shown in Plate 3; it must have considerably limited the lateral play of the guns. It might have been expected that so much wood-work would have been liable to ignition during the maintenance of a heavy fire from the batteries; but whatever precaution the Sikhs may have employed to guard against accidents from this source, appear to have been successful, for in one instance only was the timber revetment observed to be charred.
The Sikhs appear not to have been in the habit of using covered powder magazines, and were, therefore, liable to frequent explosion of their ammunition, not only from the effect of our shot and shells, but from accidents in their own camp. The occurrence of such explosions, at Ferozshah and afterwards at Sobraon, gave rise to a report frequently repeated, but quite groundless, that the Sikh entrenchments
were trained. Their imperfect arrangements for protecting their ammumition will be understood by a reference to Plate 3, where, in rear of Nos. 5 and 6 batteries, are shown two detached pieces of trench, M M, for the reception of tumbrils, and a larger excavation marked N , of which the interior slope was reveted with fascines and which was used as an open magazine. The recess, O , was deeper than the rest, and had perpendicular sides, but was uncovered.
There is some doubt as to the intended purpose of two works in the second interior line, one of which is shown in section, in Plate 2, "profile on Q." They have a good deal the appearance of mortar batteries, but were not used as such; and it is supposed from their elevation, that they were either look-out posts, or raised platforms for the assembly of the military and civil magnates of the Sikh army. Beyond the exterior line of works were several holes and detached portions of trench, affording cover to musketeers or matchlock men, in a stooping or sitting posture. These were occupied chiefly by Akalis, a kind of fanatics, who kept up a sharp fire upon our troops as they advanced, and being unable to retire were eventually bayoneted at their posts.

After it had been determined to attack the Sikh position, the assault was entrusted to General Sir R. Dick's division, who were to be placed as near the enemy's works as safety would permit, during the cannonade with which the day's operations were to commence. The duty of so placing the troops, and, finally, of conducting them to the assault, was confided to the writer of these remarks, who, after a careful reconnoissance, stationed the attacking brigades in the two dry channels shown in Plate D, which were of sufficient depth to afford them complete protection from the enemy's shot. When the signal for attack was given, the leading brigade was directed against the portion of the line embraced between two deserted intercourses near Nos. 1 and 2 batteries, as being the most eligible point of attack; our troops met with a spirited resistance, but soon gained possession of the works. The subsequent events of the day, and the final victory, have been already described in a former volume of this publication.

The plan of the battle, in Plate 4, differs in some important respects from that formerly published, and which, having been prepared in haste the second day after the action, contained some inaccuracies which have now been corrected.

## PAPER VI.

Bribf Account of some of the Survey Operations undertaken at the Cape of Good Hope for the verification of the labours of Lacaille, and some Notice of the Country, by Mr. John Hemming, formerly Sergeant of the Royal Sappers and Miners, with Prefatory Remarks and Notes, by Lieut.-Colonel Portlock, R.E.

THE writer of the brief narrative, which I now submit to my brother officers, was trained in that excellent practical school, the Ordnance Survey. At this moment, when a strong impression exists on the minds of many able men, that the men of the Corps of Sappers and Miners might be advantageously employed as foremen of works, so
as to earry military organization into that branch of the engineer department which has hitherto possessed a civil character, it is desirable that the example afforded by the survey should not be overlooked, and the means which have led to its success not be misunderstood. If the non-commissioned officers and privates of the Sappers have on the survey been taught to conduct successfully the difficult operations of surveying, and to replace the officer even in the most refined astronomical observations, it is because the leading executive officers, such as Captain Yolland, have understood fully the works they were directing. In like manner, if the Sappers are to be rendered efficient as foremen, and probably as clerks, of works, they must be direeted by officers who are themselves efficient engineers. If we wish successfully to develop and apply the energies and abilities of our men, we must begin by developing, applying, and rewarding the engineering abilities of our officers. The true meaning of the designation "Royal Engineer," should no longer be lost sight of, and every officer should feel that he is bound to acquire and maintain a scientific as well as a military character. The great work of the Ordnance Survey of Ireland was commenced in the year 1824, for the purpose of doing away those irregularities of assessment for local taxation which were the results of change in the value of territorial subdivisions. It was confided to the Ordnance, and that Board ought to appreciate the honour which such a selection conferred upon it, and respect the talents of its officers which had acquired it. I was then in the confidence of Major (now General) Colby, and was therefore cognizant of the anxious thought and patient investigation which he devoted to the first establishment of a fitting system for so great a work. He followed the example of Sir William Petty, in adopting a military foundation for the work; but as it was necessary to secure in its performance a degree of excellence proportionate to the advancement of geodetic science, a code of instructions was required, and I can testify to the hours of laborious reflection which were bestowed upon its compilation. I will not here dwell further on this part of the subject, but proceed to the triangulation, which was the field of Sergeant Hemming's employment. It commenced on the Divis Mountain, near Belfast, in 1825, and on this occasion General Colby (I shall henceforth always call him by his present rank) thought it desirable to have with him a large force both of Officers of Engineers and soldiers of the Sappers and Miners, considering the camp during this first season as a school of instruction. Drummond's Light was successfully used on this occasion as a signal for observation, on the summit of Slieve Snaght in Innishowen, being managed amidst the snows and storms of that mountain-top by its able inventor. The next season commenced on Slieve Donard, near Newcastle, county of Down. The party was still strong, though it had been found necessary to employ gunners of the Royal Artillery, as the Sappers were necessarily required for the detailed survey. Much very severe weather was here experienced, and on one tempestuous night all the marquees and tents were blown down, with one exception, the marquee of General Colby, which was kept up by bestowing upon it undivided attention. Towards the end of the season the party was reduced, and whilst I remained alone as an observer on the summit of Slieve Donard, Lieutenant Larcom, now Captain Larcom, was in like manner alone, watching a Heliostat (Drummond's) on Moel Rhyddlad in the island of Anglesey. Late in November, amidst heavy snow, our party at length descended Slieve Donard, and the event was rendered painfully memorable by the death of two servants of neighbouring gentlemen, who perished by cold, having lost their way in endeavouring to return from the camp. From this time I had the personal charge of the great triangulation, and Sergeant Hemming, who commenced his career as a bombardier, may be considered as my companion in the field. He did not, however, com-
mand the detachment of Artillery, that charge having been confided to a most excellent and steady old soldier, Sergeant Kerr. In the season of 1827, the stations visited were Vicar's Cairn, Ballygawley, Knocklayd, Sawel, and Slieve League. Having commenced early, I was attacked, after completing the observations of Vicar's Cairn, with ague, and Captain Larcom therefore joined me, and conducted the observations at Ballygawley. I resumed my charge, however, at Knocklayd, and my companion, Larcom, and myself retained our post at Slieve League till the beginning of January, 1828. Several severe storms were encountered, and on Sawel, on one fearful night, the observatory was nearly reduced to a total wreck, the great instrument having been previously removed, amidst the darkness and howling of the tempest, and placed in its case, under cover of the cook-house. The great danger to which the instrument (Ramsden's Great Theodolite) had been exposed, and the constant anxiety respecting it which had harassed me during this stormy season, led me to determine on some improvement of the observatory. When the English Survey had been first commenced, the observatory was a square tent, and, as General Colby told me, a very moderate breeze obliged the observer to desist, and pack up the instruments. He had, therefore devised a very strong hexagonal observatory tent, supported by corner posts, and kept firm by powerful guy ropes. This was a great improvement, and further security was attained by raising low stone or turf walls round the observatory; yet, as before stated, all was insufficient, and, from the height of the canvas wall, the wind aeted so irresistibly upon it, as to place the instrument frequently in imminent danger. I therefore had a small model formed in London of an improved observatory, in which the sides were made of framed boards, only leaving a low canvas top, which could be lowered for observation. The observatory was made after this model at Enniskillen, the wooden sides being clamped together, and secured to the corner posts by strong iron clamps, and further strengthened in very stormy weather by angle rods. From this time the observatory became secure; and although it has since been rendered still more comfortable, it was practically sufficient, and I never afterwards experienced that anxiety about the instrument, which before had wearied me far more than the mere watching for observations. The season of 1828 was occupied by the stations of Kulleagh, Nephin, Camdenhugh, Croghan, and the Hill of Lyons, where the observations were terminated towards the end of January, 1829. In this season, the late Lieutenant Murphy exhibited a Heliostat on the Keeper, in Tipperary, which was observed from Kulleagh, being a distance of 101 miles. A fearful storm occurred at Nephin, in which the men's tents were thrown down on two successive nights, by changes of the wind; and such was the wild character of the scene and of the weather, that it required much firmness to bear up against such reiterated disasters.

The season of 1829 was remarkbale for the observations of Kippure, a mountain on the borders of Dublin and Wicklow counties. The north of Ireland had been connected with Scotland by triangles of which the angles were observed at the Scotch stations, and the apex was Knocklayd, in the county of Antrim; but as yet no similar connection had been effected with more southern stations in Ireland, nor had any observations even been made by which their direction in space could be marked out. The station which it was intended to use for this connection was Precelly, in South Wales, and it became necessary, therefore, to re-find that long-lost station, to connect it by a long series of English and Scotch triangles with the north of Ireland, thence by another series with the south of Ireland, and finally to deduce by calculation the direction of a line from Precelly to Kippure, the distance being 108 miles, and neither station having observed the other. This was done; and having re-found the station, I placed a Drummond Heliostat at Precelly, marked on the
ground the direction to Kippure, for the guidance of the soldier left in charge of it, and went to Kippure to observe. For five weeks I watched in vain, when to my joy the Heliostat blazed out in the early beam of the rising sun, and continued visible as a bright star for the whole day. Until then, this was the greatest observed distance in geodetic operations, but it has been since exceeded in the British triangulation. Cnocanafrion, in Waterford, was the next station, and remarkable also as the point ; a fine pinnacle of rock was observed at Kippure, and selected as the station, though distant 80 miles; the intended point of the range, "Monavoola," having been cut off by the intervening Wieklow Mountains. I need not dwell on the minor stations which were visited after these great stations, and by which the season was extended into the winter, as on other occasions. 1830 was commenced on the summit of one of the Twelve Pins of Connemara, in front of the hospitable mansion of Ballinahinch Castle, the seat of the Martins, and terminated on the Keeper Mountain in Tipperary. This season was remarkable for a long continuance of most unfavourable weather; and after contending with a heavy fall of snow, and finding it impossible, from the depth of snow, to procure supplies of fuel, the party, who had consumed as firing the boarded floors of the tent, was at length forced to descend, although the observations had not been completed. 1831 was commenced at the Keeper, and the next great station was Bartregaum, near Tralee, the season terminating with a minor station. 1832 closed the great triangulation, the principal station of the season having been the Hungry Hill, opposite to Bere Island in Bantry Bay. The great triangulation of Ireland was therefore completed in the period of seven years, as contemplated in the first statement on the subject by General Colby. Brief as my sketch has been, I am sure that every one must have felt that such a work was admirably calculated to awaken the energies of active, and to develop the intelligence of intellectual men, whilst it generated habits of steady perseverance, and manifested the importance of moral discipline. The survey, indeed, has throughout its course exhibited the good effects of mental training in improving the military character, as no branch of the service has been conducted with so little necessity of appeal to punishment. In addition, however, to such moral training, the men were sent out to erect objects on minor stations; and as they were obliged, on their return, to point them out to the observer, they acquired great skill in the examination of country and selection of stations, a quality of great importance to the surveyor. They were also instructed in the use of minor instruments, so as to determine a difference of level, or perform any other subsidiary operation.

The great triangulation being finished, General Colby became desirous to apply its machinery to the improvement of the secondary triangulation. This branch of the work had hitherto been performed by the district and division officers, and being therefore constituted of several independent sections, some irregularities occurred at the junction of districts, particularly in the levels, so that I was called upon to go personally over the counties of Antrim, Derry, and Down, and correct and adjust all the levels by a new series of observations. This gave rise to a general series of observations for levels, and at the same time the whole secondary triangulation was placed in my hands. Had it been possible to make this arrangement at the commencement of the survey, there would have been no difficulty in keeping pace with the demands of the district and division officers for trigonometrical points; but it may be imagined that it was no light undertaking to enter on such a task when the surveyors had acquired speed as well as accuracy in their work, more especially as General Colby did not abstract any sensible portion of the district force to be applied as observers, one assistant, by no means efficient, having alone been obtained in this manner for me. Sergeant

Hemming, and several of the gunners who had formed part of my triangulation detachment, I immediately put in training, and I found them most valuable assistants, both in respect to their own work, and in training civil observers. On one occasion I had to place a young gentleman, who had graduated at Cambridge, under Sergeant Hemming for instruction, and he most warmly bore testimony to the zeal, intelligence, and respectability of the Sergeant. All difficulties were thus overcome, and a large observing force of more than thirty observers trained, who were able to supply trigonometrical points for more than three millions of acres per annum. This was the last of the improvements in the great trigonometrical survey planned by General Colby, which it was my lot to carry into successful practice, as I then directed my attention principally to the geological survey. The work has not retrograded since, but has continued to advance in excellence, as might be expected from the great ability of the principal officers who have, under General Colby, been connected with it. My old companion, Sergeant Hemming, and several others of the triangulation guard, were now transferred to the Sappers and Miners, and were thus retained on the survey. The well-known steadiness and intelligence of Sergeant Hemming led to his selection as a proper person to take charge of the detachment of Sappers and Miners who were to be employed under Captain Henderson in re-measuring, in conjunction with the Colonial Astronomer, Mr. Maclear, Lacaille's Base, and verifying his other geodetic operations. Captain Henderson had been long employed on the survey, and had assisted in the measurement of the great base of the Irish triangulation on the banks of Lough Foyle. That base was measured with the compensation bars invented for the purpose by General Colby; and as much misconception has prevailed on this subject, many ascribing the invention to the late Captain Drummond, I think it right to remark that nothing could be more opposed to fact, as that truly distinguished and scientific officer did not, in the first instance, approve of the idea of the bars, and made several experiments on plates of mica connected together in a measuring tape and riband. When, however, Mr. Troughton had made the first small model bar, and thereby satisfied Captain Drummond that General Colby's invention was feasible in practice, he afforded General Colby every possible assistance in all the preliminary experiments on the temperature of metals, and the determination of the compensation points, and was also one of his assistants in the actual measurement of the base. Captain Henderson did not continue at the Cape till the close of the operations, but returning home soon afterwards died. In respect to Sergeant Hemming, I shall now leave him to speak for himself.

A Communication from Serg. Hemming, Royal Sappers and Miners, to Colonel Portlock, R.E.

Cape Town, 25 th September, 1848.

## SIR,

The party of Sappers that came out with me, under Captain Henderson, consisted of seven rank and file, and we arrived at the Cape in July, for the purpose of re-measuring Lacaille's* Arc of the Meridian. A few weeks were spent in the preliminary business of adjustment of the instruments in Cape Town, and the party-

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to which a detachment of infantry had been added, left Cape Town in the beginning of September, to re-measure the base line; but as this could not be identified, a new line was laid out and measured, about seven miles in length, which occupied from October, 1840, to April, 1841. The triangulation and levelling occupied about two months, and the party returned into winter quarters in July.

The second season commenced in September, and under a somewhat different arrangement in the victualling department from the previous year; it had in the first year been managed by Captain Henderson, but in this year it came under the management of the astronomer, and I was appointed to act as QuartermasterSergeant. Captain Henderson left the work in December, and returned to England. The triangulation was continued until July, and completed up to the north extremity of Lacaille's are in the vicinity of St. Helena Bay.

The work was not resumed to the northward until the month of December; the interval had been employed carrying the triangulation to the south, as far as Cape Point.

The work to be encountered to the northward this season was of a much more formidable kind than that of the previous years, as it was intended to continue the are as far as the Orange River, if practicable, and we had with us Bradley's Zenith Sector*, and a large Theodolite. Our party was formed of different materials; the infantry had left us, by the removal of the regiment, and we had supplied their places by a lot of shipwrecked sailors collected in Cape Town, some of whom turned out very bad; in addition to this, the country to be passed over north of the Oliphant River was a mere desert, and the points to be used very high ; one exceeded 7000 feet, and another 6000 feet.

In January, 1843, the triangulation commenced at a headland north of St. Helena Bay, lat. about $321_{2}^{\circ} \mathrm{S}$., and continued nearly parallel to the coast line and about 30 miles from it, until it reached Kamies Berg, a little south of lat. $30^{\circ}$. Here the are was then expected to terminate. The party in their progress northward crossed the Elephant River on the 15th of June, and arrived at the foot of the Kamies Berg in six days after; here we had a fall of rain, which continued with very little intermission for three nights and two days, and when we commenced our march again, we found the ground so completely saturated, that our whole train had to be dug out several times each day, and we could, with great exertion, make only about eighteen miles in three days. Here we had so knocked up our oxen, that the farmers refused to go any further, and we had to get a new supply from a Missionary Institution, towards which we were shaping our course, and which was about twelve miles distant. As we were so near the Institution we had allowed our provisions to run low, not expecting any casualties, but as soon as the party commenced their mareh, about half-past six, it began to snow, and snowed heavily until nine o'clock in the evening, and the parly could not get anything to eat, nor any fire the whole day; three waggons out of five reached the Institution about seven o'clock in the evening; the other two stuck fast, and were brought up the next day. Our men, who were badly shod, suffered a good deal, but they all got the better of it. In three days after I rode to the district town for money, seven days' journey, and when I returned the instruments were comfortably fixed up and the observations commenced. Three months were spent here very pleasantly, though we had several falls of snow, and temperature very low; in October the party returned to Cape Town.

Having now completed twenty-one years' service, and finding myself a considerable

[^7]sufferer from rheumatism, so much so as to be sometimes partially lame, I applied to leave the service; I therefore did not take the field any more permanently. The astronomer being ansious to get from the neighbourhood of St. Helena Bay, along the mountain range to the eastward, to get down to Cape l'Agulhas, on the east coast, I was sent on a reconnoitring excursion to try to effect this; I did not, however, succeed; the thing turned out impracticable; I spent fourteen days at it, and returned disappointed and knocked up, and this my last field service was the worst I ever had, arising from the inaccessible nature of the country. It brought on a nervous attack that I shall never completely master in this climate. Whilst employed in connection with this move to the eastward, I received a letter from Cape Town, informing me that Sir G. Napier had appointed me (in consequence of the high character Mr. Maclear had given me) to a situation, as storekeeper to the Central Board of Public Roads, a department just established, with a salary of 1201. per annum., and an increase of $10 l$. per annum until it should reach 1501 . I, therefore, proceeded to Cape Town, and entered on my new office.

The duties on a service of this kind, that is to say, the minor duties, in this country, differ considerably from the duties in such a country as Ireland, and that from three principal causes: viz., the rugged nature of the country, the difference in climate, and the difference in the state of civilization. The arc of the meridian commences at Cape Point, skirts Table Bay, and keeps a short distance from the coast line until it reaches Kamies Berg*, where it is probably forty miles from the coast. This whole country, more than 800 miles in length, is bounded on the east by a range of mountains that form a very striking feature of the colony; they begin in the eastern part of the colony, and take a westerly direction until they reach the sea at Simon's Bay, from whence they lead off to the northward, and continue that course for more than 300 miles. The leading tops of the range are about from 5000 to between 7000 and 8000 feet, and are exceedingly bold and rugged, and some of them inaccessible; and as this range was used along the whole arc, the ascent to the tops was a rather formidable affair.

The country between the mountains and the sea is in general very badly watered, there being but two permanent rivers between Cape Town and Kamies Berg; the first is the Berg River, rising in the neighbourhood of Stellenbosch, and running westward to St. Helena Bay, a distance of about $\mathbf{1 0 0}$ miles; it is fordable at many places in the summer, but in winter it is swollen to an immense torrent; it receives several feeders from the mountain range, each in itself a formidable stream, yet such is the porous nature of the soil, and so extensive is the evaporation, that before it reaches the sea the united waters are a smaller stream than one of the feeders where it escapes from the mountains; navigation on it is therefore quite impossible, and as its banks are high irrigation seems impracticable. The country west of the Berg River, called Zwartland (Black Land), and Groenekloof, is where the base line was measured; it is badly watered. Groenekloof is generally sandy, except near the hills; it contains several salt-pits, which are the property of the Government, and some of them are let to individuals, who collect the salt and sell it. This is a very simple process: the salt-pits are merely shallow lakes, that get filled by the winter rains; when this water is dried up the salt is left in a crust at the bottom, and when dried by the sun is collected and taken to market. The winter streams, when dried up by the sun, also produce salt in the same way.

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The country called Zwartland is a fine rich colony and an excellent corn country, but badly watered.

The country north of the Berg River is generally a light unfruitful soil, somewhat better watered, but affording nothing remarkable until you come to the place called Verlonr Thei (where Lambert's Cove is erroneously marked on the map of the Society for the Diffusion of Useful Knowledge), that place being about 10 miles north of Verloor Thei. This Thei is a large lake, in winter upwards of thirty miles, in summer about twenty miles in length, and at its widest part about one and a half or two miles wide; its outlet in winter is a large and furious stream, but in the summer it scarce finds its. way to the sea, though only about one mile and a half distance; its waters in winter are fresh, but in summer it gets so brackish at the edge, that the farmers living on its border have to go in about knee-deep before they can get water fit for use.

The country north of this, as far as the Olifants Rivier (Elephant River), is what they call half Karroo, that is, a mixture of Karroo soil and sand; it is generally productive where cultivated, but badly watered. The Olifant River takes its rise in the range of mountains called Cold Bokkeveld; it passes through the district of Clanwilliam, about 150 miles, and empties itself into the sea about $31 \frac{1}{2}^{\circ} \mathrm{S}$. lat.; it is divided into the upper and lower. The upper, though flowing through some fertile valleys, is in general remarkable for its lofty, abrupt, and almost unapproachable banks, that is, from the surrounding country, for when you have reached its banks, though entangled greatly with brushwood, they are tolerably passable. The lower part is remarkable for its fertility, and it divides the Klein Karroo (Little Karroo), or Hardefeldt, from the somewhat more fertile country, and it is the entrance to the extensive country called Namaqualand; the primitive, high, solid banks of the stream vary in their distance apart from 300 yards to one mile and a half, though the present bed of the river may average about 1.50 yards wide; the intervening space is now filled with a deposit of rich Karroo mud, and when not cultivated, is covered with large closely-packed groves of mimosa, which attains a considerable height and girth; the banks are pretty well studded with farms; and when the mud becomes flooded after heavy rain, it makes the most fertile corn land in the colony, producing a return of one hundred-fold in grain, of excellent quality; and one old Boor told me he had on one occasion had a return of one hundred and eight-fold. It is not improperly termed the Nile of the Cape.

The Klein Karroo, that is, Little Karroo, or Hardefeldt, as it is generally called by the Boors, commences on the north side of the Olifant River, which is its southern boundary, and it continues to the Kamies Berg, about 100 miles. Its breadth from east to west is about 50 miles. It is generally composed of a stiff clay, occasionally mixed with gravel, and rising in small undulating hills from the river banks, which get a little higher gradually until they acquire a mountainous character, and terminate ultimately in the Kamies Berg range; the hills generally, when you get from the river, are rocky, I believe quartz, and these rocks are sometimes found cropping out in the plains. This region is crossed by two mountain streams, Black Thorn River and Green River; in the summer they are quite dry, affording no water at a less depth than two or three feet below the sand, but in winter they are swollen into frightful and often impassable torrents. The aspect of this whole district is sterile, the soil is impregnated with salt, and produces in general only a few stunted bushes, and in the summer scarcely anything can live on it; and the stillness, the dreary monotony of the scene, and the heat of the sun, render travelling over it a weary business. The farms (for scarcely any difficulties seem to deter
the Boor from fixing his homestead) are very far apart, not less indeed than from 10 to 30 miles.
The Kamies Berg is a granite range, its height in general is from 6000 to 7000 feet. In ascending the range, you come upon a table land of great extent, in which there are a number of good farms, which, for climate, may be called English; there is also a Missionary Institution (Lily Fontein) on this same table land. The tops rise above this table land in general about 1000 or 1500 feet, and jut out in dome-shaped figures, from which the upper strata have been worn by the action of the atmosphere, until they are so smooth and solid as scarcely to afford a lodging for a lizard. The tops are covered with huge.boulders; the corresponding parts to these boulders on the sides have slipped down to the base, and the boulders themselves are quite a curiosity, from their immense size, and from the way in which they are piled up on each other; they vary in size considerably: few that I have seen are less than 12 feet; it is therefore impossible to put an instrument, that is, a large theodolite, on them. The terminus to the are of the meridian was on a flat top, much lower than the tops in general.

I need not inform you that the climate is almost diametrically opposite to that of Ireland; it is generally very favourable for distant observations, but more so in the winter than the summer. In the summer the heat is so great and the motion so excessive over their hot plains, that nothing can be done during the heat of the day. The objects used for observing were invariably heliostats, which, by what seems to me a nuisance, are here called heliotropes, of about seven inches in diameter; they are used to much advantage in the summer here, where there is so much sun. On account of the heat the observations were discontinued at 11 A.M., and not renewed until 3 p.m.; notwithstanding this intermission the signal duties were rather oppressive. They were generally carried on by one responsible man, assisted by a couple of natives, and all supplies were got from such a distance as fully to occupy them both in procuring them. In the winter, matters wear a different aspect: water is then plentiful and the weather cool; the only drawback is the heavy rains.
These plains are subject to very great changes in temperature in winter and summer. In Groenekloof, when measuring the base line, the temperature in the marquees about 10 o'clock in the morning was, in the heat of the summer, frequently as high as $108^{\circ}$; and although, as a general rule, there is never any frost, on the night of the 15th of June, 1842, we had on the bank of the Elephant River, about twelve miles from the sea, and I think not more than eighteen feet above that level, ice three-eighths of an inch thick. The party and stores had crossed the river on the 15th, and had encamped on the north side, to spend their Sabbath. I do not know how to account for this phenomenon, unless it is caused from the short course of the river, which is only at that point about fifty miles from the mountains, the tops of which are covered with snow at that season of the year. Our summers are characterised by strong south-east winds, which in general set in about one o'clock, and continue about ten hours; we have also frequent heavy gales of three or four days' continuance: these are so strong in the neighbourhood of the Cape, as to make it very troublesome to take observations for a survey; but they do not generally blow so strong in the country.
Though I am not prepared, or indeed qualified, to give anything like an intelligent account of any branch of its Natural History, yet, as I am in the way of saying so much, I may remark, that in Botany the most striking feature of the country is the almost total absence of every indigenous plant that could be called a tree *. In

[^9]the flats this is very striking; and in the mountains, except a few trees about the size of a stunted apple tree, generally diffused over the small table land, to a height of about 4000 feet, there are no trees but such as are confined to very narrow localities. On the Kamies Berg there is a species of aloe, which grows to a height of about ten or twelve feet, with a trunk eight or ten inches in diameter for about eight feet, and then spreading out a wide top; these are so numerous as to give the little slopes and levels rather a park-like appearance; they seem limited to a zone of about 1000 feet in height, or rather width, and the height of this zone would, if examined, I think, be found about 4000 feet ahove the level of the sea; these commence where the mimosas, which are confined to the streams, disappear; their disappearance, however, is not sudden, but gradual, dwindling down into mere stunted shrubs, and finally disappearing altogether.

The inhabitants of this country may be considered exclusively as the Boors, as I do not know more than half-a-dozen Englishmen in the whole line of country; and the natives, who have now no property, are glad to attach themselves to the Missionary Institution for a home.

The duties of the are of the meridian were rendered very agreeable by the kind and cheerful management of Mr. Maclear, who, to extraordinary perseverance, adds a kindness and cheerfulness that attaches every one to him. He had two assistant astronomers, Mr. Smyth, son to Captain Smyth of Bedford, and Mr. Mann, son of General Mann of the Artillery. Mr. Smyth has since been promoted to be Professor of Astronomy at Edinburgh.

A few casualties occurred to the men on this service. One man was unfortunately drowned when bathing, and another was lost when in a state of intoxication, by a fall into a deep gully. I got a broken head with a bludgeon from a drunken fellow, but providentially I soon recovered.
I joined the Road Department on the lst March, 1844; this department had just been formed. Road-making had for some time excited some interest; in fact the time had arrived when roads were necessary; but society was very much divided on the subject, and it is likely had the subject been brought forward by a weak hand, it would have fallen to the ground; but the Hon. Mr. Montague, the present Secretary to Government, came into office about this time, and took the matter earnestly in hand. An ordinance was passed for improving the public roads of the colony. It authorized the establishing of a Central Board of Commissioners in Cape Town, whose office is the improving and making the main roads of the colony, and of Divisional Boards in the districts, subject to the Central Board, who look after the by-roads, or cross-roads. Their resources are, for the Central Board, a penny in the pound on all fixed property, raised in alternate years, at first limited to three levies, but it has since been extended to six; and for the Divisional Board, one halfpenny in the pound, raised in the same way. The Central Board have also at their disposal all tolls, and moneys raised from fines for trespass, and also the convict labour of the colony, which before was distributed unprofitably over the whole colony, doing little or nothing. This labour is now concentrated and applied to road purposes, in opening the mountain passes; the convicts are now formed into gangs of about 200 , and subjected to a moral training and habits of industry. They are officered by a superintendent and a proper number of overseers, and guarded by a police force. They have also a religious instructor, and a medical officer ; and it costs the public very little more to support them than when in a state of comparative idleness.

The Central Board is formed of six members, of which the Secretary to Government is the Chairman, and the Civil Engineer and Treasurer-General are also official
members; the other three are unofficial, and are supposed to represent the agricultural and the mercantile interests. Their establishment in Cape Town consists of a secretary, an accountant, two clerks, and a storekeeper ; the latter is my office. The duties of it may in a great measure be understood by the title ; but there was attached to it, as a part of the appointment, a small inspection of a road, which got me forage for a house; but economy soon made it necessary to attach the duties of this inspection to another officer. There was also attached to my duty as storekeeper the payment of a free party, under the direction of the Civil Engineer; and as these parties under his immediate direction increased, my cash account gradually increased to a great extent; and on casting my eye over my cash-book, I see from lst March, 1844, to 1st March, 1848, it has exceeded 36,000 l. ; but as the work has been much more actively carried on at some times than at others, the outlay is far from regular.

The Board have recently established a new description of office, which I should be glad to obtain at anything like moderate terms. It is that of Sub-Inspector of Roads, a duty for which I know myself qualified; but the inspection extends over 100 miles of road, and the salary 200l. per annum. I think it does not require any very great knowledge of road-making to pronounce the duties to be quite beyond the efficient management of any one man ; particularly so, as they have to be carried out in detail. It would not be a difficult matter, perhaps, if the roads were made and repaired by contract; but contracts have not yet been tried in road-making here, though they have in repairs, but have not turned out satisfactory. Perhaps one principal cause of this, is the almost total ignorance that exists among the community on the subject of road-making and mending, and also of what constitutes a good road; for they are never so uncourteous as to deny the character of a road to anything that you and eight horses can travel over, and it is not a little that will daunt a Cape traveller. These low ideas of road-making induces people to undertake the repairs at a rate so low that it will not pay them. And the Dutchmen, whose genius lies very much in buying and selling, never hesitate to speculate, let the cause be ever so desperate. I do not think the roads can be repaired by contract near so advantageously as they can be made. Indeed both undertakings seem capable of great modification, for certainly the operation of lifting and re-forming the cross-section, or of preparing materials, or spreading, never will be done by a contractor, who is anxious merely to cover a certain space, or put in his time till the quarterly pay-day arrives, so well as under the direction of an efficient inspector, whilst materials may be quarried and conveyed to the place of deposit perhaps 50 per cent. cheaper by the cubic yard than by the day. The practice followed here is, in making, wholly by the day. In repairing, small parties are stationed at every four miles; viz. one working foreman and six men, with a pair of mules and a cart, and sometimes four oxen and a cart.

The salary of a Sub-Inspector is 2002. per annum, but as he requires to keep two horses, and consequently an extra servant, it does not seem adequate to the duty.

In my domestic matters I have hitherto, thanks to the guiding hand of Providence, enjoyed much happiness; not without alloy, it is true, but that is what we have no right to expect. I have six children living, and one has died since I came to this country. Of those living, four are sons and two daughters. When I came to this country, my notice was so short, that I had barely sufficient time to get myself ready, and could not bring my family with me; but when I got to London, I was detained there for a long time waiting for a ship, and during that time my wife joined me with part of the family; but the children were all so small that two of them had to be left behind; and these two, after several years' anxiety and disappointment, I succeeded in getting out, in May last, at a cost in various ways of about 701. My eldest
son is now nearly 14 years of age, and I am beginning to look for some occupation to apprentice him to ; but that is not easily found in this country, from the very peculiar state of society.

This country, from some very unaccountable misunderstanding, appears to stand very high in the estimation of the people of England as a residence for man. Certainly the goodness of its climate cannot be too much extolled; but the country is a very rough one indeed. The want of water for irrigation will prevent its ever becoming an agricultural country; a manufacturing country it never can become, from the same cause, the want of water as moving power for machinery. It never can become a mercantile country, from the want of harbours and navigable rivers; indeed the want of water is the great drawback. On the banks of some of the rivers and small streams issuing from the mountains, some as fertile spots as any on this earth are perhaps to be met with; but these are very limited, and the want of water renders the greater part of the country a mere desert, and will prevent its ever becoming anything more than a grazing country, or supporting anything more than a very scanty population.

Our merchants may be considered, in general, as residents merely for the time being. There are some exceptions, but most of them settle here for the purpose of making a fortune, and with the view of returning to Europe; they consequently do not trouble themselves much about the state of society, if all is quiet in their day.

Our landed proprietors are not wealthy in this part of the country; they are mostly the Boors, with here and there a mercantile speculator in the way of sheep-farming; but we have very few landed proprietors coming here with capital, and purchasing tracts of land, and improving and increasing it, and, when dying, leaving estates to their children. I think, in most cases in which I have seen it tried by old officers, it has failed.

Our Government officers may be considered in their extremes as English, that is, the highest and lowest, whilst the middle is filled up with Dutch. The Dutch have all the pride of a conquered race, and all the prejudices of a slaveholding people; and therefore there is a disinclination to put their children to trades. They are strongly disposed, as a genteel profession, to educate them for clerks; and as they are scarcely a match for their active English competitors in a mercantile way, they besiege the Government for situations; and as this has probably gone on since the conquest of the Cape, it follows that many, indeed I may say most, of the head clerks are Dutch.

Our Mechanics.-There is in this city upwards of 9000 Malays, Mahometans, \&c., and these are almost all mechanics, and they are the working mechanics of Cape Town. They may not improperly be called hand mechanics, but certainly not head mechanics, for they are quite unacquainted with the principles of work; but by a division of labour, they are able to do very well, and the masters like to employ them, as, from their abstemious habits, they are able to work cheap, and from their numbers they fix the rate of wages. They use no strong drink, and are satisfied with fish and rice, with a little coffee, for food. Their dress is peculiar to their tribe: and in their lodging they form themselves into gangs, and take a large old Dutch house, and live together, ten or a dozen families, in an atmosphere the most overpowering that: I have ever encountered. These habits enable them not only to live, but to grow wealthy, on a low rate of wages ; and the Englishman that will not work for the same rate, will not get employment. The average rate of wages for mechanics is 3 s .9 d . per diem. A few good English workmen will sometimes get from 4 s . to 4 s .6 d ., but never for long together, nor in any great number, as masters are always anxious to get rid of such high-paid men. I know very different views have been held out to mechanics who are inclined to emigrate to this country, by.the emigration circulars published in Eng-
land; but these are much exaggerated, both in the wages paid, and also in the expense of living; indeed in the rate of living usually given in these circulars, they set forth the leading articles of food, and carefully avoid mentioning many others that are considered necessaries of life to an Englishman, and which he certainly does not think of depriving himself of when he emigrates, because he does so to improve his circumstances.

House rent, fuel, vegetables, are at least 100 per cent. dearer than in England. Milk, butter, eggs, cheese, bacon, and such like things, are not attainable by the lower orders, and may all be looked on as luxuries; and 1 think I do not exceed the truth when I say, that a family living in a very moderate style of comfort would be supported in England for the money that would provide them with the above articles in this country.

It follows from this, that an English mechanic, at this rate of wages and living, cannot live respectably; he cannot pay his board in a respectable place; he therefore has recourse to the black people for accommodation; this lowers him in his own estimation; he lives on fish and rice, or other equally astringent food, highly seasoned; this creates an overpowering thirst, which he endeavours to allay with bad wine, or Cape brandy. This makes matters worse, and introduces him into a downward course, from which it would take a strong resolution indeed to rescue him, and in which be goes on, spell-bound, until madness, or a violent death in some shape, closes his career, and the best that he has to hope for is a pauper's grave.

I do not think that I have exaggerated; I believe the above would be found to be the ease with a very great proportion of the English mechanics who come to this country, and that it arises from the causes above-mentioned. Some there are, of course, who act differently from this, as there are individuals to be found in all communities that will rise from strong natural abilities, but this is not the character of people who emigrate.

## NOTE A.

## On Mr. Hemming's Paper, by Lieut.-Col. Portlock, R.E., F.R.S.

## Lacaille's Arc of the Meridian.

It is scarcely necessary to remark in a paper addressed to officers of engineers, that the form of the Earth early engaged the attention of philosophers, and that the astronomers of antiquity knew that it was nearly spherical. To us, who are acquainted with the accurate geometrical and mechanical means now applied to the investigation of the exact figure and dimensions of the Earth, the methods adopted by the ancients appear rude; but we must never forget the vast distance between the first conception of a great principle and its subsequent practical development. However simple, then, the means of measurements were, the first thought of measuring the Earth by man was truly sublime. Two methods of obtaining data to determine the figure and magnitude of the Earth are suggested by the observation of astronomical phenomena; the first is, the measurement of an arc of the meridian dependent on the varying altitudes of the heavenly bodies as we move from the equator to the poles; and the second is, the measurement of an arc of parallel depending on the varying times at which the heavenly bodies came to the meridians of different places as we proceed from east to west. The first method was that adopted by Eratosthenes, 230 years before the Christian era. He observed, that

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at Syene, in Upper Egypt, the sun was, on the day of the summer solstice, vertical at noon, whilst at Alexandria it was at the same season distant from the zenith or vertical point, $7^{\circ} 12^{\prime}$; and, comparing this angular distance with the reputed distance by measurement on the Earth's surface of the two points, namely, 5000 stadia, he estimated the Earth's circumference at 250,000 stadia. Posidonius used the difference of meridional altitude of a star, having observed that Canopus was nearly in the horizon at Rhodes, when he considered it to be $7 \frac{1}{2}^{\circ}$ above the horizon at Alexandria. Adopting the reputed distance between the two places, he deduced 240,000 stadia as a rough estimate of the circumference.

Of the second principle of determination, namely, the difference of times at which a celestial body comes to the meridian of different places, mention is made by Ptolemy. He specially noticed this circumstance in reference to eclipses of the Moon, which have, subsequently, so frequently been applied to the determination of terrestrial longitudes. Ptolemy assumed the length of a degree to be 500 stadia, but this estimate is supposed to have been founded on the observations of Marinus, the Tyrian, of the differences of latitude of distant places as compared with the nautical estimate of their distances. As the exact value of the stadium is not known, and the errors of observation, as well as of the assumed distances, must have been considerable, these early attempts to determine the magnitude of the Earth, are only important as evidence of the great intelligence which had at so remote an epoch grappled with so difficult a subject. The Arabian determination of the length of a degree by Abdallah Almamoun, in the ninth century, was curious, as the distances detween the observing stations were determined by actual measurement, by rods. One set of observers moved northward, and another southward, from a point in the plains of Mesopotamia, until each had found an alteration of latitude, or of the altitude of the pole, equal to one degree. These measurements cannot now be used for comparison, as the exact value of the integral cubit is not known.
For 700 years nothing more had been attempted, when the subject was again resumed, as it now is in western Europe.
It is not my intention here to notice all the measurements which were effected by modern philosophers, and I shall, therefore, proceed at once to that of Picard, commenced in 1669. So long as it was attempted to measure directly by rods, or any other contrivance, the whole areal distance, the process was tedious, difficult, and exposed to numerous chances of error; but Snell had substituted for it, early in the seventeenth century, measurement by trigonometrical operations, and Picard's measure was therefore trigonometrical. Notwithstanding some errors, it was superior to all preceding measurements, and enabled Newton to test and establish by it his great Theory of Gravitation. Reasoning on this basis, and combining the doctrine of centrifugal forces with the theory of fluids revolving round an axis, Newton, on the supposition that the Earth had originally been a homogeneous fluid, was enabled to announce that its form must be spheroidal, and not spherical; that its equatorial diameter exceeded its polar (or axis of revolution); and that the proportion of the diameters to each other was 229 to 230 . Familiar as we now are with these theoretic discoveries, we still recognise in them so many proofs of the sublime genius of Newton.
In 1684, Cassini commenced the measure, in France, of his Are of the Meridian, and it was finished in 1701, being extended northward to Dunkirk, in 1716. By a comparison between the southern and northern portions of his arc, Cassini came to a conclusion quite opposed to that of Newton, as he found that the degrees shortened in going from the south to the north, and therefore inferred that the Earth was a prolate, not an oblate, spheroid; or, in other words, that the Earth was
elongated, not flattened. The doubts thus incited led to the celebrated expeditions of the French Academicians: the one being directed to South Ameriea, or towards the Equator; and the other to the vicinity of the Gulf of Bothnia, or towards the Pole. The southern expedition sailed in 1735 , and the arc was measured in the Great Valley of the Andes, by Bouguer, Godin, and La Condamine. The northern sailed in 1736, and the are was measured in the valley of the river Tornea, by Maupertuis, Clairault, Camus, Lemonier, and Outhier.
Before the completion of these measurements, Cassini de Thury, grandson of Cassini, aided by Lacaille, had remeasured his are, and having discovered an error in Picard's base, which he had at first used as correct, the cause of the original difficulty became apparent, and all doubts as to the accuracy of Newton's Theory were dispelled. It is not necessary, for the present purpose, to speak of any other measurement but that of Lacaille itself. This are was measured by that able astronomer in 1752, and extended over $1^{\circ} 13^{\prime} 173^{\prime}$. The result was remarkable, as it presented this variation from a perfect regularity of figure in the Earth, inasmuch as a degree in the South Hemisphere, at a latitude of $33^{\circ} 20^{\prime}$, would equal a degree in the North Hemisphere at $45^{\circ}$ of latitude. This apparent inequality in the two hemispheres naturally excited much attention, and at length it was determined to apply the more perfect geodetic instruments of the present day to the verification of Lacaille's measurement; and to this object, the scientific expedition which is the subject of Mr. Hemming's Paper was specially directed.
As no official account of this highly-interesting undertaking has as yet been published, I have abstracted from the "Astronomische Nachrichten" of Schumacher, the substance of a letter addressed by Mr. Maclear to Schumacher on the subject. As no natural or other marks remained to define the termini of Lacaille's base, it was found impossible to remeasure it; and in like manner, Lacaille's arc does not form a necessary portion of the newly-measured arc, though it has been connected with it by common stations. The situation of the new base is very near that of Lacaille; it was measured with the compensation bars invented by General Colby, and is about 42,819 feet, or something more than eight miles, long. The portion of the arc measured in May, 1846, extended from Cape Point, latitude $34^{\circ} 20^{\prime} \mathrm{S}$., to the Kamies Berg, latitude $30^{\circ} 21^{\prime} 30^{\prime \prime}$.

The angles of the triangulation were observed with a 20 -inch theodolite, furnished with three micrometer microscopes; and the differences of latitude were determined by observations with Bradley's celebrated zenith sector of $12 \frac{1}{2}$ feet radius. The sector was put up at the following stations:-

| Cape Point . . . . . . . | 800 | feet above the sea. |  |
| :--- | :--- | ---: | :--- | :--- |
| Zwart Kop . . . . . . . 2000 | $"$ | $"$ |  |
| Royal Observatory . . . . . | 37 | $"$ | $"$ |
| Cape Town (Lacaille's Station). | 15 | $"$ | $"$ |
| Klyp Fontein (Lacaille's Station) | 450 | $"$ | $"$ |
| Heerelogements Berg . . . . | 2200 | $"$ | $"$ |
| Kamies Berg . . . . . . . | 5500 | $"$ | $"$ |

For the purpose of comparing Lacaille's base with the new base, Mr. Maclear connected the latter with Lacaille's triangles by the common side, Riebeck's Casteel, Capoc Berg, the "roche à peu près cylindrique" of the Capoc Berg still remaining, and a pile of stones having been left to mark Riebeck's Casteel.

Mr. Maclear gives the following results of a comparison of the sides of triangles :-

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|  | Lacaille's lengths. | Lengths catculated from modern base with Lacaille's triangles. | Differences. | Lengths from both modern base and triangles. |
| :---: | :---: | :---: | :---: | :---: |
| Riebeck's Casteel to Capoc Berg | Feet. $135,810 \cdot 3$ | Feet. $185,765 \cdot 5$ | $\begin{aligned} & \text { Feet. } \\ & 44 \cdot 8 \end{aligned}$ | Feet. $185,766 \cdot 0$ |
| Cape Town to Capoc Berg | 183,148.8 | 183,089•2 | $59 \cdot 6$ | 183,086.0 |
| Cape Town to Riebeck's Casteel | 243,283•6 | 243,204.0 | $79 \cdot 6$ | $243,199 \cdot 3$ |
| Riebeck's Casteel to Klyp Fontein | 261,000 4 | 260,914 7 | $85 \cdot 7$ |  |
| Capoc Berg to Klyp Fontein | 263,654.8 | $268,568 \cdot 7$ | $86 \cdot 1$ |  |

It will be observed from the close approximation of the lengths, when deduced from both sets of triangles and from the new base, that the triangulation of Lacaille was good, but that the determination of his base was too long by about 14 feet.
The next comparison is that of the values of the degrees, the ellipticity being deduced by reference to the Peruvian degree:-


This comparison shows a difference between the modem determination of the degree between Cape Town and Klyp Fontein, and that of Lacaille, amounting to 160 feet, Lacaille's being in excess to that amount; and Mr. Maclear observes, that the chief cause of the failure of the measurement of 1752 may be traced to the circumstances of the termini ; as the Cape Town station is on the one hand, nearly due north of the precipitous northern face of Table Mountain, a mass nearly 3600 feet high, whilst the Klyp Fontein station is, close up to the south-west angle of large mountains which bound the extensive plain of Zwartland, on the south, the arc being thus shortened by the sum of the deflections due to these local attractions at its termini. No use can therefore be made of Lacaille's Arc, in its totality, for determining the question of the figure of the Earth, though a useful combination might be made of some sections of it, and the supposed irregularity has not, therefore, been established by these investigations.

## NOTE B.

## Bradhey's Zenith Sector.

It has been stated in Note A, that the Astronomical Observations connected with the new meridional are at the Cape were made with this instrument, the radius of which is $11_{\frac{1}{2}}$ feet, the sector or divided are being, therefore, a portion of a
circle having a diameter of 23 feet. The observations by which this great astronomer established the great phenomena of Aberration of Light and Nutation of the Earth's Axis, were made with a zenith sector; and as this description of instrument has always been used for astronomical observations in the great geodetical operations of British surveys, it is desirable to say a few words on the principles of its construction and application.

In the operation of measuring an are of the meridian two objects are included: namely, first, the correct measurement of a certain terrestrial distance; and, secondly, the comparison of that distance with the corresponding celestial arc, in order to determine what portion it is of the earth's circumference. At present, the second is the subject of consideration, and it is manifest that the comparison may be made, as stated in the preceding note to have been done from the earliest times, by ascertaining either the difference in the declinations of some star when observed at the two extremities of the are, or the difference in its zenith distances. To avoid the errors consequent on refraction, it is manifestly desirable to select stars high above the horizon, or near the zenith; and it was natural, therefore, to adopt those which, by their close proximity to the zenith, should require only a small instrumental are for the measurement of their distances to the zenith.

In the British survey, it was an especial object to secure accuracy of observation by the use of large and well-divided insiruments, provided with good telescopes, so that the power of observing with precision might be always combined with that of reading minute differences on the arc of the instrument. It is, indeed, manifest that accurate instrumental division would be of little use, were it not possible to observe with the telescope the differences which can be read in the instrument; and, in like manner, that accurate observation, to be successful, must be seconded by equally accurate instrumental division and reading. This principle was carried out in the British survey, in the construction of the two great 3 -feet theodolites of Ramsden, and the zenith sector of 9 -feet radius, by the same artist. If, independently of the dejection from irregular refraction, it had been attempted to observe declinations from the horizon with an instrument corresponding in magnitude to this sector, the difficulties of construction would have been enormous, and perhaps totally insurmountable, except on the model of a complete circle, which from its magnitude could not have been made portable. Placed in a position either horizontal, or even inclined $40^{\circ}$ or $50^{\circ}$ to the horizon, an instrument of so large a radius, and including only a sector as its arch, however extensive, could not have been secured from irregular flexure; but when the instrument is placed vertically, and the arch reduced to a very small sector, the great mechanical difficulty is removed, and it is therefore evident that this form has great advantages over the old quadrant, or any instrument in which either the telescope or the arch was subject to varying conditions of suspension. Ramsden's great sector was destroyed in the fire at the Tower, and has been replaced on the British survey, at the recommendation and on the plans of the Astronomer Royal, by a much smaller instrument, admitting of easy reversal, and of a construction so solid as to secure it from partial or varying flexure. In this new instrument, the measurements are referred to a spirit-level in place of a plumb-line, and it is considered that the observations have been quite as accurate as those of the great sector. The French have introduced the repeating circle for their observations, both geodetic and astronomical, but it is the opinion of I, believe, almost all British astronomers, that in this instrument it is not possible to guard against a variation in the instrumental errors, which ought to be constant, and sometimes no clue to the cause is apparent. It is, indeed,

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almost impracticable to secure a perfectly concentric motion to two circles related to, but not both connected with, the same internal axis; and it is also very difficult to preserve the levels in a uniform state during the movements of these circles.

Whilst the object of a mural or other circle is the observation of zenith distances throughout the whole extent of the meridian, a zenith sector ought to be restricted in its observations to a more limited extent, which, for geodetical purposes, can seldom require to be more than $6^{\circ}$ or $7^{\circ}$ on each side of the zenith, thus embracing the portion of the sky least obscured by clouds, and admitting of the use of an are of large radius, and provided with a powerful telescope and long plumb-line. For exclusively astronomical observations a still more restricted are is sufficient, Bradley's instrument having, in bis hands, been confined to the observation of a single star passing the meridian within two minutes of the zenith; and when this principle is carried out in construction, the distortions produced by the weight of the instrument may be almost entirely avoided, and the measures of zenith distances effected by the simple use of the micrometer or the spirit-level. In illustration of this latter class of instruments, the Astronomer Royal has specially described three instruments.

1. The Greenwich Zenith Tube, planned and constructed by Troughton during the direction of the Royal Observatory by Mr. Pond. It consisted of a telescope, 25 feet long, revolving in azimuth on a pin at the bottom, and between guides near the top, but absolutely confined to the vertical direction. Its range of observation was limited to that angle in which the injurious effects of obliquity of the pencil upon the image of the star is insensible, and practically it was confined to the single star $\gamma$ Draconis, at two minutes only from the zenith. The aperture of the object-glass was 5 inches, the diameter of the tube at the top 6 inches, which increased at each successive step downwards (the tube being in five separate lengths), till it was 10 inches in diameter at the bottom. Within the great tube of the telescope was a small vertical tube, nearly an inch in diameter, the top of which was about 10 inches below the object-glass, and in contact with the side of the great tube, whilst at its lower end it was about 2 inches from it. The plumb-line of silver wire descended through this tube, and passed through a hole in the bottom plate of the telescope, where it was attached to a plumb-bob suspended in a cup of water, supported by hooks upon the lower plate. The position of the wire was determined by two micrometers, one near the top and the other near the bottom of the tube; and the wire with which the bisection of the star was effected was carried by another micrometer, called for distinction sake the Grand Micrometer. The wire plate of this latter micrometer carried also the heavy eye-piece of the telescope, a 4 -glass diagonal eye-piece, which was placed below the lower plate of the great tube, and projected sideways more than 6 inches. The present Astronomer Royal, Mr. Airy, found that the attachment of the grand micrometer was very deficient in firmness, and he therefore introduced some material improvements. He also adopted arrangements to prevent irregular flexure of the plumb-line on rapid inversion of the instrument, and by the introduction of a second wire on the micrometer plate admitted of a second observation of the star in the reversed position of the instrument at each transit, which was not possible in the original construction, as the time during which the star remained in the field was too short for the numerous turns of the micrometer required to bring the wire into its new position. Notwithstanding these improvernents, the results of observations, though more accordant than before, were not such as to ward off this final judgment of the Astronomer Royal, namely, that the instrument had failed, and that its failure was owing to the dependence on the plumb-line. It was finally dismounted in the spring of 1848 .
2. The Prime Vertical Instrument of Struve, which is, in fact, a transit of peculiar construction, applied to the determination of latitude, by observations of the transits of stars over the prime vertical. It is now applied to the observation of three stars only, and M. Struve is satisfied if he can obtain eight observations of each star in a year. There are many striking peculiarities in the construction of this instrument, the design of Struve and work of Repsold. The axis has its bearings on the Ys, and is supported on stone pillars, 46 inches apart from outside to outside ; but, unlike ordinary transits, the telescope, 7 feet long, is attached to the axis, not between the pillars, but on the outside of one of them, a counterpoise being attached on the outside of the other. By this arrangement, the portion of the axis between the pillars is left free for the application of a spirit-level at the time of observation, and a fitting position is obtained for the reversing apparatus, which consists of a vertical shaft sliding through holes in cross bars fixed to the piers, and prevented by a fillet upon it from turning, until it is raised to a certain height. This vertical shaft carries a T head, about 33 inches long, at the extremities of which are the lifting forks, and also the fulcra of the ordinary counterpoises, which act by means of levers to support a bar about 41 inches long, at the extremities of which are the friction rollers, which at all times support the principal part of the weight of the instrument. By this arrangement, the greater portion of the weight of the instrument is always supported by the vertical shaft, and only a very small portion left as residual weight to bear on the $Y_{s}$, and when the shaft is raised so as to bring the lifting forks at the extremities of the T head in contact with the axis, preparatory to reversion, the only additional load it is forced to carry is that residual weight. Two massive lever counterpoises are provided below, sufficient to support the shaft when the instrument is not on the lifting forks, and it is therefore only necessary to apply a very small force to counterbalance the small additional weight when it is received upon them. So perfect also is the simple mechanism for applying this small force, that the reversion is effected with a rapidity and ease scarcely to be conceived. This advantage of rapid reversion, and that of being able to apply the level at the time of observation, are very great; but Mr. Airy, whilst he gives every praise to the admirable mechanism of this instrument, considers the weak connection of so large a telescope with the axis a serious, if not a fatal, objection to it.
3. The Reflex Zenith Telescope.-This is a new idea of construction brought forward by Mr. Airy. He assumes that the object-glass is vertical, that a pencil of light falling on it from a star near the zenith shall pass from it with its axis still inclined to the vertical, but with its rays in a state of convergence, and be received on the surface of a trough of quicksilver placed below the object-glass, at a distance somewhat less than half its focal length, whence it would be reflected with its axis still inclined in the same degree to the vertical, and with its rays in the same state of convergence, so that it would proceed again through the object-glass, and form an image of the star just above it. This image would be viewed through a 4 -glass diagonal eye-piece, with a diagonal reflector, and its position determined by the measurement of a micrometer attached to the frame of the object-glass. As the axis of the object-glass cannot be determined, the object-glass should be turned round $180^{\circ}$, and the image will now be formed at an equal distance from the axis of the objectglass, but in an opposite direction relatively to its frame, so that the distance between the two positions of the image, as measured by the micrometer, will be double the distance of either image from the axis of the object-glass, and will therefore be a measure of the star's zenith distance. This is at present, it is hoped, sufficient to give an idea of the principle of this last and most beautiful form of zenith instrument.

## PAPER VII.

On the Stone employed in the Construction of the Lighthouse at Agulhas, Cape of Good Hope.

## Devonport, Dec. 4, 1850.

Having been employed, in Sept., 1848, by desire of his Excellency Sir Harry Smith, Governor of the Cape of Good Hope, to give my professional assistance to the Colonial Engineer Department, in fixing the Light at Cape Agulhas, in conjunction with Mr. Maclear, Astronomer Royal, on the part of the Imperial Government, I have the honour to lay before you the Report addressed by us to the Secretary to Government, prior to leaving Cape Town on the duty assigned us; as also my final Report on the completion of the service, together with Mr. Maclear's description of the apparatus comected with the lenticular, for the purpose of insertion in the Corps Papers, should you consider the matter contained therein suitable to the pages of that publication.

I bave the honour to be, \&c., \&c.,
E. J. Bourcher,

Lieut. Royal Engineers.

Colonel Lewis, C.B., and Captain J. Williams,

## Royal Engineers,

Editors of the Corps Papers.

Castle, Cape Town, Aug. 28, 1848.
Sir,
We have the honour to state, that a specimen of the stone of which the tower for the Agulhas Light is composed, kindly given by Mr. Robinson from the SurveyorGeneral's Office, has been subjected to two experiments by Lieut. Bourchier, R.E.; and although the second was very imperfect, so far as they both go, in our humble opinion, they decidedly indicate the propriety of testing (as nearly as practicable) the strength of the shaft before the erection of the lantern.

The specimen was in the form of a cube, containing 216 cubic inches, and in weight 12 lbs and a few grains avoirdupois; viz. 96 lbs . to the cubic foot. Lieut. Bourchier immersed it in water, when a hissing noise, caused by the escape of gas, commenced immediately, and continued for twenty hours. When taken out it was found
to weigh $15_{4}^{1} \mathrm{lbs}$. ; that is, it had absorbed one-fourth part of its original weight in water. Having been allowed to stand eight days, several cubes of $1 \frac{1}{2}$-inch face (the usual dimensions for crushing experiments) were sawn off, and so measured and compared with each other. Three of them crushed in succession, under a shot tray weighing 61 lbs ., loaded on the first occasion with 570 lbs ., and on the second with 600 lbs . of shot. As before stated, the latter experiment is very imperfect. Theoretically, we conceive the substance to be tried to be composed of an infinite number of parallel columns in the direction of the pressure, and the problem requires that the pressure should be applied gradually, equally, and simultaneously to each. We have no reason to suppose the latter conditions were exactly fulfilled, and every error is opposed to the strength of the material. The tray was suspended from the end of a lever, and its centre of gravity roughly determined by trial and error, on a small cube of wood, of similar dimensions as the stone. The upper face of the stone surface was defended by a slip of sheet iron, and, by means of the lever, the weight was lowered upon it with all practicable delicacy; but the oblique strain, notwithstanding, may have been of large amount. By the first experiment, the porosity or spongy character of the stone, is undeniable, and explains why a cubic foot weighs 96 lbs only. By the second experiment, if worth anything, the stone after saturation is exceedingly frangible. The tower to a certain extent is in the same condition, from exposure to an unusually wet season. Before proceeding with the erection of the lantern, we propose to lay a wooden platform upon the top, and to load it with stone to double the weight of the lantern and apparatus, using the same mechanical means that Mr. Robinson proposes to employ in fixing the light in position, by which experiment no doubt will be left as to the stability of the shaft in question, which we conceive to be highly desirable should be fully ascertained.
We have the honour to be, Sir ,
Your most obedient humble servants,
(Signed) Thomas Maclear, A.R.
E. J. Bourchier, Lieut. R. E.

The Hon. J. Montagu, Secretary to Government, \&c., \&c.

> REpORT on the Erection of the Lantern on the Lighthouse, Cape Agulhas, by Lieut. E. J. Bourchier, Royal Engineers, under Letter from the Deputy Quarter-Master General, of 10th August, 1848, and agreeably to Instructions from Military Secretary, dated 29th November, 1848.

Royal Engineer Office, Cape Town, Dec. 1, 1848.

Previous to leaving Cape Town for the purpose of affording my professional aid in fixing the Light at Cape Agulhas, I addressed a report on the material of which the building was made, in conjunction with Mr. Maclear, Astronomer Royal (copy of
which is annexed *), to the Hon. J. Montagu, Secretary to Government, from which it may be seen, that I incline to the opinion that the stone in question was not eminently qualified to resist great vertical or lateral pressure, or the slower but more insidious action it must from its situation be constantly exposed to, from wind, rain, and salt-water spray; but after a very careful observation, as far as lay in my power, owing to the advanced state of the building when I first saw it, and paying due regard to the collateral evidence given by a fair comparison of the stone in the quarries with that selected for the work, I do not entertain a doubt, from its appearance externally and internally, as well as from its extreme solidity of structure, of its being fully adequate to fulfil all the conditions of stability which are likely to be required of it, provided the most rigorous attention be continually paid to prevent wasting away from any of the causes above alluded to; as a preventive to which, I should strongly recommend the whole being painted, or saturated with linseed oil, before next winter, by which time a considerable portion of the moisture now present in it will have evaporated.

But the point which appeared to me as requiring a close examination was the alteration, after completion, of the centre of gravity of the dome closing in the shaft, by a man-hole being cut through it in an oblique direction, to give access to the lenticular, by which proceeding a large proportion of the whole mass of materials of which it was composed (viz. Dutch clinkers and best hard Cape bricks) was removed, and the conditions of equilibrium disturbed. I accordingly proposed to the Astronomer Royal, to test the strength of the dome, by applying a weight of at least twice the quantity it would have to carry, on a surface of 4 feet square, over its centre, and one portion close to the edge of the man-hole; which was assented to by Mr. Robinson, acting civil engineer, by whom every facility was afforded for examining and proving the soundness of the various parts of the building; and the result was, that with a total weight of $10,400 \mathrm{lbs}$. applied as above described, not the smallest crack, settlement, or crushing was visible on its removal, thirty-six hours after being placed in position.

Fully satisfied on all the points to which it was necessary my attention should be directed, and, agreeably to my instructions, having arranged with Mr. Robinson on the method to be adopted in the erection of the lantern, and seen the framework placed in position, I conceived there was no further necessity for my remaining at Cape Agulhas, and returned to Cape Town. In conclusion, 1 have much pleasure in bearing my humble testimony to the merits of a public work of such importance as the Agulhas Lighthouse, and one which reflects so much credit on the designer, and those engaged in its completion, on the part of the Colonial Government.

## E. J. Bourchier,

Lieut. Royal Engineers.

[^10]
## DESCRIPTION OF THE AGULEAS LIGHT APPARATUS.

It is of the first or most brilliant class, and made by M. Henri le Paute, on the dioptric principle.
A hollow cylinder, with a paraboloid top of about 19 feet in circumference and 10 feet high, is composed (omitting a doorway) of twenty-eight horizontal tiers of glass, and reflectors firmly fixed in a metallic frame-work of sixteen compartments, so that each tier is divided into six circular segments.

The centre tier is a large hoop-shaped, plano-convex lens, 11 inches in depth. Next, eight tiers of circular prisms above, and eight below the centre lens. Then seven tiers of reflectors above and four tiers below. Three-fourths of the circumference of the cylinder is formed by this combination. The remaining quadrant, which is towards the land, and its centre due north, serves for the doorway into the cylinder, but the door is lined with two large concave metallic reflectors, each 2 feet in breadth and 3 feet in height. The burner, consisting of four concentric argand wicks, 4 inches in diameter, is placed in the centre of the cylinder, in the focus of the large lens. It is supplied with oil by a force pump, driven by clock-work, and there is a simple contrivance which gives notice by the ringing of a bell when the reservoir requires to be replenished. The frame-work of the lenticular (the name given to the whole combination) is firmly attached to a cast-iron circular floor, supported by a stem of cast iron, the lower end of which is let into a block of granite resting on the crown of the supporting dome, where it (the stone) is surrounded by masonry.
The theory of the lenticular may be understood as follows:-the burner being in the focus of the plano-convex lens, the rays of light that impinge upon the inner plane surface emerge outside, horizontal. The bases of the prisms are perpendicular iuside, their upper planes are horizontal, and their hypothenusal planes outside slant downwards and inwards. The depth of each base successively diminishes from 3 inches to $1 \frac{1}{8}$ inch in depth, in the order from the centre lens upwards and downwards, which is the order of the increasing inclination of the impinging rays from the burner. The effeet of the prismatic form is to turn the rays, and to send them out horizontal, upon the same principle by which objects in a horizontal direction in front of a camera lucida are seen by looking down into it. The tiers of reflectors commence at the height and depression where the still greater inclination of the impinging rays from the burner would cause a prism to decompose them in the horizontal direction into the prismatic or rainbow colours. The reflectors are concave towards the lens, their curvatures increasing as they recede from the centre lens. They reflect the rays that fall upon them to the prisms, whence they are sent out horizontal. The two large reflectors behind, on the inside of the door, return the rays from their direction to the large lens, through which they escape horizontal. Thus, all the light from the burner, save the small quantity that escapes up the chimney-glass, is bent into one horizontal sheet.
The whole is protected by a lantern, $10 \frac{1}{2}$ feet in diameter, or 38 feet in circumference, glazed with thick plate-glass and surmounted by a eepper dome, from which a lightning conductor of wire rope descends to the ground. The tower is painted, and shows alfernate bands of white and red, horizontally, two of each.


In clear weather the light can be seen in any direction seaward between East and N.W. by W., at the distance of six leagues from a deck 15 feet high. It is a steady white light.
(Signed) T. Maclear, A.R.
(True copy) E. J. Bourchier, Lieut. Royal Engineers.

## PAPER VIII.

## Note on Diallivg. By Lieutenant St. John, Royal Engineers.

1. If a rectilinear gnomon be placed parallel to the earth's axis, the angular motion of its shadow on a plane parallel to the equator will be uniform. For if the gnomon coincided with the earth's axis, its shadow would revolve uniformly on a plane parallel to the equator, because the sun's diurnal motion may be considered uniform during the same day; and since the distance between the gnomon and earth's axis subtends at the sun an angle, the greatest value of which does not exceed $8.57^{\prime \prime}$, they may be considered coincident; therefore the shadow cast by a gnomon placed parallel to the earth's axis will revolve uniformly on a plane parallel to the equator, at the rate of $15^{\circ}$ an hour.
2. A line drawn from the centre of the dial-plane in the direction of the earth's axis, is called the Style.

A declination circle drawn from the style perpendicular to the dial-plane, intersects it in a line called the Substyle.

The style's height is the angle between the style and substyle.
Hour-lines are lines drawn from the centre of the dial, coincident with the shadow of the style at the interval of each successive hour.

The shadow at any instant is the intersection of the plane of the declination circle in which the sun is at that instant with the dial-plane. Hence the 12 o'clock hourline, which coincides with the shadow of the style when the sun is on the meridian, is the intersection of the plane of the meridian and the dial.

Dials are denominated, according to the position of their planes, Equatorial, Horizontal, Vertical, \&e.

## An Equatorial Dial.

The style in this dial is perpendicular to the dial-plane, and the hour-lines are drawn at intervals of $15^{\circ}$, the 12 o'clock hour-line being the intersection of the meridian with the dial-plane. Since this dial is parallel to the equator, its inclination to the horizon is equal to the complement of the latitude.


General Equation for determining the Hour Angles. Tan. No H-Sin lat. Tan.n. $15^{\circ}$.


General Equation for determining the Hour Angles

Fig.3. East or West Dial.


General Equation for determining the Hour Angles $0 \mathrm{H}=0 \mathrm{~S}$. Tan.n. $15^{\circ}$

Fig. 4. General Dial inclined


General Equation for determining the Hour Angles Tan. S OH = Tan $\left(0-n .15^{\circ}\right) \operatorname{Sin} h$

Fig. 5

A Dial for all Latitudes.


General Equation for determining the Hour Angles
M H $=\mathrm{AM}$. Tan $(3-\mathrm{n}) 15^{\circ}$


The Curve described by the Shadow of a vertical
Gnomon on a horizontal Plane is a conic Section

## A Horizontal Dial.

Let NHLS (Fig. 1) be the plane of the dial, O P the style, N O the 12 o'clock hour-line, which, since the meridian passes through PO perpendicular to the horizon, is also the substyle, therefore PON, the style's height, is equal to the altitude of the pole, or latitude of the place.

At $n$ hours after noon, let OH , to the east of ON , be the hour-line; then drawing the declination circle POH through OH , its plane will pass through the sun, and therefore the angle N P H $=n, 15^{\circ}$; then in the spherical triangle N PH we have the angle $\mathrm{PNH}=90^{\circ}, \mathrm{PN}=$ latitude of the place, arc $\mathrm{NH}=$ angle NOH , and by applying Napier's rules to this triangle, we have

$$
\begin{aligned}
\sin \mathrm{PN} & =\tan \mathrm{NH} \cdot \tan (90-N \mathrm{NH}) \\
& =\tan \mathrm{NOH} \cdot \cot \mathrm{NPH}
\end{aligned}
$$

and, therefore,

$$
\tan \mathrm{NOH}=\sin \text { lat. } \tan n 15^{\circ} ;
$$

which determines the hour-line 0 H , and by giving $n$ the values $1,2,3, \& \mathrm{c}$., the hour-lines corresponding to one, two, three o'clock, may be drawn, and by drawing similarly situated lines on the west side of ON , these will be the hour-lines corresponding to 11 o'clock, 10 o'clock, \&c.

If OL is the last hour-line on any day, $l$ in LO produced is the sun's place at setting, and $\mathrm{N} l=$ sun's north azimuth at setting; Napier's Rules give us

$$
\sin (90-\mathrm{P} l)=\cos \mathrm{PN} \cdot \cos \mathrm{~N} l
$$

therefore

$$
\cos \mathrm{N} l=\frac{\cos \mathrm{P}}{\cos \mathrm{PN}}=\frac{\sin \text { sun's dec. }}{\cos \text { lat. }}
$$

therefore the greatest value of NL which corresponds to the least value of $\mathrm{N} l$, or the extreme hour-line on the dial, is found by the equation

$$
-\cos \mathrm{NL}=\frac{\sin 23^{\circ} 28^{\prime}}{\cos \text { lat. }}
$$

## A Vertical South Dial.

Let ZLN (Fig. 2) be the dial-plane, coinciding with the prime vertical, $O_{p} p$ the style directed towards the South Pole, $\mathrm{Z} p \mathrm{~N}$ the meridian; then ON is the 12 o'clock hour-line, and, since the meridian is perpendicular to the prime vertical, also the substyle, and the angle NO $p=\mathrm{ZOP}=90^{\circ}$ - latitude.

Let OH be the hour-line $n$ hours from noon, then, by Napier's Rules,

$$
\sin \mathrm{N}_{p}=\tan \mathrm{NH} \cdot \tan \left(90-\mathrm{N}_{p} \mathrm{H}\right)
$$

therefore

$$
\tan \mathrm{NH}=\cos \operatorname{lat} \tan n 15^{\circ} ;
$$

from which, by giving $n$ the different values $1,2,3, \& c$., the different hour-lines may be drawn, observing that the hour-lines before noon are to the west of ON, and the others to the east.

If $O L$ is the last hour-line on any day, the sun is then in the plane of the dial at $l$, aud $p \mathrm{~L}=$ sun's north polar distance $=90-\delta$ (declination) ; but Napier's Rules give us
therefore

$$
\begin{aligned}
\cos p \mathrm{~L} & =\cos \mathrm{N} p \cdot \cos \mathrm{NL} \\
\sin \delta & =\sin \text { lat. } \cos \mathrm{NL}
\end{aligned}
$$

which equation determines $N L$, when $\delta=o$ then $N L=90^{\circ}$, and $O L$ is the 6 o'clock hour-line at the equinox. It would be useless to graduate the dial beyond this, because, when the declination is south, the sun sinks below the horizon before he is found in the declination circle perpendicular to the meridian, or before 6 o'clock; and when the declination is north, he is north of the prime vertical, and therefore ceases to shine on the dial before 6 o'clock.

## An East or West Dial.

Let $\mathrm{PO}_{p}$, (Fig. 3) be the dial which coincides with the plane of the meridian, O its centre, $\mathrm{P}_{p}$ parallel to the earth's axis, AS B the style which is parallel to OP, and formed by the edge of a rectangular lamina A D passing through $\mathrm{P} p$ perpendicular to the dial-plane, then, because the plane AD is perpendicular to the meridian, CD is the 6 o'clock hour-line, and because A B is parallel to the planẹ of the dial, all the other hour-lines are parallel to AB or $\mathrm{P} p$.

Let $a \mathrm{H} b$ be the hour-line $n$ hours from 6 o'elock, O SH a plane perpendicular to $\mathrm{P} p$ or AB , intersecting the dial-plane in the line OH ; then because the sun revolves uniformly round AB , we have $\mathrm{OSH}=n 15$, and SOH is a right angle, therefore

$$
\mathrm{OH}=\mathrm{OS} \cdot \tan n 15^{\circ} \text {, }
$$

which determines the hour-line $a b$, and by giving different values to $n$, all the hourlines may be drawn.

As the sun only shines on this dial during half the day, if the dial fronts the east, it points out the time from sumrise to noon; or, if the dial fronts the west, from noon to night.

## A General Dial inclined at any given Angle to the Meridian and Horizon.

Let SON (Fig. 4) be the plane of the dial, inclined at an angle HNR $=\mathrm{N}$ to the meridian PZN , and at an angle $\mathrm{RAN}=\mathrm{A}$ to the horizon; therefore ON is the 12 o'clock hour-line.

Let OP be the style passing through the pole P, OS the substyle, therefore the angle PSN $=90$; but $\mathrm{ARN}=90$, and, by Napier's Rules,
or,

$$
\sin (90-A)=\cos (90-N) \cdot \cos R N
$$

$$
\cos A=\sin N \cdot \cos R N
$$

whence RN , and therefore $\mathrm{PN}=$ latitude +RN are known, and from the rightangled spherical triangle PSN we have, by Napier's Rules,
or,

$$
\sin (90-\mathrm{PN})=\tan (90-\mathrm{SPN}) \cdot \tan (90-\mathrm{N})
$$

$$
\cos P N=\cot S P N \cdot \cot N
$$

which gives S P N $(\boldsymbol{e})$.

Alsn from the same triangle we have

$$
\sin (90-N)=\tan S N \cdot \tan (90-P N)
$$

or,

$$
\cos \mathrm{N}=\tan \mathrm{S} \mathrm{~N} \cdot \cot \mathrm{PN}
$$

which gives SN , the position of the substyle.
The same triangle gives us

$$
\sin S P=\cos (90-N) \cdot \cos (90-P N) ;
$$

or,

$$
\sin S P=\sin N \cdot \sin P N
$$

which determines S P , the style's height $(h)$.
At $n$ hours after noon, let O H be the hour-line; therefore,

$$
\mathrm{SPH}=\theta-n \cdot 15^{\circ} ;
$$

and Napier's Rules give us

$$
\tan \mathrm{SH}=\sin h \cdot \tan \left(\theta-n \cdot 15^{\circ}\right)
$$

from which equation, by giving $n$ the values $1,2,3$, \&cc., all the hour-lines may be drawn.
To show how a dial may be constructed which shall serve for all latitudes:
Suppose the points A, B, of the line A B, moveable in two grooves, C B , C A, at right angles (Fig. 5) to one another; bisect AB in $M$, and take

$$
\mathrm{MO}=\mathrm{AM} \cdot \tan \left(45^{\circ}-h\right) ;
$$

then, if the plane A C B be made horizontal, C B the substyle placed in the meridian, $A B$ slided in such a position that

$$
\tan B=\sin \text {. lat },
$$

and the style have the proper inclination given it, CH will be the hour-line corresponding to the hour-angle $h$, for

$$
\begin{aligned}
\tan \mathrm{BCO} & =\frac{\sin \mathrm{BCO}}{\sin \mathrm{ACO}}=\frac{\mathrm{BO}}{\mathrm{BC}} \cdot \frac{\mathrm{AC}}{\mathrm{AO}} \\
& =\tan \mathrm{B} \cdot \tan h=\sin l \cdot \tan h,
\end{aligned}
$$

since $\mathrm{MO}=\mathrm{AM} \cdot \tan \left(45^{\circ}-h\right)$ gives

$$
\mathrm{BH}=\mathrm{A} \mathbf{H} \cdot \tan h .
$$

Graduate AB by the formulæ,

$$
\begin{aligned}
\mathrm{MH} & =\mathrm{AM} \cdot \tan \left(45^{\circ}-n \cdot 15^{\circ}\right) \\
& =\mathrm{AM} \cdot \tan (3-n) \cdot 15^{\circ},
\end{aligned}
$$

and in any latitude make the adjustments indicated above; then the hour will be shown by the shadow falling on the division of A B.

It may be shown that the curve traced out by the extremity of the shadow of a vertical gnomon belongs to one of the sections of a cone, or in fact is a conic section.

Let AB (Fig. 6) be the gnomon, MAP the plane of the dial, AN the direction of the shadow when the sun is on the meridian at $\odot, \mathrm{AP}$ the direction of any other shadow, the sun having moved from $\odot$ to $\bigodot_{1}$ in the plane of the ecliptic $\odot \odot_{1} \odot_{2}, \mathrm{P}_{1}, p_{1}$, the poles of the equator, $z$ the zenith, N the nadir.

From P draw PN at right angles to A N , and assume $\mathrm{AN}=x, \mathrm{P} \mathrm{N}=y, \mathrm{~A}$ being the origin of rectangular co-ordinates, AN being the direction of the axis of $x$, and a line perpendicular to it and therefore parallel to PN, through A, as the axis of $y$, all in the plane of the dial; also, let $\mathrm{AB}=a, l=$ latitude of the place, $\delta=\bigodot$ 's declination.

Now, by a careful consideration of the figure, it will be evident that

$$
\begin{aligned}
\sin \odot ' s \text { altitude }=\frac{\mathrm{A} \mathrm{~B}}{\mathrm{BP}} & =\frac{\mathrm{AB}}{\sqrt{\mathrm{AN}^{2}+\mathrm{PN}^{2}+\mathrm{AB}^{2}}} \\
& =\frac{a}{\sqrt{x^{2}+y^{2}+a^{2}}} \\
\cos \odot ' s \text { altitude }=\frac{\mathrm{A} \mathrm{P}}{\mathrm{BP}} & =\frac{\sqrt{x^{2}+y^{2}}}{\sqrt{x^{2}+y^{2}+a^{2}}} \\
\cos \odot ' s \text { azimuth }=\frac{\mathrm{A} \mathrm{~N}}{\mathrm{AP}} & =\frac{x}{\sqrt{x^{2}+y^{2}}} .
\end{aligned}
$$

Now, referring again to the figure, we have

$$
\begin{aligned}
& \bigodot \text { 's azimuth }=\text { angle } \mathrm{P}_{1} \mathrm{Z} \bigodot_{1} \\
& 90^{\circ}-\odot ' s \text { altitude }=\mathrm{Z} \bigodot_{1}, \quad \mathrm{P}_{1} \mathrm{Z}=90^{\circ}-\text { latitude } \\
& 90^{\circ}-\odot \text { 's declination }=\mathrm{P}_{1} \bigodot_{1}
\end{aligned}
$$

and by the first fundamental formula of Spherical Trigonometry we have

$$
\cos P_{1} Z \odot=\frac{\cos P_{1} \odot_{1}-\cos P_{1} Z \cdot \cos Z \odot_{1}}{\sin P_{1} Z \cdot \sin Z \odot_{1}}
$$

From which we obtain

$$
\sin \partial^{*}=\cos l \cdot \cos \bigcirc \text { 's alt. . cos azimuth }+\sin l \cdot \sin \bigcirc ' s \text { alt. }
$$

Now, substitute the values of the alt. and azimuth, as given above in terms of $x$ and $y$, and we have

$$
\sin \delta=\cos l \frac{x}{\sqrt{x^{2}+y^{2}+a^{2}}}+\frac{\sin l \cdot a}{\sqrt{x^{2}+y^{2}+a^{2}}}
$$

and, therefore,

$$
\begin{gathered}
x^{2}+y^{2}+a^{2}=\frac{(\cos l \cdot x+\sin l \cdot a)^{2}}{\sin ^{2} \delta} \\
\therefore y^{2}=\frac{\left(\cos ^{2} l \cdot-\sin ^{2} \delta\right) \cdot x^{2}+2 a \cdot \sin l \cdot \cos l \cdot x+\left(\sin ^{2} l-\sin ^{2} \delta\right) a^{2}}{\sin ^{2} \delta}
\end{gathered}
$$

Now, as this equation holds good for every shadow the sun reflects on the dial plane during its revolution in the ecliptic, it is the locus of the curve described by the extremities of all the shadows.

$$
\begin{aligned}
\text { If } \cos l & =\sin \delta, \text { or } l=90^{\circ}-\delta, \text { the curve is a parabola. } \\
\cos l & >\sin \delta, \text { or } l<90^{\circ}-\delta, \\
\cos l & <\sin \delta, \text { or } l>90^{\circ}-\delta,
\end{aligned} \quad \text { hyperbola. } \quad, \quad \text { ellipse. } .
$$

There are some remarkable properties relating to these curves, but the length of this paper, and the principles involved in the investigations, do not admit of those properties being examined. We now pass on to show how the plane of the meridian may be determined: there are methods laid down at page 331, \&c., of the Aide Memoire, and in addition to those the following may be considered as not altogether unworthy of attention. It may be done by fixing a plate of metal at a convenient distance from a plumb-line, and in such a position that two stars whose right ascensions are nearly equal, or differ by $180^{\circ}$ when viewed through a small hole in the plate, are bisected by the plumb-line. Then the plane passing through the hole and plumb-line nearly coincides with the meridian, and true noon happens nearly at the instant when the sun's rays, passing through the hole, fall upon the plumb-line.

The pole star, and $e$ in the tail of the Great Bear, whose difference of right ascension $=177^{\circ} 43^{\prime} 11^{\prime \prime}$, or a Ophiuchi, and $\beta$ Draconis, where the difference of right ascension is $7^{\prime \prime}$, or the pole star and $\gamma$ Cassiopeia, are adapted for finding the meridian by this method.

The time pointed out by a dial is apparent time, but in consequence of atmospheric refraction, which elevates the sun in a vertical circle, the shadow only points out this time exactly at noon; the dial being fast all the morning, and slow in the evening.

The gnomon is generally formed by a triangular lamina of metal ; the sides are, the style, the substyle, and a perpendicular let fall from one or the other. If the thickness of this lamina is considerable, the shadow on the westward edge points out the morning hours, and the eastern the evening; and the hour-lines must be drawn for each separately, so as to form two half dials with different centres. (Vide Fig. 1, facing page 332, "Aide Memoire.")

S. A. St. John,<br>Lieut. Royal Engineers.

[^11]
## PAPER IX.

MEMORANDA on Undersunk Foundations, as executed of late years in the North-West Provinces of India. Communicated by Lieutenant Henry Yule, Bengal Engineers.

The First Number of the " Corps Papers" contained an article by Captain (now Lieut.-Colonel) P. T. Cautley, on the use of wells in wet foundations, as practised by the natives of Upper India.
The following note by Major W. E. Baker, of the Bengal Engineers, contains a brief notice of a modification of that system, first introduced by Colonel John Colvin, C.B., when Superintendent of Canals in the North-West Provinces of India, and further improved by the former officer in works executed by him.

Note on the method of Bloch Foundations in use on the Delhi Canal, and on the particular modification of them employed in the Construction of the Rudour Bridge.

The method of founding on wells, or cylinders of masonry, sunk to the required depth through sand or loose soil, has been employed in India from time immemorial, and is too well known to need description. It is generally employed where piles would be employed in Europe, and is both more substantial than the latter method, and better suited to the circumstances of a country where timber is generally scarce, and brickwork comparatively cheap.

In constructing some of the larger works on the Delhi canals, Colonel Colvin at first employed cylinders of the description alluded to above, but finding them liable to objections on account of the hollow spaces left between them, and of the necessity of vaulting over the shafts, and connecting the cylinders at a low level, he successfully substituted rectangular blocks of masonry perforated with shafts, through which the process of undersinking was carried on similarly to that of cylinders. This method was found particularly valuable in the foundation of the great dam at Dadoopoor, which being intended to hold up water, it was an object to have a connected line of deep masonry to prevent under-leakage.

In the Madhilpoor Bridge (commenced under Colonel Colvin) the disposition of the foundation blocks was as in the annexed Figs. (PI. 1, Figs. 1, 2, 3.) It was still necessary to connect the foundations at a depth of $26^{\prime \prime}$ below foundation surfacelevel, or about 8 feet below the surface of the canal.

In the Jhydree and Indree suspension bridges, where the abutments required a broader base, the blocks were disposed as in Fig. 4.

Fig.4. Plan of Abutment


Fig. 8. Plan.


Fig.9. Section


At Jhydree the blocks were sunk to a depth of 13 feet, through coarse gravel mixed with large boulders. At Indree they were carried to a depth of 35 feet, entirely through sand. In both these cases it was necessary to bale out the water, and connect the foundations at a depth of 5 feet and 8 feet respectively below the surface-level of the canal.

In the foundations of the Rudour Bridge, this necessity, and the expense and trouble which it entailed, were successfully avoided, by adopting the description of block shown in Figs. 5, 6, 7 (Pl. 1).

Each pier, and the east abutment, were sunk respectively in one mass; the probable depth to which they were to be carried having been previously determined, the width of masonry was reduced by offsets with reference to that depth, and the shafts (also reduced) were continued up through the superstructure. Thus, when the bottom of the block had reached the required level, the surface of the masonry was still above water, the shafts were filled and closed over without difficulty, the expense of baling water was saved, and the coffer-dam need have been only of such strength as to insure still water round the pier while the process of sinking was going on. In this work we took the precaution of making the curb-framing under the masonry of very stout timber, and the result was, that the cracks were fewer, and of less consequence, than had been observed in the smaller blocks hitherto used.
This being probably the first attempt ever made to undersink a mass of such irregular shape, some further details of the operation may be interesting. On the site of the east abutment, the canal had deposited sand nearly to the surface-level of the water, and on this an additional quantity was thrown by labour, so as to form a level platform of sand just above water-level. Over the whole of this space borings were made with an earth-borer to a depth of 20 feet, and the conclusion arrived at was, that the soil to that depth consisted of sand, interspersed with a few lumps of clay. This opinion afterwards proved to be erroneous, there having been a stratum of clay about $1^{\prime} 6^{\prime \prime}$ thick, at a depth of 8 feet below the surface. The error is attributed entirely to the borings having been made without tubes, the clay baving probably been displaced from the auger by sand during the process of drawing it up, and shows how little dependence should be placed on the result of boring experiments unless when tubes are used. Under the supposition, however, that nothing but sand would be encountered down to the depth ( 16 feet) at which it was intended the blocks should rest, the curb-framing was placed and built upon to the height of 4 feet. The sinking was then commenced, and the mass was lowered to the level of the water, when an additional 2 feet of masonry was built, and so on, until its progress was stopped by the stratum of clay before mentioned, at a depth of 8 feet. Our efforts, maintained for several days, to force the block through the clay, were unavailing. The part immediately under the shafts was removed, but the rest was inaccessible to the divers, and we were obliged to suspend work until an opportunity offered for turning off the canal for four days. During this time we cut through the stratum of clay outside the block all round, and it then came up piecemeal through the shafts. No further difficulty was experienced in sinking the block to the required depth. During the progress of the work, great care was taken to keep the surface of the block horizontal, and a head-bricklayer was constantly employed in measuring the height all round, suspending work when the sinking was going on too rapidly, and generally directing the labours of the well-sinkers. It appears, however, from our experience on this occasion, that the attempt to sink so large and irregular a mass should not be made

[^12]unless it be fully ascertained, in the first instance, that no obstructions will be met with down to the depth which may be considered necessary.

(Signed) W. E. Baker, Captain, Superintendent Canals West of Jumna.

In Camp, Bhugwanpoor; Jan. 6, 1842.

Pl. 1, Figs. 8 and 9, represent a smaller work of the same kind, executed in 1846 , in renewing the abutment of a timber bridge at Phoorluk, on the Delhi Canal, which had been undermined by a flood.

But the work in which this system of block foundations has been most extensively carried out, is the Solani Aqueduct on the Ganges Canal, as designed by Lieut.Colonel Cautley of the Bengal Artillery.
The accomplishment of this great project, after undergoing various vicissitudes of favour from different governors, has been for some years past steadily advancing. Its head works are near Hurdwar, a well-known place of Hindoo sanctity, situated, as the name implies, in the portal where the Ganges quits the last outskirts of the Himalayas, and rolls its broad waters over a stony bed for the last time.

The line of the canal, in sweeping round the shallow valley of the Ganges to reach the dorsal ridge of the Doab, along which it will run for about 350 miles *, diffusing irrigation right and left, has to cross several streams which run obliquely down from the Siwalik, or sub-Himalayan range, to enter the Ganges on its right bank.

Four of these occur within the first 18 miles of the canal's course, all more or less of the same character. They have broad channels of pure sand, dry on the surface for several months, permeated by a mere thread of water for several more, but during the rainy season maintaining the semblance of respectable rivers, and every now and then bursting into full flood, which comes racing down like a charge of cavalry.

Under two of these the canal will be conducted: another it will cross at the level of its bed, by aid of a retaining dam, or Barrage, with sluice shutters. The fourth, called the Solāni, flowing in an alluvial hollow upwards of two miles in breadth, is the greatest obstacle, since the canal bed must pass at a level of 24 feet above the river, and about 16 above the flat valley.

The valley is crossed by an earthen aqueduct, affording 150 feet bottom width of channel, which is puddled and inclosed by a double wall of brickwork on each side, rising from the natural surface, and backed by massive road embankments.

This work was commenced in September, 1846, and is now far advanced.
The river Solāni is crossed by a masonry aqueduct or bridge, carrying a channel of 180 feet in clear width. It consists of 15 arches of 50 feet span, and measures 890 feet between the abutments. It is in the foundations of this work that the system of block-sinking has been practised on such an extensive scale.

[^13]The general plan of the foundations is shown in Fig. 1, PI. 2. The foundations of each pier consist of eight blocks of briekwork, measuring 22 feet by 20 in surface, and 20 feet in depth, sunk flush with the level of the flooring of the waterway, at intervals of 2 feet 3 inches only. Each block contains four shafts or wells, in which the excavation was carried on in the manner to be described hereafter.

The principal blocks of the abutments measure 26 feet by 22 superficially. Those supporting the wings of the abutments are of various inferior sizes.

There is also a small block at each end of every pier supporting the cutwaters ; and a line of almost contiguous blocks forms a protecting curtain for the whole length of the bridge, on both upstream and downstream sides. The whole of these are sunk to a depth of 20 feet.

For the convenience of accounts, these foundation-blocks, whilst in progress, were divided into four classes, according to size; the first class embracing the large blocks of the abutments ; the second, those of the piers and ends of abutments ; the third, those on the exterior flanks of the abutments; and the fourth, all the smaller blocks having only two shafts. The total number of blocks is as follows. (See also Pl. 2, Figs. 2, 3, 4, \&c.)


Containing, when completed, about $1,700,000$ cubic feet of brickwork. In his are not included a number of other blocks connecting the abutments of the aqueduct with the walls which inclose the earthen embankment across the valley. The position of these is shown by the unshaded blocks, $a, a$, in PI. 2, Fig. 1.

In commencing the foundations of a pier, the sand was dug out within an inch or two of the water-level, and the position of the eight principal blocks marked off accurately from the axis of the aqueduct. Curb-frames of whole timbers, running generally from 10 to 13 inches square (see PI. 3), were then laid down, levelled, and built on to a height of 12 feet. In building, five bonds of hoop-iron were laid in every foot of height, this way and that way alternately (see $h, h$, isometrical section of a block, Pl. 4, Fig. 5). The process of undersinking was then commenced, and the block sunk flush with the water. The remaining 8 feet of masonry was then added, but without the use of hoop-iron, and, when completed, undersinking was renewed till the full depth was attained.

Considerable saving was effected when the blocks could be commenced about April or May. The water was then at its lowest level, 2 or 3 feet under the general surface of the river bed, so that the curb frames could be laid several feet lower than in the months of October and November, immediately succeeding the rains, and a considerable fraction ( $\frac{1}{7}$ to $\frac{1}{6}$ ) of the whole amount of labour in undersinking was thus avoided.

In the first blocks which we built, the wells were octagonal in plan from bottom to top. But from a growing conviction that this form, though adding to the mass of masonry, added nothing to its strength, from its destroying the bond of the brickwork, and inducing careless workmanship, first the upper part of the blocks (as in Fig. 5, Pl. 4) was built with rectangular shafts, and latterly the entire blocks were so con-
structed. Skewbacks ( $s, s$, Fig. 5) were left near the top of every well for a three-brick arch to vault it over, as well as on the exterior of each block ( $r, r$, Fig. 5), in order to connect it with that adjoining. So that the foundation of a pier, when finished, presented a solid and continuous platform of brickwork, measuring 192 feet by 20.
The lime used was derived from the limestone boulders gathered in the bed of the Ganges and its tributaries; the mortar employed consisting of a mixture of lime and pounded brick, in the proportion of two-thirds of the latter to one-third of the former. This mixture was strongly hydraulic, though not setting very rapidly.
The usual manner of well-sinking by means of divers has been described in Colonel Cautley's Paper, referred to above. The works of the Solāni Aqueduct were commenced in the same way, but the number of professed divers being very limited, and their wages high, the work was both expensive and slow; it was, therefore, most desirable to adopt some way of working which common labourers could carry on. After trial of some schemes more ingenious than practicable, a modification of the jhäm, or ordinary well-sinker's tool, was found to answer very well.

The size of the blade used (see Pl. 4, Fig. 6) was about 24 inches by 22 inches, slightly concaved; a handle of flat iron, with a ring at the extremity, $a$, was substituted for the common wooden helve, and to the back of this handle a socket, $b$, was attached, to receive the end of a long pole. In front of this socket was a hook, $d$, curving downwards. The rope was finally attached to the ring $a$, but a yard and a half from the end of it a loop or ring was inserted between the strands, which could be hitched over the hook $d$. It is plain that when suspended by $d$, the jhām would hang vertical, with a slack bight of rope from $d$ to $a$, but when slung by $a$, the blade would be nearly horizontal.
The mode of working this tool is illustrated in the four wells shown in section (Pl. 4, Figs. 1, 2, 3, 4). The rope bearing the jhäm swung by the hook $d_{\text {, }}$, was attached to the barrel of a common handspike windlass, over the well. The long pole was inserted in the socket $b$, and by that means the blade was forced down into the sand. As soon as the blade touched the bottom, the loop at $d$ fell off; consequently, as soon as the jhüm had been forced up to the head, or as far as it would go, and the windlass was brought to bear, the lift was on the handle at $c$, and the blade, rising horizontally, scooped up with it a mass of sand. This was discharged from the top of the block by a trough, carried off in baskets, and laid in the bed of the river, to be disposed of by a future flood.
Thus the work was carried on entirely from the surface, only two or three divers being retained in case of breakage of tools or other accidents under water.
Three cubic feet was the largest quantity of sand that I saw raised by one lift of the jhām.

Excavation was always commenced by ordinary digging, both inside the wells and round the exterior of the blocks, to as great a depth as this could be carried.

The daily progress, as might be expected, varied with the depth attained, and it was found to be of great consequence to keep working. If, after sinking a block to a depth of several feet, the work was suspended, it was not till several days after the resumption of the work that good progress recommenced. This of course was owing to sand settling again in the wells and hollows round the masonry; and from this cause we found so great advantage in economy, as well as time gained, by continuing the work day and night, by reliefs of workmen, that latterly this practice was always maintained during the hot months, from March to June.

The following Table shows the average, on a considerable number of bloeks of the different sizes, of the daily progress in sinking by the process described,

| Class of Found-ation Blocks (see Pl. 2). | eachaffording theaverage. | Depth in feet |  | Entire depth feet. | $\begin{array}{c\|} \text { Average } \\ \text { number } \\ \text { of days } \\ \text { occupied. } \end{array}$ | A verage daily rate'of sinking, in feet and decimals. |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{aligned} & \text { To which } \\ & \text { the first } 12 \text { fee of ma- } \\ & \text { feotry had } \\ & \text { so be sunk. } \end{aligned}$ | Through <br> which ad- <br> ditionally <br> the com- <br> pleted <br> block had <br> to be sunk. |  |  |  |  |  |
|  |  |  |  |  |  | $\begin{gathered} \text { For the } \\ \text { first part } \\ \text { of each } \\ \text { block. } \end{gathered}$ | For the completed | $\left\lvert\, \begin{gathered} \text { On } \\ \text { the } \\ \text { whole } \\ \text { process. } \end{gathered}\right.$ |
| First Class | 10 | 12.2 | ... | ... | 19.1 | -638 | $\ldots$ | $\ldots$ |
| Second Class | 1 | $12 \cdot 125$ |  |  | 15 | 88 |  |  |
| Ditto. | 10 | 14.063 | 8 | 22.063 | 57.4 | 694 | -293 | -384 |
| Third Class | 4 | 12.22 |  |  | $15 \cdot 5$ | 78 |  |  |
| Ditto. |  | 1386 | 8 | 21.86 | 40.5 | -692 | 44 | . 54 |
| Fourth Class | 8 | 13.25 | 8 | 21.25 | 49 | $\cdot 678$ | $\cdot 341$ | $\cdot 43$ |

These results are derived from the progress of operations during part of the hot season of 1848, soon after the system of the work had been matured. The completion of the foundations since that period must have afforded far more valuable averages.

The work abstracted in the above Table was carried on by day and night, continuously (excepting Sunday); and the days registered represent the number of days of twelve hours for which wages were paid. Hence the real time occupied was only half that exhibited.

In sinking the four-shafted blocks, trifling divergencies from the perpendicular were not much regarded, as there was little difficulty in rectifying them by suspending excavation on the lower side. In a few instances, from working the jhüm too much towards the exterior of the larger wells, rents occurred in the masonry, as if from the hogging or convexing of the curb-frame. As soon as these were perceived by the officer in charge, the work was directed vigorously towards the centre of each block, which always had the effect of completely re-closing the fissures.

Though our boring had given no result but sand to a depth of 32 feet, yet under some of the piers thin local beds of clay and mud were met with. These occasloned great delay, as in such places the extraction of hundreds of cubic feet of soil scarcely affected the level of the blocks a hair's breadth. This was most especially the case with the foundations of the pier first undertaken. The large timbers on the outside of the curb, instead of being halved into each other, so as to form a flushframe (as in Fig. 1, Pl. 3), were only checked into one another one inch either way, and strongly bolted (see Fig. 3, Pl. 3) ; and the hollow spaces thus left under two of the four sides of the curb-frame happened to be turned to the outer sides of the pier, that is, towards the waterway of the adjoining arches, without any anticipation of evil consequences. The result appeared to be, that the curb-frames continued to rest nearly unmoved on the lower beams, $c c$, whilst the spaces under $b b$ formed bridges, or open traps, through which a constant flow of mud took place to replenish the wells as fast as they were emptied by the jhäm. At last, we were compelled to inclose the most refractory blocks in sheet-piling, in order to complete the sinking.
The encounter with pieces of timber was also a serious obstacle. In a part of the work a species of coffer-dam had been formed to exclude floods, the piles of which had been at one point breached and submerged. Here these obstacles were not unfrequent, and were very troublesome when they lay athwart the wells at a
considerable depth in the water. The best way to get rid of them was found to be by boring several contiguous holes through the timber, with a long auger, and then breaking it through by a violent blow with a heavy beam, after which there was little difficulty in removing the separate pieces.

The two-shafted blocks (see Figs. 7, 8, 9, Pl. 2) were not so easily guided in their descent. If they leaned over to one side, as they were very apt to do on account of the narrow base, it was exceedingly difficult to restore them; one went suddenly to pieces, probably from a sudden falling in of sand, and consequent fracture of the curb-frame, involving the loss of two lives, and forming a grievous obstacle to its replacement by another block, This was, I believe, the only fatal accident on this branch of work during three years of its progress.
At the suggestion of Mr. Thomas Login, a young engineer assistant on the work, the experiment was tried of building these narrow blocks in the form of an inverted wedge, the side walls having a considerable batter on the outside. In this form these blocks preserved their upright position much better.

A curious phenomenon several times occurred when excavation of sand from the wells had been going on some time with little visible result. The water in all the four wells of a block would boil up over the surface of the brickwork, with sudden commotion, pouring over the edge of the masonry back into the river, the level of which was several feet below. This was probably occasioned by the sudden fall of a mass of sand into the excavated hollow at the bottom of the wells.

In general, this hollow was continuous between the four wells, so that a diver could pass from one shaft to another beneath the curb-frames; and it was a jest of some of the younger assistants attached to the works, to bespeak the admiration of visitors to the length of tine a native diver could remain under water, the said diver passing under the partition wall and comfortably taking the air at the surface of the adjoining well, until the limit of the visitor's belief was thought to be reached.

As some little shifting took place with every one of these great masses, in the process of sinking, of course the line of a pier's foundations after being sunk, though affording ample verge and room enough for the superstructure, was not so mathematically straight as before sinking commenced. When Lord Gough honoured the works with a visit, one of his party remarked that the blocks did not seem very well dressed. "Never mind," said the gallant old chief, characteristically, " It's a capital fighting line."

The aqueduct has made great and accelerated progress since I last saw it, in July, 1849. The whole mass of foundation, and much of the superstructure, is, I believe, complete. Not knowing when leisure will be granted to my friends now in charge, to publish a full account of the progress of the work and of their more advanced experience, I have thought it desirable, meanwhile, to give this sketch of an interesting part of the operations.

The works of the Ganges Canal were commenced, and preparations for the aqueduct were begun, by Lieut. Richard Strachey, B.E., as Executive Engineer. The foundations were entered on by his successor, the present writer, when he took charge of the works, in June, 1846; and were carried on by him under Major W. E. Baker, and afterwards Lieut.-Col. Cautley, as Directors of the Ganges Canal, till April, 1848. Since then the operations have been conducted by Lieut. Alfred Goodwyn, and so continue.
H. Yule,

Lieut. Bengal Engineers.

## PAPER X.

## note on the Equiltbrium of the Arch. By Lieut. St. John, Royal Engineers.

The object of this paper is not to deduce a new theory of equilibrium of the arch; it is to show the great utility of an important mechanical principle, and one not generally applied by mathematicians of the present day in inquiries of a similar nature.

The famous French engineer Belidor, in his work "La Science des Ingenieurs," has treated at length on the equilibrium of the arch under a number of different heads; and a vast deal of information may be attained by a careful perusal of that celebrated author's work, especially that portion of it which treats "de la Theorie de la Maçonnerie."

The important principle which we are about to apply, the Principle of Virtual Velocities, may be briefly stated as follows :-
" If any system of bodies or points, solicited each of them by any forces whatever, be in equilibrium, and we conceive this system, consistently with its geometrical relations, to experience any small arbitrary displacement, by virtue of which each point describes an indefinitely small space, the sum of the forces multiplied each of them by the resolved part, parallel to its direction of the space described by its point of application, will be always equal to zero; this resolved part being considered positive when it lies in the direction of its corresponding force, and negative when in an opposite direction."
The resolved part of the spaces described by the points of application of the forces, are called their Virtual Velocities.

If P, Q, R . . . denote any system of forces acting on a system of points consistently with equilibrium, and $\alpha, \beta, \gamma \ldots$ denote their virtual velocities, then

$$
\begin{equation*}
\mathrm{P} \cdot \alpha+\mathrm{Q} \cdot \beta+\text { R. } \gamma+\mathrm{S} \cdot \delta+\ldots=\sigma \tag{B.}
\end{equation*}
$$

This principle was first discovered by Guido Ubaldi as a property of the equilibrium of the lever and moveable pulleys; it was, however, subsequently recognised by Galileo in the inclined plane, and other machines depending upon it.

John Bernoulli was the first to announce the principle in a more general aspect. He communicated it to Varignon in a letter dated Bâle, Jan. 26, 1717.
Wallis and Descartes both followed the principle laid down by Galileo as the fundamental principle of statics. The striking value of the principle has been splendidly exhibited by Lagrange in his "Mécanique Analytique." A very elementary investigation is to be found in Boucharlat's "Traité de Mecanique." He sets out with the following remark, p. 152:-" Lagrange, qui l'a pris pour base de sa Mécanique Analytique, le regarde comme si essentiel, qu'il pense que tous les moyens generaux que l'on peut employer pour la solution des problemes qui concernent l'equilibre, ne sont que des applications plus ou moins directés de ce principe."

Having briefly noticed the principle, as laid down by some of the best authorities, we proceed to its application, for which purpose,
Let ABCD .... be any portion of an arch in a state of equilibrium,

E E $\mathbf{M M}^{\prime}$ the key-stone, which will be equally divided by a vertical line, A D, drawn through the highest point, or crown.

Fig. 1.


W the weight of the key-stone;
$\mathrm{W}_{1}, \mathrm{~W}_{2}, \mathrm{~W}_{3}, \ldots . .$. the weights of the several voussoirs;
$\alpha, \alpha_{1}, \alpha_{2}, \alpha_{3}$, the angles which the joints make with the vertical line; and
$\mathrm{H}^{*}$ the horizontal thrust, which will be the same throughout the arch, or an equilibrium could not exist.

Now, the half key-stone, AEMD, and the several voussoirs, are kept at rest by three forces respectively, their own weights $\frac{1}{2} \mathrm{~W}, \mathrm{~W}_{1}, \mathrm{~W}_{2}, \mathrm{~W}_{3}, \ldots$ in the direction of gravity, and two other pressures, the one in an upward direction ${ }_{3}$ and the other downwards, these several pressures being at right angles to the several joints AD, E M, FL, . . . and being

$$
\begin{gathered}
O G=H, \quad O_{1} G=H \cdot \sec \alpha=O_{1} G_{1}, O_{2} G_{1}=H \cdot \sec \alpha_{1}=O_{2} G_{2}, \\
O_{3} G_{2}=H \cdot \sec \alpha_{2}=O_{3} G_{3} \cdots
\end{gathered}
$$

Having reduced the arch into a system of points $G, G_{1}, G_{2}, G_{3}, \ldots$ each of them solicited by three forces, conceive that, by an instantaneous derangement, these points experience an indefinitely small displacement in a vertical direction, by moving downwards in the direction of gravity, by virtue of which they assume the positions $\mathrm{G}^{\prime}, \mathrm{G}_{1}^{\prime}, \mathrm{G}_{2}^{\prime}, \mathrm{G}_{3}^{\prime}, \ldots$ the several lines $\mathrm{GG}^{\prime}, \mathrm{G}_{1} \mathrm{G}_{1}^{\prime}, \mathrm{G}_{2} \mathrm{G}_{2}^{\prime}, \mathrm{G}_{3} \mathrm{G}_{3}^{\prime}$, . . . . being indefinitely small, may be regarded as straight lines; and the several points being in equilibrium collectively, are so separately, and we are, therefore, at liberty to reason on them singly; resuming, therefore, our formula

$$
P \cdot \alpha+Q \beta+R \cdot \gamma+S \delta+\ldots=0 \ldots \ldots \ldots \ldots \ldots(B)
$$

we have for the half key-stone AEMD

$$
P \cdot \alpha+Q \cdot \beta=0 .
$$

Now, the virtual velocity of $\frac{1}{2} \mathrm{~W}=\mathbf{G G}$, and the virtual velocity of the force in the direction $\mathrm{O}_{1} \mathrm{G}=\mathrm{H} . \sec \alpha$, is the little line $\mathrm{G} m$.

$$
\text { Hence } \begin{aligned}
\mathrm{P} & =\frac{1}{2} \mathrm{~W} \cdot \alpha=\mathrm{GG}^{\prime} \\
\mathrm{Q} & =\mathrm{H} \sec \alpha \cdot \beta=-\mathrm{G} m
\end{aligned}
$$

We have, therefore,

$$
\frac{1}{2} \mathrm{~W} \cdot \mathrm{GG}^{\prime}=\mathrm{H} \sec a \cdot \mathrm{G} m
$$

But since $\mathbf{G} m=\mathrm{GG}^{\prime} \cdot \sin \approx$, we have

$$
\begin{aligned}
\frac{1}{2} \mathrm{~W} \cdot \mathrm{GG} & =\mathrm{H} \cdot \sec \alpha \cdot \mathrm{GG}^{\prime} \cdot \sin \alpha, \text { or } \\
\frac{1}{2} \mathrm{~W} & =\mathrm{H} \cdot \tan \alpha, \text { and therefore, } \\
\mathrm{H} & =\frac{\mathrm{W}}{2 \tan \alpha} \ldots \ldots \ldots \ldots \ldots(1) .
\end{aligned}
$$

Reasoning in a similar manner with the voussoir EFL M, we have

$$
+Q \cdot \beta+R \cdot \gamma=0
$$

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Now,

$$
\begin{gathered}
\mathrm{P}=\mathrm{W}_{1}, \quad \alpha=\mathrm{G}_{1} \mathrm{G}_{1}^{\prime}, \quad \mathrm{Q}=\mathrm{H} \sec x, \quad \beta=\mathrm{G}_{1} m_{1}, \\
\mathrm{R}=\mathrm{H} \sec \alpha_{1}, \quad \gamma=-\mathrm{G}_{1} m_{2}, \text { therefore } \\
\mathrm{W}_{1} \cdot \mathrm{GG}_{1}^{\prime}+\mathrm{H} \cdot \sec \alpha_{1} \cdot \mathrm{G}_{1} m_{1}-\mathrm{H} \cdot \sec \alpha_{1} \cdot \mathrm{G}_{1} m_{2}=0 \text {, hence } \\
\mathrm{W}_{1} \cdot \mathrm{G}_{1} \mathrm{G}_{1}^{\prime}=\mathrm{H} \cdot \sec \alpha_{1} \cdot \mathrm{G}_{1} m_{2}-\mathrm{H} \cdot \sec \alpha \cdot \mathrm{G}_{1} m_{1} \text { 。 } \\
\text { Now, } \mathrm{G}_{1} m_{2}=\mathrm{G}_{1} \mathrm{G}_{1}^{\prime} \cdot \sin \alpha_{1}, \quad \mathrm{G}_{1} m_{1}=\mathrm{G}_{1} \mathrm{G}_{1}^{\prime} \cdot \sin \alpha, \text { hence } \\
\mathrm{W}_{1} \cdot \mathrm{G}_{1} \mathrm{G}_{1}^{\prime}=\mathrm{H}\left\{\sec \alpha_{1} \cdot \sin \alpha_{1}-\sec \alpha \cdot \sin \alpha\right\} \cdot \mathrm{G}_{1} \mathrm{G}_{1}^{\prime}, \\
\text { or, } \mathrm{W}_{1}=\mathrm{H}\left(\tan \alpha_{1}-\tan \alpha\right) ; \operatorname{similarly}, \\
\mathrm{W}_{2}=\mathrm{H}\left(\tan \alpha_{2}-\tan \alpha_{1}\right), \\
\mathrm{W}_{3}=\mathrm{H}\left(\tan \alpha_{3}-\tan \alpha_{2}\right), \\
\mathrm{W}_{4}=\mathrm{H}\left(\tan \alpha_{4}-\tan \alpha_{3}\right), \\
\vdots \quad \vdots \\
\vdots \\
\&
\end{gathered}
$$

The same method of reasoning is applicable throughout the entire arch.
From the above relations, it is evident that the ratio that the weights of the several voussoirs must bear to each other, is "as the difference of the tangents of the angles which their joints make with the vertical." From these conditions, we may either determine the weights when the inclination of the joints are given, or vice vers $\hat{\text { a }}$.
In a future paper, we propose to explain in what manner friction tends to preserve the equilibrium of the arch, and some other pronerties dependent on mechanical principles.

## PAPER. XII

PLAN \& SECTION OF THE SEA WALL OR BREAKWATER IN FRONT OF THE CTRCULAR REDOUBT NEAR HYTHE


## PAPER XI.

The Sketch of a Monument which will be found among the Plates in this Volume, erected at Ceylon, by subscription, to the memory of the late Captain Wm. F. Dawson, Royal Engineers, has been sent to the Editors of the Professional Papers, as deserving of record in the annals of that Corps, with an extract from a General Order, dated Colombo, 2nd April, 1822.

## EXTRACT FROM GENERAL ORDERS.

"Colombo, 2nd April, 1822.
" M. General Sir Edwd. Barnes cannot allow Capt. Dawson, of the Royal Engineers, to quit this island, without the strongest expression of his admiration of the zeal, talent, and exertion he has displayed for the public service. The laborious undertakings in which he has been engaged have impaired his health, and have compelled him to return to Europe, where, however, it is hoped that a speedy recovery will enable him to reflect with pleasure on the great good he has done.
" Under any circumstances, the Giriaga and Galgeddera, but more particularly the Kaduganawa Pass, will stand the test of time, as lasting monuments of his fame, and on which the name of Lieut. Yule of the Royal Engineers, must also be inscribed."

## PAPER XII.

On a mode successfully adopted for Preserving the Breakwater at the Circular Redoubt, near Hythe, from the action of the Sea. By Captain Skyring, Royal Engineers.

The Breakwater at the Circular Redoubt near Hythe, having repeatedly got damaged by the action of the sea, and at times to such an extent as to put in jeopardy the fort itself, a new one was proposed and executed, under the superintendence of Colonel Tylden and Captain Gordon, R.E. (Mr. Howe, C.W., and Mr. Studd, Foreman); but, notwithstanding this, the sea in heavy gales caused damage, and the foot of the wall was endangered by the shingle being carried away. This probably was occasioned by the sea-wall maintained by the Lords of the Romney Marsh, which joins the Breakwater on either side, and the foot of which projects beyond it, as shown by the dotted lines, $g h, k l$, on sketch. See Plate.

To remedy this evil, Captain Gordon, R.E., proposed to run sheet-piling, $a b, b c$, in the form of a salient angle, towards the sea, which being approved of by the Commanding Engineer, was carried into effect, and has been found to answer very uell.

The action of the tidal influence appears to be diverted along the faces $a b, b c$, and the impetuosity of the waves abated in their progress and reaction.

The planking serves as a groin to retain the shingle, which is generally kept well up to the foot of the Breakwater; and since it has been laid down for nearly two years, there is, I think, every chance of its continuing to act beneficially towards the preservation of the work.

## C. F. SKYRING,

Captain, Royal Engineers.
Hythe, Aug., 1850.

## PAPER XIII.

## I. PRELTMINARY OBSERVATIONS on the Mining Operations

for Blowing Down the Cliff near Seaford, on the Coast of Sussex, in August and September, 1850. By Major-General Sir John F. Burgoyne, K.C.B., Inspector-General of Fortifications.

Along the coast of Sussex, the banks of shingle afford protection to the rich low lands within them from the encroachments of the sea.

The shingle, however, is in a gradual but irregular state of movement from west to east, and at times a great impression is made on particular parts, that would lead to much damage, if not arrested by projections of timber and planking, between high and low-water marks, termed groins. These groins are very expensive, and their useful effects extend but for a short distance.

Mr. William Catt, jun., whose family have considerable possessions in the plain between Newhaven and Seaford, a distance of about three miles, considered that by

Vide lithographed map of the coast, No. 1. constructing a very substantial groin on a large scale, under the Cliff near Seaford, which is at the east extremity of the plain above mentioned, and the foot of which cliff was washed by the sea at high-water, and thus stopping the progress of the shingle, it would have some influence in protecting the whole extent of the beach to Newhaven.

He also considered that the most efficient, lasting, and economical mode of establishing such a projecting obstruction would be by throwing down the cliff, which was nearly perpendicular, and about 200 feet high, on to the beach, by a great explosion of gumpowder.

The Board of Ordnance was applied to for assistance, and it was finally agreed, that the Royal Engineer Department, without being responsible for the effects as regarded the ultimate protection to the lands, should undertake the mechanical operation of blowing the cliff down.

The estimate amounted to $800 \%$; and in consideration of two batteries and a tower that belonged to the Board, and on the side that was nearest to the part to derive any benefit from the operation, the Board consented to incur 300l. of the expense, the private parties paying the other $500 l$.

Colonel Lewis, C.R.E. of the district, had the control of the whole service, and appointed Captain Frome, R. E., to be the executive officer in charge, having under him Lieutenant Warde, R.E., who had some experience in mining and blasting ope-




1.2.3.4.5 Charges of 600 tbs each

Fig. 5
Plan of Seaford Cliff


$$
\frac{\text { Low Wazer Ordinary Sorings }}{\text { Nins. }}
$$

$\qquad$

GROVE'S BATTERY,
1/4 Size
Section on Line A.B.
Fig. 1 .


Filevation of Clamp
Full Size




Plan of Battery and Box


Section on Line A.B
Fig. 5


Scale ${ }^{1 / 2}$ of the full size

Plan of Smee's Battery.
Fig. 6


John Weale 59 High Halborn Ayril 1851
rations; and the major part of the 4th Company, Royal Sappers and Miners, were employed in executing the work.

A project was first devised by Captain Frome, which was modified by Colonel Lewis, and subsequently by the Inspector-General of Fortifications.

In the main feature of the application of the two great charges, there was no difference in principle between the three, though there were some in the proposed modes for carrying it out, as will be subsequently explained.

The plan finally adopted was to lodge two large charges, each of $12,000 \mathrm{lbs}$. of powder, 120 feet asunder, with lines of least resistance of 70 feet to the face, and 58 feet above the level of the foot of the cliff.

Five smaller charges, of 600 lbs . each, were to be placed in rear, at a higher level, to clear that part from overhanging remains; and the whole to be fired by voltaic batteries, the two main charges first and simultaneously, and the five smaller ones immediately after. In consequence of not receiving in time a supplementary demand of gunpowder, only three of the smaller charges were loaded.

Everything being prepared, on the 19th September, at 3 P.M., the circuit of the wires connected to the two great charges was completed at the batteries, and on the instant the ignition of both took place, throwing down the face of the cliff for a length of 500 feet, and to the rear 15 or 20 feet beyond the five shafts, so as to bring down and bury the three upper charges unfired, cracks and fissures extending nearly to the shed in which the batteries were placed.

Plan, No. 3, shows the result of the explosion of these two mines; and on the sections is also described the effect produced by the action of the sea upon the mound formed by the fall of the cliff on the 25th September and 18th October.

The projection of the mound, as first thrown out, was about 300 feet.
The mass thrown down, according to dimensions taken the day after the explosion, was about 200,000 cubic yards, or 292,000 tons nearly, at 121 lbs . per cubic foot, which was found by actual trial to be the specific gravity of the chalk.
J. F. B.

## II. Mining Operations at Seaford. By Captain Frome, R.E.

The opening made in the face of the cliff for the commencement of the central gallery by which both the chambers were reached, was 35 feet above the high-water mark (ordinary spring tides), which, at this spot, was the level of the beach at the base of the cliff. It was commenced on the 20th August, 1850, from a rough stage supported by scaffold poles, and reached by a common ladder, the stage being necessary in consequence of the impossibility of making any impression on the face of the cliff by men working on the ladder itself". A mound of chalk, that had

[^14]fallen a few days before just at the spot, afforded, when levelled on the top, a base Scaffolding. 14 or 15 feet above the beach, on which to erect the scaffolding. As soon as the men had penetrated a sufficient distance into the eliff to be able to work in security, the scaffolding was strengthened, and a convenient platform with a step ladder constructed for use during the remainder of the operations. To this scaffolding was also fixed a crane-post and derrick capable of lifting nearly half a ton, by means of which the sand-bags and chalk used for tamping were raised to the mouth of the gallery by a crab on the top of the mound. See Figs. 1 and 3 of diagrams below.

Fig. 1.


Entrance chamber and recess.

System of reliefs.

At the entrance, a cave of the dimensions shown by Fig. 2, was formed, for the purpose of keeping all tools and materials out of the way of the men working at the gallery, and this space subsequently proved of the greatest service, as a depott for the powder, sand-bags, and chalk, before they could be passed along the gallery and branches. Similar advantage was found from a recess (see Fig. 2) at the end of the central gallery, formed by its prolongation, originally as the mode of arriving at the spot where a third service of 2000 lbs , was proposed, which was afterwards considered unnecessary, and the further advancement of the gallery stopped. The use made of these two depôts fully compensated for the cost of their excavation, though, had the rock been of a hard nature, smaller spaces, particularly with reference to the upper recess, would have answered the purpose, and would have been advisable on the score of economy.

The men employed driving the gallery and branches worked in reliefs for the whole 24 hours. For the gallery, three reliefs of four men each were told off; and subsequently for the branches three reliefs of six men for the two, which were carried on for the most part simultaneously, each man receiving ls. working pay for each
relief. The hours for relieving were 6 A.M., noon, 6 P.M., and midnight, excepting at periods when the high spring tides prevented the relief passing a projecting part of the cliff at the proper hours, when arrangements were made to equalize the extra time; the men were consequently employed. The reliefs going on at 6 A.M. had their

Fig. 2.

breakfasts brought to them, and dined after leaving work; those relieving them at 12, dined before that hour; and similar arrangements were made for the evening. The work was hardly ever interrupted between $6 \mathrm{~A} \cdot \mathrm{M}$. on the Monday and 6 f.M. on Saturday. By compelling each relief to be in barracks six hours before their turn came for work, the men were always fresh at the commencement of their time; and as the working pay was good, and the best miners were thus employed, the average amount of work performed by night fully equalled that by day.
The dimensions of the entrance-gallery are given in the Figs, 2 and 3. The content was $47 \frac{1}{2}$ cubic yards; the rate of progress about 16 cubic yards in the 24 hours ; and the cost, for Sapper labour only, $1 s$. per cubic yard.

Fig 3.


The main gallery of the section given in Fig. 4, had an area of 27 superficial feet, so that each lineal foot gave 1 cubic yard of excavation. The average rate of progress was 8 lineal feet, equal to 8 cubic yards, in the 24 hours, and the cost for labour only about 2 s . per cubic yard.
The branches, of the dimensions given in Fig. 5, had a section of about $12 \frac{1}{2}$ superficial feet: the rate of progress of the two was at first about 16 feet $=7.4$ cubic yards in the 24 hours, and the cost for labour only 3 s .3 d . per cubic yard, six men, as before stated, being employed in each relief, instead of four, as in the gallery; but as the distance from the entrance increased, this rate was not maintained, the latter portions averaging little more than 13 feet in the 24 hours, being at a cost of 1 s .10 d . per foot run, or $4 s$. per cubic yard.

From measurement of the work, the cost, per cubic yard, for the total number of yards in the entrance-chamber, gallery, and branches, and the time occupied in the excavations, were as follows, for Sapper labour only :-

Fig. 4.


Fig. 5.


|  | Cubic yards. | Number of <br> hands em- <br> ployed. | Cost per <br> cubic yard. | Average <br> number of <br> men in the <br> three reliefs. |
| :--- | :---: | :---: | :---: | :---: |
| $\left.\begin{array}{l}\text { Entrance-chamber...... 47 } \\ \begin{array}{l}\text { Main gallery ...........61 } \\ \text { Branches ............. } 55^{\frac{1}{2}}\end{array}\end{array}\right\}$ | 164 | 440 | $2 s .4 d$. | 12 to 18 |

Taking into account the repair of tools (by Sapper workmen) and superintendence, this average cost per cubic yard would be augmented to about $2 \varepsilon .10 \mathrm{~d}$.

From the foregoing data, the general rate of progress of the works mentioned above may be assumed at 9 cubic yards in the 24 hours, by five men constantly employed day and night.

In comparing the progress of the gallery and branches, it appears that the former advanced at the rate of 8 feet in the 24 hours, and each of the latter, though less than one-half the area, at an average rate of only about $7 \frac{1}{2}$ feet in the same time. The increased distance of the branches from the entrance would, of course, partly account for this difference, but it is, in a great measure, to be attributed to the slow progress made by miners when working to a disadvantage in a very confined space. Had these branches been 5 feet 6 inches high, and 3 feet 6 inches or 4 feet broad, it is probable that they would have been completed in rather less time than was occupied by the smaller size adopted, particularly as no gunpowder was used; the subsequent tamping would, however, have been proportionally increased.

The chambers for the two lower mines were cubical, the side of the cube being 7 feet 2 inches, and giving a content for the two of 27 cubic yards. The time occupied in their excavation, and in squaring their floors and sides to receive the joists and uprights to support the rough planking with which they were lined, was about 138 hours, making the rate of progress only 4 cubic yards in the 24 hours, and the cost for labour only about 5 s .4 d . per cubic yard.

The five shafts sunk for the five mines of 600 lbs . each, intended to have been fired simultaneously, directly after the ignition of the lower mines, were each 40 feet deep, and of the section shown in Fig. 6, having an ascent of about 19 superficial feet.

The total content of the five was about 140 cubic yards, and the cost per cubic yard, including superintendence and repair of tools,

Fig. 6.
 2s.*

* The prices recently paid for sinking a well at Brighton, 6 feet in diameter, through a similar chalk foundation, were as follows, showing the very great increase of the cost after the first 50 feet in depth :-

| First 50 f |  |  | 4s.6d. |  | , | 2s. 5 d. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Nextso | " | , | 6. 0 d |  | ". | 5s. 9 d . |
| 20 | " | " | 6s.0. | , | , |  |
| 20 | " | " | 78.6a. | , | " |  |
| 20 | " | " | 9s. od. | " | " | s. $112 d$. |
| , 20 |  |  | 10s. $6 d$. |  | " | 12.2 |

Total 180 feet, cost $50 \% .10 s .6 d .=5 s .7 d$. per running foot, or $5 s .2 d$. per cubic yard. The above was for labour only. All tools, tackle, and machinery, were provided, which must have increased the actual cost considerably.

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Three men were generally employed upon each shaft; the stuff brought up was piled round the mouth of the shaft, ready for tamping, and no gunpowder was used, the chalk being of a much softer character than in the gallery, and not intersected in the same manner with flint. The task set to each gang of three men for the greater part of the work was 2 feet 6 inches for every 6 hours. The average rate of progress for the first three shafts was 3 feet 7 inches, equal to nearly $2 \frac{1}{2}$ cubic yards per diem. The two last shafts, which were only decided upon within a few days of the explosion, were carried on during the night by reliefs. Their progress in the 24 hours was nearly 6 feet $=$ about $4 \frac{1}{4}$ cubic yards each shaft.
The returns at the bottom of the shafts, and the chambers for the powder, were as shown in Fig. 7, and cost at the rate of about 5 s . 2 d . per cubic yard. The difficulty of working in so confined a space, and the trouble of squaring the returns accurately, so as to admit the boxes containing the powder, were the causes of this

Fig. 7.
 great increase in the expense.

The directions of the gallery and branches were laid out by a theodolite, with reference to a line assumed as parallel to that joining the centres of the two charges, fixed during the previous survey of the ground, and the inclination of their floors was tested by a mason's level, the miners being provided with a rough level adjusted to the required slope, to direet them during the progress of the work.

The tools used in the main gallery were, the common miner's pick, and a large shovel, for which, in the branches, a mining shovel, 2 feet 3 inches long over all, was substituted. Wheelbarrows were found more manageable in the gallery than miners' trucks, which, owing to the very great inclination at which the floor was driven ( 1 in 3 ), were very difficult to hold back when descending the slope filled with chalk, and to draw them up empty. In the branches, which had a rise of 1 in 9 to 1 in 10 , trucks were always used; the recess at the end of the gallery, already alluded to, being found very useful for turning them, and for keeping tools, \&sc., \&c., out of their road.
The tools, \&ce, were, with the exception of a few miners' picks, made at Seaford, all obtained from the contractor at Brighton, but were kept in repair by Sapper blacksmiths and carpenters, for whose use part of a forge and carpenter's shop was hired. The cost of repairing tools was considerable, being about one-eighth of the working pay of the men employed upon the various descriptions of excavation, not including the price of coals, or iron and steel, or hire of the workshops.

## Ventilation.

The air was so pure in the whole of the galleries, and even in the chambers, that, excepting when the miners were actually at work and the candles burning, no artificial ventilation was required; had any quantity of earbonic acid gas been present, it would, owing to the steep inclination of the main gallery, have flowed outwards along the floor towards the entrance, and its place have been supplied by a stream of fresh air along the roof of the gallery. In the branches this effect would of
course have been much lessened, from their more gradual rise; and in the chambers, which were sunk below the level of the floor of the contiguous branches, the heavy gas would have settled immediately, but in this instance the air on the floor of the chambers appeared as pure and light as at the entrance. The air-pump by which the ventilation was effected, had been used for exhausting the foul air at the bottom of a deep well sunk in the neighbourhood of Brighton, and by mounting it upon a rough stand it was made available in the gallery and branches. The tube, secured to the wall about 3 feet above the floor, was, for the whole length of the gallery, part of the old wooden pipe that belonged to the air-pump, but in the branches gutta-percha tubes of $2 \frac{2}{3}$ inches diameter, and $\frac{1}{16}$ of an inch thick, were made use of.

By adding length after length to these, as required, the hot impure air breathed by the miners at work was drawn off by the air-pump, which, in fact, was all the ventilation needed. Had the air become foul as the miners advanced into the cliff, this air-pump would not have been sufficiently powerful for the purpose, to be prepared for which contingency, arrangements were made for the use of a blowing apparatus from a foundry at Brighton, which, however, was never required.

The gutta-percha tubes weighed about $3 \frac{1}{\frac{1}{2}} \mathrm{oz}$. per foot run, and cost, at $3 s$. per lb ., rather more than $7 \frac{1}{4} d$. per foot. After being used, $6 d$. per lb, was allowed by the person who supplied them, for the sake of the material, which can be again worked up for other purposes.

## Lighting the Galleries and Chambers *.

During the progress of the gallery and branches, the miners worked by the light of candles, in the accustomed manner; but to avoid any risk of accident from the use of lamps, during the operation of loading the mines, fixing the bursting charges, and laying and securing the copper wires leading from them, a contrivance was resorted to for lighting the chambers by reflection from plates of bright tin tacked upon deal frames, which plan was previously tried and found to answer perfectly, during their excavation. A board of about 4 feet square was first covered with bright sheets of tin, and fixed at an angle of $45^{\circ}$ with the direction of the centre line of the main gallery, at the spot where the branches turned off nearly at right angles. The light thus first obtained by reflection from the white chalk was very feeble, and hardly perceptible near the extremity of the branches, excepting at one short interval in the day when the sun was nearly in the line of the gallery, and its seattered rays were reflected from the sea (particularly when calm) up the slope; and the smaller reflector was then placed just outside the mouth of the gallery, in such a position as to catch obliquely the first rays of the sun that the overhanging cliff allowed to visit the spot, which was between 10 and 11 A.M., from which hour till sunset, by oceasionally moving the outer reflector and adjusting it like a heliostat, to throw the direct rays it had attracted upon the set of plates at the upper end of the main gallery, a brilliant light was reflected along the branches and into the chambers, where the smallest and most indistinct writing was as legible as it would have been in broad daylight. Had the operations extended over a longer space of time, this outer reflector would have been fixed in a frame, and means contrived to render the adjustments in any way required more easy; but, for the short period it was needed, a rough plank to support it, and two or three sand-bags to retain it in the required position, were found sufficient.

[^15]
## Loading the Mines.

The gunpowder ( $24,000 \mathrm{lbs}$.) used for the lower mines was obtained from the Government magazines, having been supplied at the lowest rate at which the proprietors of the Battle Mills had offered to furnish merchants' blasting powder, of good quality, but inferior in strength to Government cannon powder in about the ratio of 9 to 13 .

It had been made up at Woolwich in flannel bags containing 10 lbs . of powder, nine of which bags were packed in each of the barrels, which were lined with zinc cylindrical cases, having lids fitted to openings on the top, rendered impervious to moisture by a thick coating of water-proof composition. These were sent round to Seaford Bay in one of the Ordnance sloops, and landed almost immediately after the arrival of the vessel on the 29th August (soon after low water) on the beach, before one of the Martello towers (No. 74), which had been prepared to receive them until required for use. The whole number of barrels, weighing nearly 130 lbs . each, were carried by hand up the beach, and stored in the tower between the hours of 8 and $11 \frac{1}{2}$ A.M. The powder required for the mines at the bottom of the shafts sunk above the cliff, which did not form part of the original project, was not applied for at the time that the first quantity was dispatched, and, owing to some delay, did not arrive at Seaford until within two days of the time fixed for the explosion (Sept. 19), so that it was only possible to load three of the five mines of 600 lbs . each that had been prepared.

The distance from the tower to the entrance of the gallery, nearly three-fourths of a mile, rendered it necessary to employ three carts to assist in moving the powder along the beach, on account of the time that would have been consumed in conveying all the barrels to the spot upon hand-barrows. A portion of the men were, however, so employed with nine barrows, and a party of 30 sappers, under an officer, were told off for this work, and for carrying the powder-barrels up the ramp leading to the foot of the ladder, and passing the bags up the steps into the entrance-chamber. These operations commenced on the 12 th September, at 10 A.M.

As rapidly as the barrels were brought to the top of the mound at the foot of the ladder, they were opened, and the bags passed by hand up the steps by men stationed at proper distances upon them, the convenient size of the bags enabling this to be performed with great ease and rapidity; and by the time the men went to dinner, onethird of the powder had been piled up in the outer recess, upon tarpaulings previously laid to receive the bags. After dinner, part of the men (12) were employed passing the bags up the gallery to the inner recess, also by hand, the men being stationed between 5 and 6 feet apart, along one of the walls, and the gallery lighted in the manner already described.

Later in the afternoon, the men who had been occupied with the powder-barrels were made to line one of the branches, sitting down with their backs to the side of the branch, and passing the bags from hand to hand to the chamber, where they were built up in a compact form, under the eye of one of the officers; the chamber having been previously floored, and lined to the height of 5 feet with rough planks, fastened to uprights by copper nails, to prevent the powder from coming in immediate contact with the chalk.

When one-half of one chamber was completed, the men were transferred to the other branch, and by half-past 5 P.m. both chambers had been loaded with half their quantity of powder, the whole time occupied by the above operations being only $6 \frac{1}{2}$ hours. Two sentries were then mounted at the entrance of the gallery, and on
the following morning the work was recommenced, and the loading entirely completed by half-past 4 P.M. Before leaving work the remaining sand-bags were all filled, and about 90 of these hoisted into the mouth of the gallery by means of the derrick, and taken up to the upper recess, to be in readiness for commencing the tamping as soon as the bursting charges should have been fixed, and the first portion of the wires leading from them secured from any risk of being moved or injured, which was effected by passing them through tubes drilled in strong pieces of scantling, secured across the entrance to the chambers, and fastening them by wooden plugs, and afterwards leading them along the floor of the branches in grooves cut in narrow strips of plank, covered by other pieces nailed over them with copper nails.

The whole of the operations detailed above, from commencing to move the powder from the tower to the completion of the loading of both the mines, occupied 3 carts and 30 men for 11 hours, and 12 men afterwards for about 4 hours.

The lines of least resistance of each mine being exactly 70 feet and the charge $12,000 \mathrm{lbs}$., the proportion the latter bore to the cube of that line was about $\frac{1}{28}$, rather more than was originally proposed ( $\frac{1}{32}$ ).

## Tamping.

The materials used for tamping in the galleries were sand-bags (filled, some with dry chalk, but the greater part with sea-sand,) and lumps of chalk. The sand-bags, only 600 of which were supplied, extended about 30 feet from each chamber along the branches, the remaining length of which, as well as that portion of the main gallery which it was considered advisable to fill up, being completed with chalk hoisted from below by means of the derrick, in large baskets containing 6 bushels, weighing about 9 cwt . The greater part of the sand-bags were lifted into the gallery in the same manner by slings, five or six together.
In the shafts above the tamping consisted merely in shovelling down the stuff that had previously been drawn up and piled round the opening, the charges not being sufficient to create apprehension of their producing any effect upwards, the line of least resistance in that direction being 40 feet.
The sand-bags filled with dry chalk, free from any particles of flint, were used in the branches for blocking up each of the chambers, and extended about 8 or 10 feet from them, so as to prevent the possibility of any damp reaching the powder from those filled with wet sand, which were afterwards built in promiscuously with the others.

Large blocks were built across at intervals, and the finer stuff thrown in behind and rammed sufficiently to make a tolerably compact mass, the wires from the bursting charges being secured from injury during the operation by the manner in which they were inclosed in the grooves already alluded to.

The extent of the tamping is shown by the shaded parts to diagrams 2 and 3, pages 71 and 72 , and occupied from 18 to 20 men for three days ( 16 th to 18 th Sept.), as also 12 men for one night. The distance from the crossing of the branches down the gallery to the spot where the tamping was discontinued, was only 20 feet 6 inches, which, though not what would be generally considered necessary with moderate charges, the point A being considerably less than the length of the $\mathbf{L}$ of LR from the centre of one of the mines, was thought sufficient; the section of the gallery being quite insignificant, when the enormous expansion that would be caused by the explosion of the two charges was taken into account.

The result proved that this idea was correct; indeed, it is probable that the effect would have been the same if the main gallery had been left entirely open.

In the branches the rate of progress with sand-bags was' about 12 feet per hour,

Rate of progress of tamping branches.

Cost. rather more than 100 sand-bags being required for every 10 feet; they were passed along nearly in the same manner as the powder, the men being necessarily placed at less distances apart, and the branches lit as before, by the tin reflectors.

With loose chalk, the rate in the branches was 7 to 8 feet per hour, equal to about $3 \frac{1}{4}$ cubic yards, the section being $12 \frac{1}{2}$ super. feet.
The cost of tamping the branches with sand-bags and loose chalk, the distance being 108 feet (equal to 50 cubic yards), was at the rate of 9 d . per foot run, or 1s. $7 \frac{1}{2} d$. per cubic yard. This amount was rather increased by the delay and interruption caused by the men being frequently obliged to get out of the way of the carpenters fastening battens over the grooves containing the wires. Near the extreme ends of the branches also, the air became so hot and impure from the number of men crowded into them, that they were obliged to be occasionally withdrawn for short intervals.

In the main gallery the rate of progress for the distance tamped, 30 feet 6 inches, equal to $30 \frac{1}{2}$ cubic yards, was about 4 feet 8 inches, equal to 4.7 cubic yards per hour; and the cost about 1 s . per foot run, or $2 \mathrm{~s} .2 d$. per cubic yard, the section being 27 super. feet.

The above statement of the number of men employed and the rates of progress and cost, includes those working at the derrick and passing the sand-bags and chalk up to the party at work. The cost of the sand-bags was not, however, taken into account.

In passing the sand-bags and chalk to the end of the branches from the entrancechamber, from 20 to 24 men were required; from the upper recess, which was also used as a depôt for these materials, 12 men were found sufficient for passing on the sand-bags, and tamping.

At the derrick seven men were employed:-two at the crab, three collecting chalk and filling below, and two emptying the basket above, which was in this manner loaded with six bushels of chalk, lifted a height of 22 feet, and returned in $4 \frac{1}{2}$ minutes. The same quantity carried up the ladder upon men's shoulders in half-bushel baskets occupied about 6 minutes with the same number of hands. Another advantage in favour of the derrick was, that there was no difficulty in continuing the work for the whole day; whereas the men could not have stood the fatigue of carrying the baskets up the steps for any length of time.

The estimate for these operations, only the two mines below the cliff being at that time contemplated, was $800 \%$. The subsequent addition of the five mines above, created of course an additional expense. The cost of the voltaic batteries and the acids, \&ce., required for their manipulation, also exceeded considerably the estimated sum which it was imagined would be sufficient for them. The actual cost from beginning to end was as follows :-
Gunpowder-24,000 lbs. for two lower mines, and 1800 lbs . for threeupper; delivered at Seaford Bay, at 45s. per 100 lbs .$580 \quad 15 \quad 0$
Boat hire and cartage, landing and moving powder ..... 800
( Sapper labour-ditto ..... $\begin{array}{lll}3 & 9 & 7\end{array}$
Levelling ground, and other preliminary operations ..... $13 \quad 30$
言 Excavating galleries and chambers ..... 31141
Ditto, shafts and chambers ..... 141210
Trench above the cliff
Trench above the cliff ..... 6186 ..... 6186
Loading and tamping mines above and below ..... 9120
Surveys and sections ..... 194
Laying and preparing wires ..... 446
Clearing away debris ..... 6193
Voltaic batteries, wire, acids, and other contingent expenses ..... $75 \quad 15 \quad 9$
Miscellaneous cartage ..... 8410
Gutta-percha tubes for ventilation ..... 386
Materials for scaffolding, ladders, battery shed, tackle, candles, boxes for
powder, coals, use of forge and workshops, \&c., \&c., \&c. ..... 1311711
Fencing round edge of crater, 25 rods. ..... $7 \quad 710 \frac{1}{2}$
III.-Description of the Voltaic Battery, and other Arrangements for firing the Mines at Seaford Cliff, in September, 1850. By Lieut. Ward, Royal Engineers.

The position of the mines above and below is shown in the accompanying drawings (see Plates 4, 5, 6, and 7). The position of the battery house, that is, the shed where the voltaic batteries were placed, and to which the conducting wires from the mines led, is also drawn in plan (see No. 5).

The conducting wires from the large mines were brought up the face of the cliff, and then into the battery house.

It was originally intended to have fired the large mines below simultaneously by one battery, arranging the conducting wires as shown in Plate No. 4, that is, the wire proceeding from the battery was to have been carried directly to, and connected with, the bursting charge of one of the lower mines; from this again a conducting wire proceeded to the bursting charge of the other, which again was connected by the same means with the other pole of the battery. The whole circuit by this arrangement would have been about 360 yards. Subsequent experiments have proved that it would have been successful. When the time fixed for the explosion drew near, doubts were expressed in influential quarters of the safety of the plan, and as, from want of time, there was no means of proving its practicability by a sufficient number of experiments to remove all doubts, it was thought advisable to adopt the old method of firing each lower mine by a separate battery and separate set of wires.

Description of voltaie batteries.

Plate 6.
Figs. 1, 2, \& 3.

It was also originally intended to have fired the five mines above by the arrangement shown in plan No. 4. Two mercury cups situated in a convenient position, such as shown in the plan, had each to receive one wire from each mine; two main wires proceeded from these cups to the battery house, one from each cup.

The object of the cups in this case was not only to economize wire, but to prevent them from being dragged from the hands of the person who fired them.

This method was also abandoned subsequently, having the means of firing each mine by a separate battery, as will be described hereafter.

There were three voltaic batteries available for the Seaford explosion. The two principal ones were exactly similar, being both after Grove's construction.

Grove's consisted of five cells each, and by reference to the drawing the description will be better understood (see Pl. 6). The batteries were not originally designed expressly for the Seaford explosion; one was for sale at a Mr. Woolven's, Chemist, in the High Street, Portsmouth, and having been found sufficiently powerful for the purpose required, was purchased; and, subsequently, a second one ordered precisely similar (as a reserve one). The description need not extend further than for one cell, as the others were similar. The positive metal was zinc, and the negative platinum : two zinc plates 9 inches by 7 inches and the platinum 9 inches by 6 inches. Sulphuric acid diluted in the proportion of one measure of acid to eight of water, and concentrated nitric acid, were the elements for generating the electricity. The zinc plates were amalgamated, and placed in a porcelain cell with the diluted sulphuric acid; between the two plates was inserted a cell of porous earthenware filled with nitric acid, and in this was immersed the platinum, which was attached to a bar of wood, the wood being rather thicker than the exterior breadth of the porous cell : a clamp of brass, as shown in the enlarged sketch, firmly received the two zinc plates, and secured them against the wooden bar. The connection of the zine of one cell to the platinum of the adjacent one being made by slips of copper, as shown in the drawing.

This form of battery was very convenient, as it could be charged without difficulty and be arranged for firing by two people in 10 minutes; and those in the habit of using it could prepare it in 6 or 7 minutes. It was also a very constant intensity battery, for at the end of 5 or 6 hours, which was the longest time the battery was ever kept in action here, it was in full strength. The same acid has been repeatedly used for charging the battery for a period of 20 hours, with simply adding a little water to the sulphuric acid solution, and up to that period no diminution in its strength has been discovered.

The cost of originally charging the battery of five cells is about $9 s$., as it takes $5 \frac{1}{4} \mathrm{lbs}$. of nitric acid (spec. grav. $1 \cdot 500$ ) at $1 s .9 d .=8 s .0 \frac{3}{4} d$., and rather less than 3 lbs. of sulphuric acid (spec. grav. $1-82$ ) at $4 d$. = say $1 s$. The expense of working the battery, then, is not known, but it does not exceed $6 d$. per hour for acids.

Grove's battery (of the afore-mentioned size, \&c.) is capable of firing one charge at a distance of 600 yards, or through a circuit of 1200 yards; it will fire two charges simultaneously, arranging them as was originally proposed for the larger mines at Seaford, through a circuit of 1000 yards, the conducting copper wire being $\frac{1}{3}$ inch in diameter, and the platinum wire in the bursting charges $\frac{3}{8}$ inch long-

The cost of the battery originally was $10 \% .10 \mathrm{~s}$. ; the porous earthenware cells, though they have been frequently used, are as good as at first.

The method of preserving them (as practised here) is, after the battery is taken to pieces, to soak them in a tub of water for half-an-hour, thus removing most of the
nitric acid and metallie salt that may be in its pores, and then put them in some fresh water for an hour or so longer; the sulphate of zinc being soluble in water, is removed by this measure.
The outer porcelain cells may be made of gutta percha, which, however, though answering every purpose and not being fragile, would require a little care to keep them free from strong nitric acid; the dilute solution of sulphuric acid used has no effect on them.
This battery has many advantages: its connections are very simple, and easily cleaned, which are very essential points with a Grove's battery, for the nitric acid fumes will attack brass, copper, solder, and all such metals as are within the range of its influence. It is very constant in its power on different days, for whatever intensity it has shown on one occasion may always be confidently expected from it on another. With Daniel's battery this is not the case, the temperature having a great effect upon it, and the ox gullet especially.

The details of the expense of the battery as it actually cost, are as follows, viz. :-

| Platinum, 50 s , per oz. .................... | $\begin{array}{llll}£ & s . & \text { d, } \\ 5 & 4 & 6\end{array}$ |
| :---: | :---: |
| Zinc, at 8 s , per lb . | 0140 |
| China cells, $5 s$, each.. | 150 |
| Porous cells, 3s. 6 d . each | 0176 |
| Binding screws, large, 5 at 3 s .6 d . | 0176 |
| Ditto, small, 5 at 1 s . | $0 \quad 50$ |
| Workmanship and wood | $1 \begin{aligned} & 16\end{aligned}$ |
| Total | $£ 1010 \quad 0$ |

The above are retail prices; platinum can be obtained at $32 s$. an oz, instead of 50 s . ; porous cells at 2 s . instead of 3 s .6 d .; and the other things similarly cheaper. It is particularly necessary that the very best platinum should be obtained, as if it contains any alloy the nitric acid will destroy it.

1. The third voltaic battery was of Smee's construction; it was in charge at Portsmouth, and, therefore, was made use of for firing one of the small mines above, as it is not generally adapted for firing charges at great distances: it will not be necessary to describe it minutely. The positive metal was zinc, amalgamated; and the negative, platinized silver; the exciting fluid was dilute sulphuric acid, one measure of acid to eight of water being generally used. It had 12 cells, and was very easily charged for use. For plan, \&cc., see Plate 7.
The conducting wire was composed of three strands of copper-wire, $\frac{1}{10}$ inch in diameter, twisted as a rope, and then covered with tape, and a solution of shellac and varnish over that again. The advantage of twisting the wire thus is, that it is less liable to fracture, and is more flexible. A single strand of wire, having the same weight per yard, would convey electricity equally well, but would soon get hard and unmanageable; it is very apt to break at bendings, and so break the circuit; twisted rope wire has a better chance, for one or even two strands may break, and the third be still left to complete the circuit. The conducting medium used at Seaford being the first attempt made of twisting wire, cost 52 s . for 100 yards, including every expense of copper and manufacture. Since, the same description has been made at a less price, and the following is the cost it can be manufactured for at Portsmouth:-

or say $2 l$. for 100 yards. The tape was barely $\frac{1}{2}$-inch broad linen, and of close texture; a piece of 9 yards costing 1 d . The quantity of tape used for 1000 yards was 25 dozen pieces, 11.5 s .
Varnish for wire. The shellac varnish was composed of the following ingredients, and the proportion used as mentioned below:-


27
Making $1 \frac{1}{3}$ pint of mixture for $2 s .7 d$., or at $2 s$. a pint; and 3 gallons were required for 1000 yards.

The above covering for the wire is quite sufficient for land explosions, and is very soon put on clean to handle.

Besides the above covered wire available for use, of which there was only 500 yards, there was copper-wire of single strand $\frac{1}{3}$ and $\frac{1}{8}$ inch in diameter. A sufficient quantity of this wire was in store at Portsmouth, it having been previously used for experiments with a voltaic battery there. And it became very serviceable at the last moment, when the original design of explosion was altered for the one adopted.

By the first plan for exploding the two large mines below, 360 yards were required; but when it was determined to fire each mine by a separate battery, 641 yards became necessary, making a difference of 281 yards at 52 s . a hundred yards, or 77.6 s . in money.
Bursting eharges.
The bursting charges were made similar to those described by Captain Larcom, in No. II. of the "Corps Papers;" those for the large mines below being 9 inches long, and cylinders 2 inches in diameter; and for the smaller mines about 6 inches long. They were lodged in the middle of the mine, and connected with the main conducting wire, which was brought through a piece of wood placed across the entrance of the chamber, and so jammed into it, as to prevent the charges being dragged from their position.

By way of precaution, two charges were placed in each large mine, and connected with separate conducting wires, in case one pair might be damaged in tamping. The length of platinum wire for these bursting charges was different for those in each mine, one being $\frac{\pi}{8}$ inch long, and the other $\frac{5}{8}$ inch.

It was doubtful, at the time when these charges were placed, by what method the mines would be fired. The short length of wire had been found quite sufficient for exploding charges, and it was intended to have used that if both mines had been fired by one battery; but as subsequently each mine was fired by a separate one, the bursting charges having the longer wire were attached to the main conducting wires
at the mouth of the gallery, as giving a larger spark. However, either set of eharges might have been used for either method with perfect success.
The twisted conducting wire, of which there were only 500 yards available, was kept for such parts as were likely to come under the observation and close inspection of the spectators; for instance, from the battery-house to the edge of the cliff, and to the top of the three shafts. That down the face of the cliff and the shafts was the single strand of thick wire before described, and covered with coarse canvas and pitch, tempered with tallow hastily made up. From the mouth of the gallery to the bursting charges below, the same thick wire was used bare, in this way :- A piece of deal, 3 inches broad, had two plough grooves run down it, in which one wire from each bursting charge of one mine was placed, and a fillet nailed over it, previously tarred. Another similar piece of deal had the other wires from these bursting charges fixed in it; these two were kept on different sides of the branch, and brought down the main gallery on one side. The same was done with the conducting wires from the other mine, which were brought down the other side of the main gallery. (See lines on Plate 5).

The wires proceeding from the battery-house were passed over the edge of the cliff through two double blocks, that were run out on two poles. The poles were placed about 10 feet apart, on the ground, and projected over sufficiently to enable the wires to clear the face of the cliff. One wire from each mine was run through each double block; thus the pair belonging to each mine were kept 10 feet apart down the face to the entrance-gallery, where they were attached by soldering to those from their respective bursting charges : previous to soldering on these wires to those leading to the mines, the continuity of the circuit was tested by a galvanometer; and as every one was complete, the charge having $\frac{5}{8}$ inch platinum wire, was selected for the purpose of firing. One Grove's battery was devoted to each large mine.

The three small mines above, each charged with 600 lbs . of powder, had each a battery to fire them, the two extreme ones by the two Grove's, and the centre one by the Smee's already alluded to. The wires were brought from the shafts into the batteryhouse. The arrangement for firing was made as sketched below-

Fig. 8.


M, M, M, M, are mercury cups into which the poles of the Grove's battery were plunged. Captain Frome had charge of one Grove's battery; Lieutenant Ward of the other; and Lieutenant Crossman of Smee's.

The operators stood with their backs to the cliff, facing their respective batteries, the mercury cups being between them and the batteries.
$\mathrm{W}_{1}$ and $\mathrm{W}_{2}$ represent two wires, one proceeding from one large mine below, and the small one above on that side. $W_{3}$ and $W_{4}$ represent two others, one proceeding from the other large mine below, and the small one on the side above. $\mathrm{W}_{5}$ represents the wire from the centre mine above.
$\mathrm{W}_{1}^{\prime}, \mathrm{W}_{2}^{\prime}, \mathrm{W}_{3}^{\prime}, \mathrm{W}_{4}^{\prime}, \mathrm{W}_{5}^{\prime}$, are those corresponding to $\mathrm{W}_{1}, \mathrm{~W}_{2}, \mathrm{~W}_{3}, \mathrm{~W}_{4}, \mathrm{~W}_{5}$, that is, leading to the same mines.

The orders for firing the mines were to explode the large ones first, and when it was known that they had gone off, the three small ones were to be fired. On the word to make ready, $\mathrm{W}_{1}, \mathrm{~W}_{2}, \mathrm{~W}_{3}, \mathrm{~W}_{4}$, were inserted in their respective mercury cups, as shown in diagram 8; and $\mathrm{W}_{s}$ was attached to the binding-screw of one terminal pole of the Smee's battery.
$\mathrm{W}_{1}^{\prime}, \mathrm{W}_{2}^{\prime}$, were held by the officer in charge of that battery, one wire in each hand, $\mathrm{W}_{3}^{\prime}, \mathrm{W}_{4}$, were similarly held by the officer over that battery, and $\mathrm{W}_{5}^{\prime}$ was in Lieut. Crossman's charge.

Captain Frome arranged to give the signal thus:-" One, two, three, fire," and "One, two, three, fire;" the first fire referring to the large mines (when the wires leading to those were to be plunged into the other mercury cups), and the second fire to the three small mines (when all three officers had to complete the circuits corresponding to those). At the first word fire, the two large mines exploded, and the effect produced separated the cliff behind the three smaller mines so quickly as to drag all the remaining wires out of the window, thus preventing the upper ones from being fired. The wire $\mathrm{W}_{\mathrm{s}}$ attached to the binding-screw of Smee's battery, pulled it over, and the shock made the other batteries jump on the table, mixing and spilling the acids.

With respect to the plan originally proposed for firing the mines below, viz., by one battery, and placing the charges in one continuous circuit, it was asserted to be an uncertain method; because, if one platina wire was a little shorter than the other, the short one would fire first, and, thus disconnecting the circuit, would prevent the other from exploding.

Subsequent experiments (as has been before stated) have proved this opinion erroneous, for in all trials that have been made at Portsmouth of that method of firing, the length of platina wire was always judged by the eye, never accurately measured. But a safe means could have been adopted to prevent even this contingency, and have placed beyond possibility the chance of only one charge exploding. The following diagram will explain it.


The dotted lines represent the copper conducting wires leading to charges $C_{1}$ and $\mathrm{C}_{2}$. The length of platinum wire in $\mathbf{C}_{1}$ may be made $\frac{8}{8}$ inch long, that in $\mathbf{C}_{2}$ $\frac{\pi}{8}$ inch; and at points $a$ and $b$ connect copper wires of the same thickness as the conducting wire, leading towards each other, but not approaching nearer than one inch,
and this interval connected by soldering on a platina wire one inch long, between the two, and encasing it in wood to protect it from possible fracture in the tamping, and securing it from all strain. On completing the circuit at the battery, $\mathrm{C}_{1}$ would fuze before $\mathbf{C}_{2}$, being $\frac{1}{4}$ inch shorter, but the electric circuit through $\mathbf{C}_{2}$ would still be complete by the aid of the connection, $a b$; similarly, $\mathrm{C}_{2}$ must fuze before the platina wire at $a b$, being shorter by $\frac{8}{8}$ of an inch, and the interval between the explosion of $\mathrm{C}_{1}$ and $\mathrm{C}_{2}$ would not be more than $\frac{1}{4}$ th of a second at the most; indeed, practically, instantaneous.

This idea occurred at the time that doubts were expressed of the original plan but, not having sufficient time for trial, was not recommended for adoption. Subsequent practice has proved the practicability of the scheme, and it only requires a series of experiments to determine what should be the difference in the length of platina wires to ensure $C_{1}$ and $C_{2}$ exploding in the order described; that is, $C_{1}$ before $C_{2}$.

| (Signed) E. W. Ward, |
| :---: | :---: |
| Lieut. Royal Engineers, |

## IV. Concluding Observations on the Explosion at Seaford, in 1850. By Colonel G. G. Lewis, C.B.R.E.

Several reflections suggest themselves as to the effects produced by the mining operations at Seaford, which may influence future explosions of a similar nature.

1. It may be worth while to consider whether, without any additional expense, one charge placed with a line of least resistance of 90 feet, would not have effected the object better, and so by this one explosion have projected the mass into the sea in a more homogeneous mass?
2. Whether too much powder was not used?
3. Whether the upper mines were necessary ?
4. And, lastly, whether piercing the face of the cliff was the most economical in point of time and cost, and equally secure, to that of sinking a shaft from the summit?

Persons undertaking a similar operation can form their own judgment by the perusal of Captain Frome's paper.

It would appear, from some observations which have fallen from Sir John Burgoyne, that he is inclined to admit the force of the three first queries.

I take the liberty to submit that the question resolves itself into this:-Was the mass required to be thrown down, so as to be projected as far as possible into the sea, or in sufficient breadth to resist the action of the waves between high and low water? I think that the farther the chalk went into the sea, the greater the chance of its being carried away by its action, and hence the plan adopted of having two mines was the most judicious.
The upper mines were purely precautionary, in the event of the upper part of the eliff hanging on to the summit.

And in respect to the charge, I would recommend, in ground of a like nature in respect to tenacity, that only $\frac{1}{34}$ th L L R ${ }^{3}$ be used.

But I would suggest that an engineer officer should well consider before he attempts to pierce the face of the cliff, as at Seaford. By good luck all the loose particles of chalk had fallen off a few days before the operation commenced, and thus all danger removed; and the deposit on the beach served to assist in reaching the point to commence the gallery from.

As sinking a shaft in chalk is neither a dangerous nor a tedious operation, and inexpensive, I would recommend this course to be adopted in most cases; and what time is lost in sinking the shaft and cutting the galleries, is made up in the facility of tamping and firing the mines.

I think the double charge, as adopted at Seaford, is preferable, taking care that the distance between the mines does not exceed that of double the line of least resistance.

There is one circumstance it is desirable to record, that the operation was wholly a military one, and the labour of excavating the galleries and mines, loading, tamping, and exploding, was executed by Sappers, including the landing of the gunpowder, as well as all mechanical operations attendant upon the work; that no accident or confusion occurred of the slightest nature during the operations, although there were at least 10,000 persons present when the explosion took place ; everything passed off without any alarm or apparent danger.

It would appear that the object proposed has not fulfilled the expectations of the projectors, who had anticipated that the mass would have resisted the action of the sea; but this was unreasonable. The points to be gained were, checking the march of the shingle eastward, until it had accumulated in sufficient quantity to replace that lost. The works executed for the improvement of Newhaven Harbour has probably caused the denuding of the beach, and I think before the mass blown down in September, 1850, disappears, it will cause the shingle again to be collected in Seaford Bay.

G. G. Lewis, Colonel Royal Engineers.

## PAPER XIV.

# On the Battle of Meeanee. By Lieutenant-Colonel Waddington, Bengal Engineers. 

## Gentlemen,

Aden, Sept. 28, 1849.
As you have admitted into the 10th volume of the "Royal Engineer Professional Papers" some observations by Major-General Sir W. Napier, author of the "Conquest of Scinde," on my account of the battle of Meeānee, published in the 9th volume of the same papers, I trust that you will allow me the advantage of making my reply to the Major-General's strictures in the next volume, as well as in the next number of your "Corps Papers." The latter request I prefer, under the impression that a considerable period may elapse before a sufficient number of contributions shall be collected to form another volume of the "Professional Papers." Major-General Sir W. Napier's deservedly great reputation as an author makes it of importance to me to show that my account of the battle of Meeānee was carefully composed, and that every particular not coming under my own personal observation was attested to me by competent eye-witnesses. Some of the discrepancies between the Major-General's statements and mine admit, I am happy to say, of explanation, and will be shown to be only so in appearance. Without further preface, I now proceed to notice the Major-General's observations in the order in which they occur. After some prefatory sentences, his first specific stricture is as follows:-
" Major Waddington states the British forces to be about 3000 strong. They were perkaps so on paper, ten days before the action, and including sick; but I am assured by Sir C. Napier, that, for the reasons mentioned in my work, not more than 1700 , including officers, were engaged in the battle; and this enumeration is the result of a very careful examination by the Staff of the General, made after the action, to correct the dispatch, which, written in the confusion of the moment, was certainly inaccurate. This result has also been recently confirmed by the assurance of two officers of the 22 nd Regiment, and one of the Company's service, who were present in the fight." *

My statement was prepared from information given me at the time by adjutants and other regimental officers, who had the means of knowing with accuracy the numbers of their men. As to those who were actually engaged in the battle, I cannot, in any way, bring down the number to 1700, as stated by Sir William Napier, unless the cavalry are to be struck out of the list. I have not preserved a copy of my memorandum of the strength of the several regiments, but I can, from memory, state nearly how the 1350 bayonets, mentioned by me as composing the infantry line just before the advance was made, were distributed. Her Majesty's 22nd Regiment, which had been joined by its Light Company from Hyderabad, mustered about 470 bayonets; the 25 th Regiment, N. I., had about 250 ; the 12th Regiment, N.I., about 440; the Grenadiers about 190 bayonets. Here are 1350 men, exclusive of commissioned officers; and if we take the artillerymen and sappers at 150 more, how are we to bring the 700 or 800 cavalry, which were certainly in the action, within the number admitted by Sir W. Napier?

The statement in my account selected for objection is that which is given at its
very beginning, and which makes the British force on the day preceding the battle 3000 strong. I have above enumerated 1500 infantry and artillery, and 700 or 800 cavalry. The latter were 850 streng, according to my information at the time. To these add the baggage-guard, 450 , and 200 men detached in the steamers, and we have 3100 men, from whom are to be deducted the Light Company of Her Majesty's 22nd Regiment, which only joined us after our arrival at Muttara.

There are two obvious methods by which the actual strength of the force on the day of battle might be accurately ascertained. One of these would be a reference to the Adjutant-General's returns, which I presume were Sir Charles Napier's authority for writing in his dispatch, "We formed in order of battle about 2800 of all arms ;" the other is a reference to the Abstract of Prize-money, from which I observe that the number of individuals of all ranks, who shared for the battle of Meeānee, was 4744. (Bombay Government Gazette, No. 435, Aug. 23, 1849.) In this Prize Abstract the actual fighting men who were with Sir Charles cannot be discriminated; but after making due allowance for the crews of two vessels of the steam flotilla, for the commissariat and medical departments, the sick, and some non-combatants, such as drivers and bheesties, I arrive at the conclusion, that the effective force at Sir Charles's disposal the day before the battle, could not have been under 3000 men, but probably somewhat exceeded that number.

Second observation:- "Major Waddington states that the top of the Shikargah wall was at first thickly studded with matehlockmen, but on the advance of the line was abandoned." Sir Charles Napier writes as follows:-
"The Beloochees were not crowded on the wall, which was only a foot thick; one man-sat astride on it, firing at us, I believe at me, and that he was a marksman put there as knowing me. He had only time for three shots, or so; for seeing how be fired at me and my staff, I told some of the 22 nd to shoot him, and he fell like a lump of lead on our side. We had seen matchlocks handed up to him. I swept the whole wall well with my telescope before we advanced, and while under the cannonade, and there was not a man but him on it. I saw through the opening A B obliquely, my light passing A to a good way behind B, and I ascertained there was no scaffolding to enable them to fire over, no loopholes to fire through. It was this made me think the wall was purposely broken to let them sally out on our rear. When I was satisfied there were neither loopholes nor banquette, I ordered the advance. I was so particular, that, though my horse, Red Rose, stands steady, I could not satisfy myself while on the beast's back, and I dismounted, and again steadily swept the wall and examined the breach.
"I did not think of sending on Pew till we were advancing, and I was thinking of how to deal with them if they rushed out from the wall: many things came like flashes across my mind. I was unsatisfied at this moment; the fire from the matchlocks in front was heavy, and no time to lose. Suddenly the idea came into my head to attack them through the wall as the best chech, and I ordered one company, about 60 or 70 men, I could not spare more. I told Pew he must defend the entrance to the last; or rather I sent him that order, for the 22nd had got to firing; there was confusion, and matters had put on a very dangerous aspect. Pew beat them back, and he found plenty there, and fell about 60 yards within the gap; but his men held on. He could not have gone further; thousands filled the wood, upon whom, soon afterwards, we opened a 9 -pounder through the wall. It told tremendously, and relieved Pew's men, who would otherwise have been sorely pressed; yet I could have aided them with guns, had they been driven back." *

[^16]In the extract here given from Sir Charles Napier's letter, there is a direct eontradiction of the statement assigned to me by Sir William Napier. A reference to my account of the battle will show, however, that my real statement differs widely from Sir William's version of it, and is perfectly reconcilable with Sir Charles Napier's letter. Sir W. Napier has inadvertently altered my expression, "the approach of our column" (of march), into "the advance of the line," and hence the apparently flat contradiction. Sir Charles describes the wall after bis line was formed, but before it advanced, and says that there was but one man on it. What does my acount say? That before our column reached the ground where it was wheeled into line, the wall was deserted. While we were yet at a distance from the Shikargah, however, I shall take leave to repeat that the wall was covered with armed men; and I do so without fear of contradiction, for the fact must have been notorious. Sir Charles is combating an imaginary assertion on my part, that the wall was not abandoned till the advance of our line. I said nothing of the sort. The wall was abandoned long before that. The spot from which we saw the wall studded with Beloochees was that marked on my plan as "Sir C. Napier's position while awaiting the arrival of his main column." The spot from which Sir Charles describes himself as sweeping the wall with his telescope, was in front of the " British Infantry Line, 1st Formation," as marked also on the plan. There is a distance of half a mile between the two positions.

In my account of the battle the episode of the single man who remained sitting on the wall was omitted; but I see that he is mentioned in my journal, written at the time, of which the following is an extract, verbation :
"Opposite to us, but closing to within 900 yards on our right front, and running E.S.E. from the Foolailee for nearly a mile, was the wall of the Shikargah, about eight feet high, the eastern or receding end of which was covered with armed men, and immediately beyond that were two standards, with a dense mass of infantry and large bodies of horse in its rear. Here also were their guns. After a considerable delay at this spot, (waiting, I believe, for the camel-guns,) an advance was again made of 1000 yards still in column, and edging off to nearly S. E., so as gradually to approach the Shikargah wall to within 300 yards, which, after some discharges of matchlocks, was deserted as we neared it, one man alone remaining squatted on the top of the wall. The General here fixed on a tree to his left, on which to direct his column of infantry, and as soon as it had taken up sufficient ground, he halted and wheeled it to the right into line."

Third observation:- "Major Waddington would seem to imply, for I am not quite sure of his meaning, that the close fighting did not last more than one hour.
" Upon this point I have consulted the three officers alluded to before, having first requested them to read the Major's account. They were unanimous that he was mistaken, and gave several strong facts within their own peculiar knowledge in support of their view; and from Sir Charles Napier I received the following remarks :-
". The battle began at nine o'clock, and we formed on the opposite bank of the Foolailee at one, firing still geing on. What the dispatch says was taken from all our watches.'
" Now, Major Waddington says the opposite bank was gained at half-past one, thus giving an additional half hour; and as the lowest calculation gives four hours' fighting, the greater part must have been spent in the close conflict, thus confirming my account, which gave three hours and a half of rugged battle." *

* See page 67, 10th Professional Volume.

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It certainly was my intention, in writing my account of the battle, to record my opimion that the duration of the close fighting had been over estimated, and that in all probability it did not much exceed one hour. I was aware that this was at variance with the General's dispatch, but that dispatch had necessarily been written in haste, and I trusted that I should incur no imputation of disrespect, in assigning, on what appeared to me sufficient grounds, a shorter duration to the actual decisive struggle. The point was by no means easily determined, but I think the conflicting accounts may be reconciled in the following manner:-

Sir Charles writes that the battle began at 9 o'clock, the meaning of which somewhat vague expression, we learn from his dispatch to be, that he formed his men in order of battle at that hour. Now, this was a long operation, for after the line had been formed, it was dressed with unusual care. The pioneers of H. M. 22nd regiment, I recollect, were ordered out to cut down some brush-wood which was in the way of the regiment. Skirmishers were thrown out, and Sir Charles describes himself as carefully reconnoitring through a telescope, and again dismounting from his horse for the purpose. At length, when the General's plan of action was finally decided, the word was given to advance from the right in echellon of battalions. We advanced 200 yards, halted, and our guns then unlimbered and opened their first fire on the enemy. At this time I looked at my watch; it was not quite 11 o'clock. Surely we could not have spent two hours in forming and dressing the line, in reconnoitring, and in marching 200 yards: certainly not; but I think it possible, and even probable, that half that time had passed in this manner, which would bring the formation of the line to between 9 and 10 n'clock. I am the rather disposed to the opinion that the line was formed at some considerable time after 9 o'clock, because the dispatch says that, "at 8 o'clock the advanced guard discovered their (the enemy's) camp; at 9 o'clock we formed in order of battle." Now, the time which elapsed from the discovery of the enemy's camp to the formation of our line, must, in my judgment, have been nearer to two hours than to one; and, if this be admitted, the formation of the line would have taken place at about half-past 9 o'clock, which, in common parlance, might be called 9 o'clock.

With respect to the time of opening our first fire, I addressed Major Lloyd, the officer who commanded the artillery on that point, thinking it likely that he might have noted the time. The following was his reply :-
"My dear Waddington,
"The first shot was fired from our batteries a little before 11 o'clock, as you say. There was a very large canal to cross that morning, which occasioned considerable delay. And we were also delayed that morning by the store-cart of the horse battery, and also indeed of the camel battery, one or two of the pintle-eyes having broken, which is always a nasty troublesome business.

> "Yours sincerely,

## (Signed)

"JNo. Lloyd.
"P.S. A wagon of the camel battery was also upset just as we were leaving our encampment that morning, which caused very great delay.
" To Major Waddington,
"Commanding Engineer."
Assuming, then, that our first shot was fired at a little before 11 o'clock, let us bear in mind that, after opening this first fire, we advanced and halted again twice,
each time unlimbering and firing before we made our final advance to the bank of the Foolailee; and when the distance passed over is also taken into account, it does not appear to me that less than an hour would have sufficed for the three halts and three corresponding advances. This would bring us to the near bank of the Foolailee, at a little before 12 o'clock, and as all the fighting there was over by about 1 o'clock, or even somewhat sooner according to the time furnished to Sir Charles Napier, I have shown, at least, how my conclusion was formed, that the close fighting at the river did not last much above an hour. The following is the entry in my journal, written as before stated, when the impression of events was still fresh in my mind :-" I believe that the actual combat, hand to hand, did not last less than an hour." *

Fourth observation. "Major Waddington says, ' By some misconception of an order, the lst Grenadiers, N. I. faced to the right-about, and retreated some distance before their officers could rally them.' Sir Charles Napier says, emphatically, - They went about by Clibborn's order, but there were a thousand causes assigned at the time for their conduct '"

I cannot deny that I had heard a report of Major Clibborn's having ordered his men to retire, but I had also heard that this was a mistake, and that his order had been misunderstood. I was of course inclined, and, indeed, thought myself bound, to give the most favourable version of the story.

Fifth observation. "Major Waddington says, 'Lieut.-Colonel Pattle had not received the General's orders to charge, but, seeing the necessity of checking the enemy's movement, and being urged by Captain Tucker, of the 9th Bengal cavalry, after some hesitation, permitted the cavalry to act.' $\dagger$
"This statement, qualified by the acknowledgment that it was hearsay, would give all the merit of the conception of that brilliant movement to Lieut-Culonel Pattle and Captain Tucker, and all the merit of the execution to the 9th cavalry. Major Waddington, however, only writes as he says, from the information he received from others; he was, I believe, close to the General all the action, and carried no orders to any other part of the field. He has been misinformed on this interesting portion of the action. Sir Charles Napier informs me he sent three officers, one after the other with the order, fearing death might intercept it. Those officers were-Lieut.Colonel McPherson, Captain Pelly, and Captain Thompson; and their letters, declaring this fact, are in existence, but he had only that of Captain Thompson at hand to send to me; it is given below.
"As to the charge being led by the 9th cavalry, it is true, and, nevertheless, the irregular Sinde horse did perform the part assigned them in my work, namely, attacking the enemy's camp, and spreading confusion and terror in their rear after passing the Foolailee; for the Bengal troopers, while in the dry bed of that river, turned a little to the left, and thus the Sinde horsemen passed them and fell on the camp.
" Captain Thompson's Letter.
" • Simla, 22 nd May, 1844.
" . Colonel Pattle was mistaken when he told you he received no order to charge at Meeānee, for you gave the order to me, and I met the Colonel about half-way between the cavalry and infantry; he was riding towards the latter, and asked me how they were getting on? I made no reply, but told him your order. He
said, "tell Storey; " and I rode on. I told Major Storey, and saw the 9th cavalry advance, and remember Garrett beginning to trot, when Storey called out "Gently, Garrett! gently !" On my return, I met McPherson, who asked me if I had given the order, and I think he rode on to the cavalry; so there can be no mistake about the Colonel having received the order."
(Signed)
", H. Thompson.'"

Besides Captain Thompson's letter there is one from Lieut.-Colonel McPherson, given in a note by Sir W. Napier; but as it appears from Colonel MePherson's letter, that "Thompson had been before him," and I shall show that, when Captain Thomson delivered his order, a portion of the 9th Bengal cavalry had already moved, it is unnecessary to copy Colonel McPherson's letter here.

The following are extracts from letters, received by me from two officers of the 9 th Bengal cavalry, eye-witnesses of what occurred.

## Extract of a letter dated Simla, 18th June, 1843, written by Captain Tucker.

"At that period of the engagement of the 17th of February, when the 9th Bengal light cavalry had been ordered up as a 'support' to the left of the infantry line, we found ourselves some 20 or 30 paces in rear of the 1st Bombay grenadiers, the left squadron over-lapping their left, by about its own extent. Whilst conversing with Lieut.-Colonel Pattle, and Captain Bazett, in front of the squadron, we observed the regiment in our immediate front fall into some confusion, and come to the right-about; a bugle was at this time sounding, and for a moment we feared a general retreat was about to take place. The officers of the regiment, however, by their exertions, succeeded almost instantly in getting their men to face round again, and we one and all perceived it was a movement confined to that one corps, and, I have since heard, was 'entirely owing to some misconception of an order: ' be this as it may, no sooner had it taken place, than I observed the enemy at and near the village on our left, and between our position and the bank of the Foolailee, showing themselves in every direction, evidently encouraged by what had occurred; it then became evident, that unless some step was taken immediately to check this feeling in the enemy, and to give confidence to our troops, our flank might be turned, and the most serious consequences ensue. The troops on the right, where Sir Charles Napier was commanding in person, were still, we saw, engaged hand to hand with the enemy, and I urged strongly that the left squadron be allowed to advance, and drive the enemy into the bed of the river. The Lieut. Colonel for some time hesitated, not from any disinclination to be amongst the enemy, for a more gallant soldier never lived, but in consequence of having no orders to that effect from the General; but, on my again representing that, unless something were done, and that quickly, with or without orders, it might be too late, and that Sir Charles, from his position in the hottest of the fight, was probably not yet aware of the state of affairs on the left, the desired permission was given to advance, but without any specific order. The squadron advanced at a trot, driving the enemy, who made no organised resistance, into the bed of the river, followed them into it, and was the first portion of the whole force which descended the bank. A considerable number of the enemy were drawn up in rear of the village, and it was whilst dislodging them from a strong position I received five wounds, and shortly afterwards fell, and was sueceeded in the command of the squadron by Captain Bazett, who completed the dispersion of the enemy in that direction."

## Extract of a letter, without date, written by Captain Buzett, at Hyderabad.

"The advance was made without any order to that effect having reached Colonel Pattle from the General, on the urgent entreaty of Captain Tucker, who pressed on the Colonel the very critical situation in which our line was, so desperately engaged in most parts, hand to hand at times, and unable to gain much ground, even at times giving way, and the desirableness of a movement threatening their right flank, and probably turning it, which, whilst it would give confidence to our men would dishearten the Beloochees, and his conviction that, could Sir C. Napier see the opportunity we had on the left of doing this, he would instantly order it ; but he was probably far too deeply engaged in the hottest of the fight on the right to observe it at that moment. After repeating this more than once, Colonel Pattle took on himself the responsibility of ordering the advance, and we set forward. I heard that an officer came with the order a few minutes later, but cannot say if this is correct, or who he was."

Nobody, after reading these extracts, will, I think, doubt that the 3rd squadron of the 9th Bengal cavalry had already descended into the bed of the Foolailee, when Captain Thompson arrived and communicated the General's order to Colonel Pattle. In my account it is said, "The 3rd squadron was followed by the 2nd, under Captain Garrett," and this is evidently the advance which Captain Thompson describes in his note; and which he was not aware had already been forestalled by the advance of the 3rd squadron under Captain Tucker. I confess, however, that I cannot understand how Sir Charles Napier is robbed, by this fact, of "all the merit of the conception of that brilliant movement," for he gave the order in complete ignorance of its having been already partly carried into execution. At the same time, Captain Tucker deserves, in my humble opinion, the highest praise, not only for his spirited representation and his distinguished bravery, but for his cool judgment enabling him to take the same clear view of the emergency which had simultaneously prompted the General's order. "There was," says Sir Charles Napier in his dispatch, " no time to be lost, and I sent orders to the cavalry to force the right of the enemy's line."

Sixth observation. "Major Waddington, speaking of the enemy's loss, says, 'The enemy left upwards of four hundred dead in the bed of the Foolailee, and there were probably as many more in different parts of the field, and the Shikargah, killed by the artillery and cavalry.'
"The officers of the 22 nd and Company's service, who read this at my request, were unanimously and decidedly opposed to its correctness, but the following observations by Sir Charles Napier will probably be deemed the best authority; and it is to be remembered, that the detailed returns made to the Ameers by the different tribes, of the loss of each in the battle, fell afterwards into the English General's hands, and gave an amount of 8000 .
" As to the dead, Waddington is decidedly wrong. Two officers, I think Pelly and Fitzgerald, counted four hundred bodies within a semicircle of fifty paces' radius, where I chiefly stood, near the little nulla running into the bed of the river. Now, to the left of that were all those killed by the 12th regiment, by the grenadiers, and by the cavalry-a pretty good lot. The ground was covered by the dead. Then, again, in the Shikargah, no one can tell; it was a dense wood; the artillery and Pew's men must have killed many, but no one could count the whole, or even see them.

Waddington did not, but 400 may have been the number there; far more, people said at the time. I did not see them; I never entered the wood. The cavalry killed none in the wood, no horse could go three yards in it.' $"$ *

On this point, namely, the number of the enemy's dead, I had no guide but my own observation and computation. On the day after the battle I made a survey of the field, from which the plan given with my account was taken. Whilst in the field I noticed attentively the several heaps of slain in the Foolailee, as well as the bodies scattered in the ditches, the village enclosures, and the Shikargah. I looked well about me, and, in company with my lascars, searched the skirts of the Shikargah for bodies. There were not many there nor in the village inclosures. In one of the latter we found a dead horse of the 9 th cavalry. It is possible that some bodies might have been removed in the night, but not, I think, very probable.

Sir Charles Napier remarks, that "the cavalry killed none in the wood, no horse could go three yards in it;" alluding, no doubt, to my statement that "there were probably as many more in different parts of the field and the Shikargah, killed by the artillery and cavalry." When properly punctuated, as in the original account, and taken in connection with the preceding sentence, the plain meaning of my words is, that the artillery and cavalry together had probably killed as many in all other parts of the battle, Shikargah included, as the infantry had killed in the bed of the Foolailee. But in Sir W. Napier's quotation from my account, a comma has been introduced accidentally after the word "field," which quite alters the meaning of the sentence; and no doubt provoked Sir Charles's remark, by the unintended and absurd construction which the sentence will then bear, namely, that those slain in the Shikargah had been killed by the cavalry, and those in the field by the artillery.

## I am, Gentlemen,

## Your obedient Servant,

Charles Waddington,
Lieut-Colonel, Bombay Engineers.
To the Editors of the Royal Engineer Professional Papers.

[^17]
## PAPER XV.

## NEW GUNPOWDER invented by M. Augendie, having for its base Prussiate of Potash. Extracted from the Comptes Rendus of the French Academy, by Lieut.-Colonel Portlock, R.E., F.R.S.

M. Augendie, after many experiments, has arrived at a mixture which to him appears to combine many advantages, being very simple in the proportioning of its composition, and giving the greatest amount of useful result with the least amount of residuum. The mixture is as follows:-

| Crystallized yellow prussiate of potash, in powde |  | Parts by weight. |
| :---: | :---: | :---: |
| White sugar, | do. | 1 |
| Chlorate of potash | do. | 2 |

These three substances are reduced to fine powder separately, and are then mixed by hand; either dry, in an agate mortar, if only a few ounces are required, as no danger may be apprehended from the most energetic friction; or, if a larger quantity be necessary, moistened by two or three hundredth parts of water, and beaten in a bronze mortar with a wooden pestle, or vice versâ. M. Augendie has long used a bronze mortar and wooden pestle without experiencing the slightest accident. The mixture need not be so perfect as in ordinary gunpowder, a quarter of an hour's manipulation being sufficient for a small quantity. It may be granulated in the usual manner, and dried in the air. .

This powder is in colour white, and inflames with the utmost facility, whether in grains or as a fine powder, by contact either with a red-hot or with a burning body. The flame produced is larger than that of common gunpowder, and the residuum is very small. Taken out of the mortar it inflames perfectly, so that there is no chance, as with ordinary gunpowder, either of flashing in the pan or missing fire. Unless extremely dry, a violent blow with a hammer upon iron would not cause the powder to detonate; and there is no danger from friction between two polished bodies, nor from a blow with wood upon wood, or wood upon iron.

The advantages of the powder are:-lst. That it is formed of substances which are perfectly definite and fixed in their chemical composition, so that the same results may always be expected from the same charges. 2nd. That these substances are unaffected by the action either of dry or moist air; the powder being therefore indestructible from such causes, which is not the case with any powder formed in part of charcoal. 3rd. That the preparation requiring little time, the constituents may be kept separately in store, and only made up when required, an arrangement which would do away with the dangers of large magazines. 4th. The dynamical effect being very great, a greater number of cartridges might be kept in artillery ammunition waggons, and whilst the diameter of hollow shot or shells might be diminished, their thickness could be increased. 5th. That the simple powder is as effectual as the powder granulated, so that it might be prepared quite safely by drying in the air, or mechanically, and then mixing the three dry constituents in a leathern barrel, made to turn slowly round an axis.

Its inconveniences are:-lst. That the prussiate of potash, one of its constituents, would oxidise iron arms, so that the powder could only be adopted for bronze cannon, such as used so generally in France, or for charging hollow shot and shells. 2nd. That it is more easily inflammable than common gunpowder, though much less so than any powders hitherto formed of chlorate of potash.

In the preparation of this powder, precaution must be observed to prevent the accidental mixture of any charcoal or sulphur, as such a combination would assimilate it, in part, to other chlorate of potash powders, and render it dangerously detonating. In like manner, and for the same reason, it must never be used in combination with common gunpowder. M. Augendie experienced a very serious accident from putting some of his new powder into a flask which contained a small quantity of ordinary gunpowder, and then proceeding to rub the mixture together with a newly-prepared portion of his powder in the mortar he commonly used with the utmost safety, when an explosion instantly occurred.

## J. Portlock.

Feb. 22, 1851.

## PAPER XVI.

REMARKS on Fortification, with reference to the Defence of the United Kingdom*. By Lieut.-Gen. Thackeray.

As the Writer of these Remarks studied Fortification very much against his will, he runs no risk of deceiving himself, or misleading others, by a predilection for a favourite pursuit. Persuaded that he is not entirely mistaken in his conception of the subject, but distrusting his ability to convince those who have followed a different system for many years, he is not so sanguine as to expect that his opinions will be cordially received, or hastily adopted; but, if right, his arguments will finally prevail; for it is the property of truth to carry conviction with it, when prejudices have been removed.

As there is no disposition to attach blame to any individual for what is supposed to be wrong, the discussion cannot be injurious.

Fortresses, which are absolutely necessary on a frontier, like that conterminous to France and the Netherlands, besides costing much more in this country than on the Continent, from the high price of labour and materials, would produce no accession of strength, in any degree proportioned to their expense; because, from our vast resources, our insular position, and our naval superiority, there is no probability that England can ever be invaded by an army, numerous enough to contend, on her own shores, with her united forces, and escorted across the channel by a victorious fleet, freighted with trains of battering cannon, and all the impediments which encumber modern war. There is much more reason to apprehend, that small vessels, eluding the vigilance of our cruisers, may throw troops on shore, or force their way up the

[^18]river, with the intention of destroying one of our great naval arsenals, or of seizing the eapital in its present uncovered state.

If this is a candid exposition of our defensive relations as a belligerent power, Portsmouth, Plymouth, and, if possible, London, should have been fortified; not in the contemplation of their having to sustain a long siege in the regular forms, but with such works as would enable the troops on the spot to resist a sudden attack, till a force could be collected to repel the invaders.
A system of detached forts seems best calculated to effect this purpose, as they cannot be insulted; but an assailant must break ground before them, though defended by very small garrisons; and they exclude the enemy from the occupation of a considerable space, which can be converted into an entrenched camp on the arrival of reinforcements.

It is too late to apply this theory to Portsmouth; but its adoption at Plymouth would be attended with economy, besides rendering the dock-yard more secure. What might be done for the protection of London, will be considered subsequently.

Very large sums have been expended on works of defence at Dover and Chatham, but it is difficult to conceive on what principle this expense has been incurred at Dover. There is hardly any part of the coast where it is more improbable that an enemy would endeavour to land, than the beach under Dover Cliff. Is it supposed that a diminutive harbour, left dry every tide, is suited to the communications between the Continent and an army that would venture to undertake offensive operations on English ground, against the forces of the British empire? It certainly lies on the post road to France; but, perhaps, a French army would take a different route, if Dover had never been fortified. The harbour no longer exists, for the protection of which Dover Castle was originally built. The surrender of Calais would not, in these days, as in those of our forefathers, enable the English to invade France.

It is yet more difficult to account for the illusion, under the influence of which the importance of Chatham has been magnified, till it was thought necessary to secure it by such extensive fortifications. Its dock-yard is an object of minor consideration, compared with those of Portsmouth and Plymouth. The enemy would never risk the safety of an army for the sake of destroying it: and if he were actually landed in force on our southern coast, all care about Chatham, or its fortifications, would be absorbed in the great concern of impeding his progress towards the capital. The troops which were destined to defend these works amounted to a numerical force, strong enough to dispute, for some time at least, the passage of the Medway, if posted on its left bank; from thence, they could fall back to take part in the general action, which would probably be fought for the protection of the metropolis; where they would be much better employed than they could have been if shut up in Chatham lines, with the Medway close in their rear to prevent the possibility of retreating, and the prospect of laying down their arms as soon as the first division of the enemy passed the river.

The Spanish government was censured for constructing a very strong fortress at Figueras, which, as had been predicted, on falling into the enemy's possession was very prejudicial to Spain. The British Government cannot be accused of having committed a similar error, either at Dover or Chatham.

As to our coast defences, undoubtedly the most vulnerable points ought to be occupied; but we should not undertake to prevent a debarkation on an extent of many leagues, by a series of towers and batteries, which, in many cases, must be abandoned without support to the protection of their own weak garrisons. In all

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wars, the most terrible disasters have constantly resulted from endeavouring to cover too much; and this is now so well understood, that what has been called the system of ubiquity, finds few advocates in the nineteenth century.

The reader's indulgence must now be solicited, to an attempt to show the possibility of defending London, by forming an entrenched camp round it, in consideration of the great interest at stake, and the admitted impractibility of converting so large a city into a fortress. The author's desire to be useful would be accomplished, if, by exciting attention to an object of such importance, he should induce a more able man to propose something better.
It might be as wise to employ the poor on fortifications, which may eventually be of service, as to make them dig holes only to fill them up again; and a considerable sum would be profitably expended, to prevent the recurrence of the disgraceful panic which was produced by the enemy's threat of invasion.

It is fortunate, that the part of London situate on the right bank of the Thames affords the greater facilities for defence. From Vauxhall to the curve of the river near Deptford, a distance of little more than four miles, in a straight line, the ground is so low that great part of it can be laid under water; for the Surrey canal, in many places, is not excavated, but the banks have been built up to contain the water which it receives from the river, and prevent it from overflowing the meadows.
If three forts were constructed on this line, and were connected by a chain of redoubts, it would be a very serious affair, whether the plain was inundated or not, to attack such a force behind them as could always be assembled on an emergency. Nor would the siege of one or more of the forts be a less arduous operation; for those within the lines could make parallels and batteries quite as expeditiously as the besiegers.

Should this part of the project only be ever carried into execution, it would be advisable to remove the ordnance from Woolwich to the Surrey side of London, and cut a canal from thence to Portsmouth for conveying ordnance stores to expeditions fitting out, and avoiding the circuitous navigation down the Thames and round the Forelands.
As the river Lea covers London for five miles from its confluence with the Thames, some dams and a few batteries are all that would be required to the eastward.

If forts were built on Stamford Hill, Highbury Hill, that on which Copenhagen House stands and over which Maiden Lane passes, Primrose Hill, the bank in front of Maida Hill to the right of the Edgware Road, the part of Bayswater Hill which the ha-ha crosses, dividing Hyde Park from Kensington Gardens, and the intervals, including that between the last-mentioned fort and Chelsea Hospital, were occupied by redoubts, entrenched villages, or batteries, the propriety of which is indicated by the respective locality, a very strong line would be formed, covering London to the northward and westward, the defence of which would be facilitated by the village of Stoke Newington, the Regent's and Paddington Canals, the Serpentine River, the houses on the right of Sloane Street, the Military Asylum, and Chelsea Hospital. If these two buildings were not considered of sufficient strength for a flank, a work might be thrown up behind Chelsea Creek, which, with Grosvenor Place, would form a second line behind Sloane Street.
All this will be better understood, by referring to a plan of the environs of London, sold by Faden.
It can scarceiy be necessary to state, that it is not proposed to make continued lines, but lines with intervals.

The forts protecting these lines might be as strong as the Citadel of Bayonne, and should be erected during a peace. As the other parts of the defence could be deferred till there was a prospect of their being immediately wanted, a short time being required for their construction, it would only be necessary to buy the ground on which the forts were to stand, the purchase of which would be a principal part of the expense: of course, precautions would be taken to prevent its being made a job.

The whole circumference of this camp, inclosing the Cities of London and Westminster, the Borough of Southwark, numerous villages, and a considerable tract of country, would be about twenty-one miles; twelve of which, viz. the course of the River Lea, the Isle of Dugs, and the inundation, \&c., on the south of the Thames, present so many obstacles that it is very improbable an enemy would endeavour to surmount them; so that from Stamford Hill to Chelsea Hospital, the part most likely to be attacked, is only about nine miles.

The lines of Torres Vedras, from Alhandra on the Tagus to the mouth of the river Zizandra on the Atlantic, were thirty-four miles in length. The chord subtending the are they described, is twenty-five miles.

The Austrians and Russians, with their immense superiority in 1761, did not venfure to attack the King of Prussia's camp at Buntzelwitz, though it was more than eighteen miles in circumference.

The system of defence here proposed, possesses the great advantage of enabling the most irregular and undisciplined description of armed force, if only disposed to stand, and able to load and fire, to oppose veteran troops; for, as their flanks are supported by a powerful artillery, which cannot be silenced or taken, but by the tedious process of a siege, they are not required to manœuure, and can only be attacked in front; while there are everywhere large openings in the defences, through which the regular troops can move to take the assailant in flank, the moment he is checked by a cannonade from guns of a much larger calibre than are usually seen on a field of battle.

At Zaragossa, the towns-people became so inured to fire, before the French could master some of the convents, which seemed to be their sole defence, that they afterwards disputed the city, street by street, with the most heroic courage; made the enemy buy every house of which he got possession with torrents of his blood, and finally surrendered, only from the want of provisions. Yet these very men could not have opposed a French army, in the open field, with anything like equal numbers, for ten minutes.

A few field-works, and the barriers of Paris, inspired the wreck of Waterloo with such confidence, that a treaty was concluded with the conquerors, who had surrounded the capital; which removed the army, protected by these formidable works, to a good military position behind one of the most considerable rivers in France. It is not intended to insinuate, that the Allies were not influenced by political considerations.

When considering the defence of the south side of the Thames, it was observed, that it would not be an easy operation to besiege a fort, forming part of an extensive line of works: the siege even of an isolated work, which is in immediate communication with a large army, must be attended with prodigious loss. The Austrians, before Kehl, were deprived of nearly all the advantages aequired in the Archduke's brilliant campaign of 1796.
The author can form no judgment with respect to the quantity of provisions usually kept in London. He knows not whether it may amount to a week's or to a month's consumption; but he is convinced, from the commercial intercourse carried
on by this city, and from its means of transport, that such a stock could be laid in as would be more than sufficient for its supply during a longer period than an army could keep the field to blockade it. It is probable that a much larger force could always be assembled than would be required for the lines; but if it were judged expedient to remain within them, and act on the defensive, a detached corps might be strongly entrenched on the chain of hills extending from Highgate to Hampstead, as this would materially increase the difficulties which an army always experiences when investing a place divided by a large river : the communication with the country could not be cut off.

It is to be regretted that well-educated Englishmen, not of the military profession, have considered themselves incompetent to form any judgment on questions concerning military affairs; in consequence of which, the statesmen of England have left these matters to be decided by professional men, who did not always possess the information for which credit was given them. Surely, in a country where so much attention is paid to education, the science of war ought to be cultivated as a branch of general knowledge. If a gentleman of the plainest understanding, but with habits of application, would take the trouble of perusing attentively the work of Jomini, for the movements of armies ; and those of Bousmard, Noizet de St. Paul, and Cormontaigne, for fortification, with its attack and defence; he would be as capable of appreciating the merits of a project for offensive or defensive operations, as if he had commanded armies. The theory of war is very simple, and its principles have been defined with accuracy and precision; the quality, much more rare than is commonly supposed, which characterizes the great general, seems to be, in the gifted few, the power of perceiving, in an instant, the application of the general rule to a particular case, under circumstances of danger and responsibility, which deprive some men of the use of their faculties. A wise government would promote and employ such officers, whenever it discovered them, without any consideration of their family connections or parliamentary interest.

Before the author concludes, he has only to observe, that if the case is really as here represented; if, after expending many millions, much that was not expedient, but essential, has been omitted; and of that which has been executed at such an expense, much is useless or prejudicial; as there is no natural unfitness in the capacities of Englishmen for the acquisition of this, or any other kind of knowledge, may we not infer that there is something defective or erroneous in our institutions? Fortifications ought to be constructed with reference to the intended distribution of the army, in the event of hostilities taking place; but in this country they are under the control and direction of the Board of Ordnance, the Master-General * of which may be of higher rank in the state and in the army than the Commander-in-Chief of Her Majesty's Forces, and must always have great influence, from possessing, $e x$ officio, a seat in the Cabinet. Is such an arrangement calculated to insure the concert and subordination which ought to pervade every branch of the service? It will hardly be denied, that the naval part of the Ordnance ought to be under the direction of the Admiralty. Common sense, experience, and the example of the great military powers, point out the policy, or rather the necessity, of placing the artillery, engineers, their establishments, and everything connected with their equipment, as completely under th - orders, and at the disposition of the Commander-in-Chief, or War Minister, as is the commissariat, or any other department of the army.

The history of the wars of Europe, for the last two centuries, shows that fortifica-
tions judiciously placed, and not disproportioned to the object they are intended to secure, are the solid base on which rest the permanent prosperity and military power of a nation. But a real Uncle Toby would find them very expense playthings, if he paid for his own amusement; and when these conditions have been totally disregarded, they can only be considered as monuments of folly, and a national disgrace.

Mem. - Whole streets of houses, and lines of railroad, would probably modify the reasoning in the foregoing pages.

Feb. 18, 1851.

## PAPER XVII.

NOTICE of the Arrangements which have been made for taking Meteorological Observations at the principal Foreign Stations of the Royal Engineers. By Captain Henry James, Royal Engineers, F.R.S., M.R.I.A.

The following Memorandum from the Inspector-General of Fortifications to the Commanding Officers of Royal Engineers, will explain in general terms the object proposed:-
" It having been suggested to the Master-General that it might be highly useful to science if a series of Meteorological Observations were recorded in different parts of the world, on one uniform system, under instructions and by authority, his Lordship has consented that the object should be carried out at the nineteen stations as enumerated below, by or under the immediate directions of the Commanding Royal Engineers at each.

Names of Stations.

1. Bahama.
2. Barbadoes.
3. Bermuda.
4. Саре.
5. Ceylon.
6. Corfu.
7. Demerara.
8. Gibraltar.
9. Guernsey.
10. Halifax.
11. Hong Kong.
12. Jamaica.
13. Malta.
14. Mauritius.
15. Newfoundland.
16. New South Wales.
17. St. Helena.
18. Toronto.
19. Quebec.
" Instruments, instructions, and books of reference of an uniform description will be forwarded to each station.
" The endeavour, in the arrangements, has been to commence, upon a system that shall be compatible with the acquirements of any Officer of Engineers, and that shall enable him, without difficulty, to take measures for a due record being kept of every matter required, and, at the same time, not call upon any exertions or unneces-
sary attendance that shall interfere with the more regular necessary duties of the department.
" The Inspector-General of Fortifications attaches very great importance to this measure, and trusts to meet with the zealous co-operation of the several Commanding Royal Engineers, to carry it out in the most perfect manner.
"He requests an early communication from the Commanding Royal Engineers of the first measures taken by them in the matter, with any remarks they may have to offer; and subsequently he would be glad of information, from time to time, of the mode and regularity of the proceedings, with any circumstance worthy of observation.
"J. F. Burgoyne."

## List of Meteorological Instruments.

1 Barometer, by Barow and Co.-The index errors of the barometer will be determined by a comparison with the standard barometer at the Royal Observatory at Greenwich.
6 Thermometers (self-registering) by Troughton and Simms.
1 For maximum in the sun.
1 For minimum in the grass.
1 For maximum in air.
1 For minimum in air.
1 For maximum, wet bulb.
1 For minimum, wet bulb.
And one standard thermometer, the index errors of which will be determined by a comparison with the standard thermometer at Greenwich, and by which the index errors of the six selfregistering thermometers are to be determined.
Hygrometers-Dry and Wet Bulb.-The four last thermometers are arranged so that they may serve for two independent dry and wet bulb hygrometers, or using the mean of the readings of the two air thermometers, and of the two wet-bulb thermometers, as a double dry and wet-bulb hygrometer.
Daniel's Hygrometer.-Much difference of opinion existing amongst scientific men as to the accuracy of the indications of the dry and wet bulb hygrometers for determining the temperature of the dew-point, particularly in climates subject to the extremes of temperature and humidity, it is proposed to have direct observations upon this point made with Daniel's hygrometer at the following stations, viz., Newfoundland, Toronto, Demerara, and the Cape.

The temperature of the dew-point by Daniel's hygrometers to be inserted in red ink, under the computed dew-point in the 8 th and 3lst columns of the register.
1 Wind Gauge.-1 to each station, by Barrow and Co.
Books.

I copy of the "Report of the Committee of Physics, including Meteorology," adopted by the Royal Society.
1 copy of Mr. Glaisher's "Hygrometrical Tables, and Description of the Dry and Wet Bulb Thermometer."
1 copy of " Description of the Mode of Using Daniel's Hygrometer, with Tables."
1 copy of Belville's "Manual of the Thermometer."

## Directions for Putting-up or Taking down the Barometer.

THE barometer may be placed in any ordinary room, but care should be taken, in selecting a position for it, that the sun cannot shine on it, nor should it be near a fire; at the same time it should be in a good light, so that the point P and the Vernier V can be well seen. If the bottom of the board to which the barometer is attached is placed at about 2 feet 9 inches from the ground, the height will be found a convenient one for most observers. The instrument should be put up as nearly vertical as possible, and secured to the wall by means of the screws through the board. The screw at B is then to be turned back till the mercury in the cistern falls to the level of the point $P$; the ivory plug at $\mathbf{C}$ is then taken out with a pair of pliers, and for safety may be kept in the hole at E. The thermometer $\mathbf{T}$ is then inserted into the hole at C, and slipped over the heads of the screws at D, which serve to keep it in its place; the small piece of gutta percha round the thermometer should be pressed down so as to close the hole at C and keep out dust.

The perfect vertical adjustment of the instrument is then made by means of the three screws at A; the point $P$ is brought into exact contact with the surface of the mercury, and as the instrument is turned round by the hand, if it is vertical, the point P will keep in exact contact with the mercury in every position; if not, it must be adjusted till it does do so.

In taking down the barometer, the thermometer is first taken off, and the ivory peg firmly screwed into the hole C; the screw B is then turned, and the mercury raised till it is within less than a quarter of an inch of the top of the tube, or till the screw is stopped by a piece of wire across it, which is placed there to regulate the height of the mercury; the instrument may then be taken down, and packed in an ordinary case, but it is better to carry it with the cistern upwards, and great care should be taken to prevent its receiving a fall or blow, or concussion of any kind.

The barometers are of the construction recommended by the Astronomer Royal; their index errors have been ascertained by a comparison with the standard barometer of the Royal Observatory at Greenwich.

The index error of each, and the amount of capillary action, is recorded in a note pasted to the board on which the instrument is mounted, and should always be stated in the comer of the printed register.


## Directions for Reading the Barometer.

The level of the mercury in the cistern should be adjusted by the screw under it, so as exactly to touch the ivory point, which, with its reflection, will then appear as a double cone.

This point is the zero of the scale; the height of the column of mercury is then taken by adjusting the lower edge of the vernier, so that it shall be exactly tangent to the convex surface of the mercury in the tube, care being taken, by gently raising and lowering the eye, to see that the eye is in exactly the same plane with the back and front lower edge of the vernier. The height should then be read.

Officers of Engineers are so familiar with the reading of all kinds of instruments with verniers, that no directions are required for them in explanation of the mode of reading off the height, but as many of the observers may not have been accustomed to instruments with verniers, the following directions may be found useful:-

The brass tube which surrounds the column of mercury is the scale of the instrument, though only a small part of it, at the upper end, is graduated; it is there divided into inches, tenths of inches, and half-tenths, or 05 . The vernier is graduated to 002 , and the observer can read to $\cdot 001$, or the one-thousandth part of an inch.

For example, in reading such a umber as $29.763,29.750$ will be read on the scale, and

- 013 on the vernier ; that

$$
29 \cdot 763
$$

is, the coincidence of the lines will not be exactly at 012 or •014 but would be intermediate between them.

A learner should set the bottom of the vernier exactly at 30 inches, then, slowly raising the vernier, mark the coincidence of the lines of the vernier and scale at $30 \cdot 002, .004, \cdot 006, \cdot 008.010, \cdot 012, \& \mathrm{c}$. , to $\cdot 050$, when he will see that the bottom of the vernier has also reached the 05 on the scale, so that, continuing to raise the vernier, he commences to read again at the bottom of it, but adding the $\cdot 05$, the readings become $30 \cdot 052, \cdot 054, \cdot 056, \cdot 058, \cdot 060, \cdot 062$, \&c., to $\cdot 098, \cdot 100, \cdot 102$, \&e. A very little practice will enable anybody to read off the instrument accurately and quickly ; and it is important that the observations should be taken quickly, as the heat of the body and of the hands is very rapidly communicated to the instrument, and will affect the readings.

The reading off the attached thermometer should be taken at the same time the barometer is read.

## Thermometers.

Six thermometers in a case, numbered as represented in the opposite engraving, will he forwarded to each station ; they are all made to register maximum and minimum temperature. The maximum, No. 1, 3, 5, are filled with mercury; the minimum, No. 2, 4, 6 , are filled with spirit.
The maximum temperature is indicated by a small piece of steel wire in the tube of the thermometer, which is pushed along as the temperature increases, and as the temperature decreases is left at the highest point it had reached; the position of the end of the index nearest to the bulb is therefore the point to be registered.

The small magnets, M, at the ends of the thermometers, are for holding the steel

indices there when travelling; if the indices are left free they are apt to become entangled in the mercury, from which it is sometimes difficult afterwards to free them, but it can always be done by raising the temperature so as to drive the index into the end of the tube, and holding it there with the magnet whilst the mercury is shook together and allowed to descend in an unbroken thread. See directions at page 60, Royal Society's Report of the Committee of Physics.

The minimum temperature is indicated by a small piece of porcelain, in the form of a dumb bell, which is immersed in the spirit, and will not (unless violently jerked) go beyond the end of the spirit. As the temperature diminishes, the index is carried back with the spirit till it reaches the lowest degree of temperature, at which point it will remain, as the spirit in ascending passes freely round it without disturbing it; the end of the index furthest from the bulb is therefore the point to be registered.

No. 1 is for registering the maximum temperature in the sun, and should be placed out in a position to receive its full power, but where the air freely circulates.
No. 2 is for registering the minimum temperature on the grass; the scale is engraved on the glass tube, and in use should be laid horizontally on the grass. In taking it out of the wooden frame, it should be gently pushed with the thumb against the small end of the tube. If the temperature is not read whilst it is on the grass, it should be lifted gently and horizontally, that the position of the index may not be altered.
The maximum and minimum of Nos. 1 and 2 give the extreme range of the temperature for the previous 24 hours.
Nos. $3,4,5$, and 6 , should be kept in the case in which they are sent out, the front and back of which takes off, leaving a skeleton frame to which these thermometers are attached. The case should be put up in a position where the air freely circulates, and where the thermometers will be perfectly shaded, as well from the reflected as from the direct heat of the sun.
The sketch of the stand used at the Royal Observatory, at Greenwich, will enable the officers to construct similar ones. They should be fixed firmly in the ground,

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and the case of thermometers may be kept about an inch from the back of it by blocks of wood. These thermometers all turn upon screws at their ends, so that

Fig. 1.

they may be tilted up, and gently tapped to cause the indices to slide into their places. A magnet may be used for the steel indices.

The standard thermometer may also be kept in the case under the side of the frame, when Nos. 1 and 2 are taken out.

No. 3 is for registering the maximum temperature of the air in the previous 24 hours; and
No. 4 for registering the minimum temperature of the air, during the same period.
The mean of the above gives proximately the mean temperature of the air at the station in the previous 24 hours.
No. 5 is for registering the maximum indications of the wet-bulb thermometer; and
No. 6 the minimum indications of the wet-bulb thermometer during the previous
24 hours. 24 hours.

A piece of cotton wick from the trough of rain, or distilled water (W), preserves the requisite degree of moisture on the bulbs.
The index errors of the thermometers are to be determined by comparison with the thermometer previously compared with the standard thermometer at Greenwich Observatory.

Fig. 2.


Directions for determining the Index Errors of Thermometers.
Take some pounded ice in a basin, and place the standard and the thermometer under examination in it; then pour in a little cold water, and note the readings of the two thermometers as they descend to $32^{\circ}$.
Next, holding the two thermometers together, place them in a basin or jug of cold water, and gradually pour in hot water, stirring the water with the thermometers all the while that the heat may be equally diffused, and note the readings of the two thermometers as the temperature is gradually raised to near the boiling point.

P 2

In this way, two columns of readings will be obtained from the freezing to near the boiling point, which should be entered in a table with four columns; the first for the readings of the standard, the second for the readings corrected for their index errors, the third column for the readings of the thermometer under examination, and the fourth for the differences plus or minus between the corrected readings of the standard and the readings of the thermometer under examination.

These differences or index-errors can then be grouped as thus :-

$$
\begin{array}{rlll}
\text { from } 32^{\circ} \text { to } & 44^{\circ} \text { index error } & -5 \\
45 & \text { to } 60 & " & +-25 \\
61 \text { to } 100 & " & +75
\end{array}
$$

and entered in the corner of the Register.

## Hygrometers. <br> Dry and wet bulbs.

Nos. 3, 5, and 4, 6, thermometers, may be considered as two \%hgrometers, or the mean of the corrected readings of 3 and 4 , and 5 and 6 , may be entered in Nos. 5 and 7 columns of the register. These readings furnish the data for computing the temperature of the dew-point, and the degree of humidity of the air.

Each station will be furnished with a copy of Mr. Glaisher's " Hygrometrical Tables," in which there is a full description of the dry and wet-bulb hygrometer, and the precautions to be observed in using it; it is, therefore, only necessary here to refer to that work.

## Daniel's Hygrometer.

Some stations will also be furnished with a Daniel's hygrometer, that the officers may have the means of comparing the indications of the instrument, and of testing the accuracy of the factors and formula used in computing the dew-point in Mr. Glaisher's Tables, and the accuracy of Dr. Apjohn's formula. Tables for using the formula will be sent with the instruments.

These observations should be entered in red ink, under the computed dew-point in columns No. 8 and No. 31.

As has been before observed, a considerable difference of opinion exists amongst scientific men as to the value of the dry and wet bulb indications compared with the indications of Daniel's hygrometer, and it is hoped that very careful observations will be made with these instruments, to furnish data for deciding the question.

A description of and directions for using Daniel's hygrometer will be sent with the instruments.

## Wind Gauge.

The wind gauge is designed to indicate the direction and force of the wind, and its maximum pressure in a given period of time. It consists of a vane supported and turning on an iron tube, $\mathbf{T}$, and a plate of tin, P , one foot square, sliding on a horizontal rod above the vane, from which a short piece of chain is passed over the wheel, W , and attached to a wire in the tube, from the index I .
The plate P is thus always held at right angles to the direction of the wind, and as it is made to slide with great freedom along the rod by means of friction rollers at F and F in the tube which carries the plate, and the friction at the wheel $W$ is inconsiderable, the pressure of the wind on the plate is very accurately transferred to the index I, (which is an ordinary circular weighing machine,) and shown by the position of the hand.


Scale $\frac{1}{16}$ th the full size.
The maximum pressure is known by the position of the smaller hand of the index, which remains at the furthest point to which it has been carried by the other hand.

The direction of the wind may be seen by the usual cross bars for the compass points; but as it is impossible to foresee the various positions which the officers may think it desirable to place the wind gauge in, provision has been made for having the indications both of pressure and direction seen in a room of any house upon which it may be thought desirable to place the gauge, and I have represented it standing on a stool, to explain the arrangement.

A truncated hollow cone of brass is screwed on to the head of the iron supporting tube T, upon which the vane turns; but there is also a smaller copper tube, C , passing up through $T$ and the hollow cone, and secured to the vane by screws at S ; thus this inner tube, which is steadied by friction rollers in the lower part of T, turns with the vane and carries a hand over a horizontal dial, D, the wire from the plate to the index passes down through the inner tube, and, to prevent torsion, there are two swivels on the wire.
The spur wheel at A is for the purpose of leading a string from the plate, to which weights may be attached and the accuracy of the readings of the index tested; the error for friction may be taken as half the difference between the weights and the readings. The gauge will require to be cleaned occasionally, when the error for friction should be ascertained, and added to the reading of the index.
The tube $\mathbf{T}$ is fitted and screwed into the socket B, which has four feet, and can be secured by screws on the top of a house, or a post; if placed on a post, it should have cross-trees at the head to give the means of studying the wind gauge, and to admit of its being so far placed off the centre that the wire from the plate to the index may lead straight down.

The post which carries the wind gauge might have a sort of umbrella roof around it, at about 6 feet from the ground, under which the index and the thermometer stand turning round the post might be placed.

The post should of course have ropes, to keep it as steady as possible.
The small tube may be lengthened to suit the height of the roof of any house on which it may be placed.

In the event of the spring of the index getting out of order, many means will suggest themselves for supplying its place. A light lever of the second order would be a simple plan; the wire would be attached to the end of the lever, and the weight moved from the fulcrum towards the end till it balanced the pressure: or a light tin vessel, or a bag might be attached to the wire, and weights placed in it till it counterbalanced the pressure.
The index errors of the wind gauge which I have examined, were-

but the errors of each gauge should be separately ascertained at the stations.

## Directions for filling in the Diagram.

Barometer. The heights from the corrected readings of the morning daily observations should be plotted on the lines for the days, and connected by a dotted line, and the whole space below this covered with a light wash of indigo, and a dotted line drawn across the diagram at the mean height.
Pressure of Wind. The readings should be plotted in the same manner, and a shade of grey put over the space.
Rain. The quantities should be shown by dark lines $\frac{1}{16}$ th of an inch wide, to represent the depths.
Maximum Temperature. Should be plotted like the barometer heights, and the tint of indigo washed over all the lower part of the diagram.

Minimum Temperature. To be plotted in the same way, and a second darker shade of indigo washed over.
Mean Temperature. Draw a dotted line between the maximum and minimum for the mean temperature of the days, and a firm line straight across the diagram for the mean temperature of the month.
Humidity. To be plotted and shaded like the pressure of the wind.
The diagrams thus filled in will exhibit at a glance any peculiar atmospheric phenomena, and by comparing the diagrams from the different stations the peculiar character of the climates will be seen, and probably the extent of great atmospheric disturbances. The connexion also between the height of the barometer, the force and direction of the wind, the quantity of rain, the temperature, and the humidity of the air can be traced by mere inspection.

## Rain Gauge.

Two are supplied to each station. The receiver is merely a 10 -inch cubical box, made of zinc, with a partition half-way down, in the form of an inverted pyramid $\mathbf{P}$, with a half-inch pipe at the apex, through which the rain-water descends into the lower half of the receiver. The object of this partition is to prevent loss by evapo-

ration, by protecting, as far as possible, the water which has been collected from the action of the sun and wind. A glass measure, graduated for every one-hundredth of an inch of the quantity collected in the receiver, is supplied with each rain-gauge, into which the water collected in the previous 24 hours should be poured and measured. The greatest quantity it will measure at a time is one-fourth of an inch; it will therefore be frequently necessary to fill the measure several times. One of the rain-gauges should be placed in a hole in the ground so that its mouth shall be exactly level with the surface of the ground. It would be well to have the hole lined with bricks; or a rough box may be placed in it, leaving a space of not more than onefourth of an inch round the gauge. Provision must be made to allow water to drain away from the hole.
The other rain-gauge should be placed about 20 feet above the ground, in some convenient position on a building, or on a pole put up for the purpose ; care being
taken that both gauges are, as far as possible, removed from the influence of eddies of wind, from buildings, trees, \&c. It will be found convenient, in many places, to have a small tube of lead or gutta peroha from the bottom of the upper receiver to the ground, to obviate the necessity and discomfort of getting up to the rain-gauge to measure the quantity collected.

## Periods at which Observations are to be taken.

Daily observations are to be taken regularly at $9 \frac{1}{2}$ A.M. and $3 \frac{1}{2}$ P.M.
The indications of the self-registering instruments are also to be taken at $9 \frac{1}{2} \mathrm{~A} . \mathrm{M}$. As these hours fall within the regular working hours of the officers and of those who are employed in the offices, all of whom may be instructed accurately to read and register the instruments, it is expected that the observations at these hours will be made with great care and regularity; but it is hoped that many of the observers will take an interest in Meteorological Science, and make arrangements to have observations also taken at $9 \frac{1}{2}$ P.M. and $3 \frac{1}{2}$ A.M., as often as possible. These observations to be inserted in a separate register, writing the word "Night" in the right-hand upper corner, and using columns 1 to 12 for the $9 \frac{1}{2}$ P.M., and columns 23 to 35 for the $3 \frac{1}{2} \mathrm{~A}, \mathrm{M}$. observations.
Hourly observations are to be taken on the 21st of March, 21st of June, 21st of September, and 21 st of December, commencing at 6 A.M. on those days, unless they fall on a Sunday, in which case the observations will commence at $6 \mathrm{~A} . \mathrm{m}$. on the 22 nd .
The same form of register will answer for the hourly observations, using 24 of the lines for the days of the month, for the hours of the day.
It would add greatly to the value of the observations of the station, if the hourly observations are taken more frequently; and it is recommended to those who are desirous to furnish more exact information (and it is hoped there are many who will do so), to take hourly observations on the 21 st of each month.
Occasional observations should be taken hourly, or even more frequently, when any sudden great rise or fall in the barometer should seem to indicate great atmospheric changes, as well as during periods of hurricanes, or very severe gales of wind, or earthquakes. See Report of the Royal Society on Physics, page 55 .
The original Registers are to be transmitted monthly, or as soon as opportunities occur after the expiration of each month, to the Inspector-General of Fortifications, and authentic copies of the Registers are to be kept at the station. The diagrams are to be filled like the example sent.
The officers are recommended to furnish the editors of local papers with extracts from the registers.

## NOTES ON METEOROLOGY.

It may be interesting to those who are not already familiar with the leading facts which meteorological science has made known to us, if to the description of the instruments, and the observations to be taken with them, a few notes on some of the more interesting phenomena are added.

## Daily Atmospheric Tides.



If a circle be divided into 24 parts, representing the 24 hours of the day, and the mean height of the barometer for each hour of the day is set off vertically upon the circle, we shall have a pretty correct idea of what are called Atmospheric Tides. In the above diagram, the mean beight of the barometer at Madras, for the year 1845, at $3 \frac{3}{4}$ P.M., has been deducted from the mean height of the barometer at $9 \frac{3}{4}$ A.M., $9 \frac{3}{4}$ P.M., and $3 \frac{3}{4}$ A.M., and the numbers plotted above an imaginary atmospheric zone. It will thus be seen that the maximum pressure of the atmosphere during the 24 hours is at $9 \frac{3}{4}$; that it gradually decreases till $3 \frac{3}{9}$ P.M., when it reaches the minimum of the 24 hours; that it then gradually increases till $9 \frac{8}{2}$ P.M. ; and again gradually diminishes till $3_{4}^{3}$ A.M. This increase and decrease in the pressure of the atmosphere has given rise to the idea of aerial tides regularly ebbing and flowing.
Baron Humboldt says: - "The horary variations of the barometer, which, under the tropics, present two maxima (at 9 or $9 \frac{1}{4}$ A.M., and at $10 \frac{1}{2}$ or $10 \frac{3}{4}$ P.M.) and two minima (at 4 or $4 \frac{1}{4}$ P.M., and at 4 A.M., which are nearly the hottest and the coldest hours of the day), were long the object of my most careful daily and nightly observations. Their regularity is such, that, in the daytime especially, we may infer the hour from the height of the column of mercury, without being in error, on an average, more than fifteen or seventeen minutes. In the torrid zone of the New Continent, I

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have found the regularity of this ebb and flow of the aerial ocean undisturbed either by storm, tempest, rain, or earthquake, both on the coasts and at elevations of nearly 13,000 feet above the sea, where the mean temperature sinks to 44.6 Eahrenheit." Cosmos, vol, i. p. 308.

Lieutenant-Colonel Sykes states that, in a paper published in the "Philosophical Transactions," in 1835, upon the Meteorology of the Deccan, he "established the fact of the existence of four atmospheric tides within twenty-four hours-two diurnal and two nocturnal, each consisting of a maximum and minimum tide; and the occurrence of these tides within the same limit of hours as in America and in Europe; and that these tides took place regularly, without a single instance of intermission, whatever the thermometric or hygrometric indications might be, or whatever the state of the weather, even storms and hurricanes only modifying, and not interrupting them." To which he adds:-" It is very satisfactory to find in the discussion of the meteorological observations in the present paper, from a very extended area, from different heights, and from observations, some of which are hourly, and which run through several years at the same station, that, after an interval of twenty years, the accuracy of the former deductions should be established almost to the letter."*

This regular recurrence, however, of a double maximum and a double minimum pressure every 24 hours, does not take place in all parts of the world; thus we see by reference to the observations taken at the Royal Observatory at Greenwich, in the years 1842-43-44-45-46-47, that although a double maximum and a double minimum pressure occurs during nine or ten months of each year, a triple maximum and a triple minimum occurs in the remaining months of the year. And Lieut.-Colonel Sabine, R.A., in a note to his translation of "Cosmos," says:- " It has become known that, at stations situated in the interior of great continents very distant from the ocean or from large bodies of water from whence supplies of aqueous vapour may be derived, and where the air consequently is at all times extremely dry, the double maximum and minimum of the diurnal variation of the barometer either wholly or almost wholly disappear, and the variation consists in a single maximum and minimum, which occur respectively nearly at the coldest and at the hottest hours of the day; the greatest height of the mercury being at or near the coldest hour, and the least height at or near the warmest hour. For this simple state of the phenomenon an equally simple explanation presents itself: the surface of the earth becoming warmed by the sun's rays, imparts heat to the strata of the atmosphere in contact with it; the superincumbent air thus rarified, the column, extending in height, overflows laterally in the higher regions of the atmosphere, and the statical pressure at the base of the column is diminished. In the afternoon the converse takes place; the column of air cools, condenses, and, contracting in height, receives the overflow from the adjacent air, which in its turn becomes heated, and thus the statical pressure is increased. The stations at which this more simple form of the barometric diurnal curve has hitherto been found to take place, are Catherinenbourg, Nertchinsk, and Barnaoul, all in the Russian territories, on the confines of Europe and Asia. Whenever a free communication with a sufficiently extensive evaporating surface exists, a diurnal variation is also found to take place in the tension of the aqueous vapour in the atmosphere, proportioned in amount to the diumal variation of the temperature. If the sources of vapour be ample to supply the drain of the ascending current of the air which carries vapour with it, as well as to furnish the increasing tension which the increasing temperature demands, the diurnal variation of the vapour tension has its maximum at or near the hottest hour of the day, and its minimum at or near the coldest hour, being the converse of the diurnal variation of the dry air

[^19](or of the gaseous portion of the atmosphere), which, as before stated, has its maximum at or near the coldest hour, and its minimum at or near the warmest hour. The combination of the diurnal variations of the vapour and of the dry air, which conjointly produce the diurnal variation in the pressure on the barometer, occasions the double maximum and minimum of the barometric curve in the temperate zone, at stations not so far removed as Russian ones from the sources from whence vapour can be supplied. If the elastic force of the vapour be observed by means of a hygrometer, with the same care that the barometer is observed, and if the respective pressures of the elastic forces of the air and the vapour upon the mercury of the barometer be separated from each other, the diurnal variation of the dry air exhibits at all stations in the temperate zone at which observations have hitherto been made, a similar curve to that which the whole barometric pressure produces at the Russian stations, where the air is naturally dry.
"At Prague, in the interior of Europe; at Toronto, in the interior of America, but situated near extensive lakes; and at Greenwich, in the vicinity of the ocean, the diurnal variation of the $d r y$ air has but one maximum and one minimum, and these coincide, or nearly coincide, with the coldest and the warmest hours *. Hence it has been inferred that the normal state of the diurnal variation of the gaseous portion of the atmosphere in the temperate zone is that of a single progression, having a maximum at or near the coldest hour of the day, and a minimum at or near the warmest hour; and that at stations of remarkable neutral dryness this curve is given directly by the barometer; and that at other stations, where aqueous vapour mixes in the atmosphere in a greater degree, the same curve is deducible from that of the barometer, by separating the elastic force of the vapour from the whole pressure shown by that instrument. As a concomitant phenomenon with the diurnal variation of the gaseous pressure, and due originally to the same cause, (viz., the alteruate heating and cooling of the earth's surface by radiation, although an immediate consequence of the ascending current, ) we find a diurnal variation taking place in the force of the wind at or near the base of the column. At Greenwich and Toronto, where the force of the wind is continually recorded by self-registering instruments, it is found to undergo a diurnal variation consisting of a single progression, having a minimum at or near the coldest hour, and a maximum at or near the warmest hour of the day. Soon after the ascending current has commenced, a lateral influx is produced to supply the drain which it occasions; the cooler air, as it arrives, becomes heated in its turn and ascends; as the upward current gathers strength with the increasing temperature of the day, the lateral influx augments also, and attains its maximum about the hour when the phenomena of increasing temperature give place generally to those of decreasing temperature.
"The insight which has been obtained into the mutual relations of these meteorological phenomena, and into the sequence of natural causes and effects by which their connection is explained, is a further illustration of the progress which is made in the physical sciences by the aid of mean numerical values. The connection which the knowledge of these values has established between the diurnal phenomena of the different elements, and the dependence which it has shown them to have on a common cause, (viz., on the rotation of the earth on its axis, whereby each portion of its surface is successively turned towards the sun, and each meteorological element is thus subjected to a fluctuation of which the period is measured by a day,) adds another beautiful instance to those which have been cited by M. de Humboldt in the text, of the simplicity with which general results in the physical sciences can be pre-

* Sabine, Reports of the Brit. Assoc, 1844, pp. 42-62.
sented, when the links of mutual relation are discovered between phenomena which, when looked at singly and superficially, appear unconnected, and, when a deeper insight is obtained into the intricate play of natural forces, by pursuing the strictly inductive method of investigation, resting on the secure basis of correct quantitative determination. The annual variations of the meteorological elements afford a not less striking example of the more or less immediate dependence of several apparently unconnected phenomena on the variations of the temperature occasioned by the earth's annual revolution in its orbit. The method and systematic direction which characterize the meteorological researches of the present period promise in a peculiar degree to reveal the 'constant amid change,' the 'stable amid the flow of phenomena.' M. Dove (to whom is primarily due the new aspect which this beautiful branch of physical investigation has assumed by the separation of the pressures of the aqueous and gaseous portions of the atmosphere) has very recently shown, in a memoir read to the Academy of Sciences at Berlin (March, 1846), that the same single progression of the diurnal variation of the dry air extends also into the intertropical regions. At Buitenzorg, in Java, the dry air is found to have a single maximum and minimum, the epochs of which coincide respectively with the coldest and warmest hours. It was previously known*, that at Bombay, also within the tropics, a less simple law prevailed, the gaseous atmosphere having there a double maximum and minimum in the twenty-four hours, accompanied by a corresponding double progression in the force of the wind. The phenomena at Bombay are by no means, however, to be viewed as a contradiction to the principles on which the more simple progression prevailing elsewhere has been explained; on the contrary, an extension of the same principles to the more complicated relations produced by the juxtaposition of surfaces of land and sea, and by the different affections of these surfaces by temperature, had led to the expectation that such exceptional cases would be found within the tropics; the mutual relations of the diurnal variations of the gaseous pressure and the force of the wind have received a further and very striking exemplication in this exceptional case; one minimum of the pressure is found to coincide with the greatest strength of the land-breeze, the other minimum with the greatest strength of the sea-breeze, and the epochs of the two maxima of pressure correspond respectively with those of the two minima of the force of the wind."
mean height of barometer and thermometer for each month of the years 1843 , 1844, and 1845, from hourly observations taken at madras.

| Month. | 1843. |  | 1844. |  | 1845. |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| January ...... | $\begin{aligned} & \mathrm{Bar} \text {. } \\ & 29.985 \end{aligned}$ | $\begin{aligned} & \text { Ther. } \\ & 77.6 \end{aligned}$ | $\begin{gathered} \text { Bar. }^{29 \cdot 998} \end{gathered}$ | $\begin{aligned} & \text { Ther. } \\ & 75.7 \end{aligned}$ | $\begin{aligned} & \text { Bar. } \\ & 30 \cdot 015 \end{aligned}$ | Ther. $768$ |
| February ... | $29 \cdot 966$ | 77.9 | $29 \cdot 980$ | 77.7 | 29.965 | $79 \cdot 4$ |
| March ...... | 29.886 | 81.5 | $29 \cdot 907$ | $82 \cdot 2$ | 29.924 | 831 |
| April . | 29.864 | 85.2 | $29 \cdot 809$ | $86 \cdot 3$ | 29.818 | $86 \cdot 6$ |
| May | 29.692 | 85.0 | 29.700 | 87.0 | 29.712 | 88.6 |
| June | 29.709 | 85.5 | 29.668 | 88.6 | 29.705 | 866 |
| July | 29.709 | 85.8 | 29.723 | 85.8 | 29.726 | 86.1 |
| August | 29.759 | 84.5 | 29.731 | 85.2 | $29 \cdot 742$ | 85.9 |
| September... | 29.788 | 84.2 | 29.793 | $83 \cdot 0$ | 29.830 | 83.9 |
| October ...... | 29.863 | 80.7 | $29 \cdot 868$ | $80 \cdot 5$ | 29.850 | $82 \cdot 9$ |
| November ... | 29.926 | 77.8 | 29.963 | $79 \cdot 2$ | 29.984 | $79 \cdot 1$ |
| December ... | 30.001 | 75.9 | 29.926 | 76.9 | 29.965 | 77.7 |

[^20]If the mean height of the barometer for each month of a series of years be taken and compared with the mean height of the thermometer during the same months, it will be seen that the greatest height of the barometer corresponds nearly to the lowest temperature, and the least height of the barometer to the highest temperature; thus, in the accompanying diagram, which has been protracted from the Madras Observations for 1843,1844 , and 1845 , the barometer was highest in December or January, in which month the temperature was lowest; and the barometer was lowest in May or June, during which months the temperature was highest.


RAIN.
From observations made at York, during three years, by Professor Phillips and Mr. W. Gray, it will be seen that the quantity of rain which falls at different heights above the ground, has a certain relation to the heights, and to the temperature, and to the humidity of the air.

In the year 1884-5, the total quantities collected in the rain gauges, were as follows :-


In fifteen warm months, the mean temperature being $57^{\circ} 4$, the quantities that fell were-

| On the ground ........................ $27 \cdot 5$ inches. |  |
| :---: | :---: |
| On the museum |  |
| On the minste |  |

whilst the quantities which fell in fifteen cold months, the mean temperature being $39^{\circ} \cdot 4$, were-

| On the ground ............................ 14.2 inches. |  |  |
| :---: | :---: | :---: |
| On the museum | 8.8 |  |
| On the minster | $5 \cdot 9$ | " |

Professor Phillips, in his remarks on these experiments, says, "No sooner was the first series of results tabulated, than they were easily seen to be principally dependent on two ascertainable conditions, viz., the vertical measure of the tract of air intervening between the stations, and the temperature of the season of the year; the former determining the ratio of the difference of quantity of rain at different elevations above the ground, the latter influencing the amount of these differences. The dependence of this amount upon the temperature inversely, and, consequently, upon the humidity of the season directly, led to an attempt at a simple explanation of the phenomenon, not materially different from that proposed (as M. Arago has informed me), without experimental proof, by M. Boisgiraud.
"The second series of observations confirmed very completely the conclusion previously adopted, of the dependence of the amount of the difference of rain between a station on the ground and others at some height above it, upon the temperature inversely. But the ratio of the differences at different elevations, which had formerly been supposed constant, was found to vary, and also to exhibit some characteristic variations in different seasons of the year."*

Subsequent observations made by Professor Phillips, at York, by Mr. Miller, at Whitehaven; in the Surveyor-General's Office, at Calcutta ; by Dr. Buish, at Bombay, confirm the general fact, that the nearer the rain-gauge is to the earth the greater is the amount of rain collected. But Lieut.-Colonel Sykes has shown, by the observations made in India, and Mr. Miller in the lake districts of Cumberland and Westmoreland, that "the supposed law may hold good for small differences in elevation on the plain, but the law is reversed in mountainous districts:" and that the elevation of the line of maximum fall in India is about 4500 feet, whilst in England it is at about 2000 feet: "this difference no doubt results from the difference of latitude, and consequent mean temperature, and would indicate that the stratum of vapour supplying the maximum quantity of rain floats at a less height beyond the tropics than within them. The explanation of the prodigious fall of rain at the level of 4500 feet, is simple and satisfactory.
"The chief stratum of aqueous vapours brought from the equator by the S.W. monsoon is of a high temperature, and floats at a lower level than 4500 feet;

[^21]indeed, I have looked over and upon the upper surface of the stratum at 2000 feet. It is dashed with considerable violence against the western mural faces of the ghâts, and is thrown up by these barriers in accumulated masses into a colder region than that in which it naturally floats; it is, consequently, rapidly condensed, and rain falls in floods." *

The extraordinary variation in the amount of rain which falls in different parts of India, is pointed out in this admirable paper, from a register kept at Kurrachee, at the mouth of the Indus, from April, 1847, to July, 1848. It appears that "in these 15 months only two showers occurred, and these so light as not to be appreciable by the pluviometer," whilst the quantity which fell in Bombay, in 1848, was 118.88 inches; and the mean of 15 years shows the quantity which falls at Mahabuleshwur, 4500 feet above the level of the sea, to be 254 inches. The quantity of rain which fell at Sprinkling Tarn, in the lake district, 1900 feet above the sea, was in $1848,148.59$ inches; whilst the mean quantity which falls at Greenwich is only $22 \cdot 25$ inches.

A short paper on the Law of Storms, No. 53, "Chambers's Papers for the People," will be sent with the other books, at the recommendation of Lieut.Colonel Reid, R.E., but that officer's own work on the Law of Storms should be studied by all.
"Kaemtz's Meteorology," by Walker, is recommended to those who wish to study this science.
H. J.

## PAPER XVIII.

Royal Mint, 12th Sept., 1850.

## My dear Williams,

Observing that Sir William Denison in his remark upon Retaining Walls, in the 3rd number of the Corps Papers, says that he believes he derived the idea therein suggested from me, I write to you as one of the Editors of the Corps Papers, to request you to explain in the next number, that I am not entitled to the credit which Denison would give me, and to refer you to the following extract from the 86th page of the 7 th volume of our professional papers, which will show that the suggestion referred to had been offered by the late Lieutenant Hope.
"The opinion expressed by Lieut. Hope, in conversation, was in favour of leaning revetments with narrow counterforts at short intervals, and the experiments appear to justify that opinion. He wished to continue them, with a view to determine an arrangement by which the material used might be reduced to the smallest possible quantity; and he conceived that the face of the revetment might be a mere shell, hardly exposed to any pressure, the earth being chiefly supported by its friction against the sides of thin but frequent counterforts."

$$
\mathrm{I} \mathrm{am},
$$

My dear Williams,
Very sincerely yours,
H. D. Harness.

[^22]
## PAPER XIX.

## BUILDING in Countries subject to Convulsions. *

One of the objects proposed in drawing up the Paper No. 11, of this Volume, was to show that some difference of construction should be made in buildings between countries subject to the most violent hurricanes, and countries which are not. Yet, in the West Indies, it is too often the practice simply to place a roof on its walls, as is the custom in Europe, and to copy the details of construction from the modes adopted in England.

In places where buildings are subject to hurricanes, the whole of the roof should be fixed down to the wall-plate; the wall-plate should be fixed down to the wall; and the wall itself made strong enough to resist the current of air that may rush against the house. Where buildings are of wood, the frame-work should be tied into the ground, or into stone piers fixed in the ground.

In re-establishing the buildings blown down in 1831, in Barbadoes and St. Vincent, as far as I was employed in that duty, the wall-plates were in general tied down by irons, having $L$ heads inverted, and built two feet down in the walls, with a nut screwed over the wall-plate; and in most of the angles a piece of hardwood timber, of a triangular section, placed in the corners, was strongly framed to one angle-tie above the wall-plate, and to another built into the wall, near the foundation of the building.

It was observed that buildings having substantial partitions at short intervals withstood the blast, whilst others without them were blown down. Where large rooms, therefore, could not be divided, they were broken into portions by substantial projecting walls, serving as inside buttresses; and in general an elliptical arch was thrown across the room from one side to the other, on which one of the principal rafters was placed, and tied down at the ends. Most of the window-shutters of soldiers' barracks and store-houses, having no glass, were made to turn on their centres, on strong vertical pivots, one at the top, the other at the bottom of the shutter, and thus balanced they shut against rebates; for it was found that, where there had been shutters opening inwards, as in England, the wind bursting them open on the windward side, pressed and shut the leeward shutters; so that either the roof was carried off, or the leeward wall thrown down. Many buildings fell owing to the joists of the floors for upper galleries, or verandahs, having one end let into the main wall of the building: these acted as so many levers, and upset the walls when the galleries began to vibrate.

When reconstructed, the joists ran paralled to the walls, their ends resting on arches, which were carried across the galleries from strong brick piers, to pilasters connected with the main wall, and every part of the galleries was tied down.

The brickwork was of the old English bond + ; and it was grouted throughout, the bricks having been always saturated with water, which is a measure essential to strong building in tropical climates. In St. Vincent, the sand used for the mortar was selected with great care, and procured from crevices in the basaltic rocks.

[^23]Four proportions of this sand to one of coral lime were always used; and it was found to have set so strongly, that on taking down a part within six weeks after it had been built, the bricks often broke before they could be separated.

One small building, reconstructed in a very exposed situation, was arched like a gunpowder-magazine, as kitchens so constructed had been found to stand uninjured ; and one room at least in each house should be so constructed.

An hospital, with much iron in its construction, and having iron ties reaching quite across it, so as to have the supports of one gallery bolted to the main building and to the opposite gallery, withstood the hurricane.

In re-establishing the roofs, diagonal bracing was inserted in most of the buildings, to stiffen the rafters.

Copper gutters were found to have decayed after twenty years' use, and had not lasted longer than the wooden shingles of the roofs to which they belonged, the copper sheets having worn into holes by the action of the heat and moisture of the climate, by which the metal was converted into the red oxide of copper: and iron nails decay very fast from the same cause.

Parapet walls were found to protect roofs; and perhaps the best roofs are flat ones, such as those used at Mauritius; and no doubt the Pitch Lake of Trinidad would afford a good material for such a construction, if properly prepared.

END OR VOL. I. NEW SERIES.

## ERRATA.

II has been considered necessary to notice the following Errata in Colonel Waddington's article, "The Doctrines of Carpentry examined in their application to the construction of a roof," inserted in the 10th Volume of the Royal Engineers' Professional Volumes.

Page 72, art. 2, line 6, for "three solid figures" read "three-sided figures."
84, line 2 from bottom; page 85 , line 1 ; page 87 , line 6, and lines 5,6 , and 8 from bottom, for "W "read "w."
92 and 94, arts. 37 and 38, and note 29 throughout, for " $w$ " read "W."
106, line 7 from bottom, for " $\frac{5 \cdot 6875}{5 \cdot 21875}$ " read " $\frac{5 \cdot 6875^{3}}{5 \cdot 21875^{3}}$ "
107, line 1, for "pressures on $e e$ " read "pressures ee."
113, line 4, for "described" read "divided."
132, note 74, line 2, for "Art. 163 " read " Art. 143."
134, Girard's Experiments, right division, 3rd column, 9th row, for " 1229 " read " 1291."
139, note 88, line 1, for "scarped" read "scarfed."

Page 77, Fig. 6, left hand, for " $c$ " at vertex of truss write "C."
82, Fig. 9, the line ke, should join CA at e. The intersection of CA with WD', mark " $v$ " instead of " V."
84, Fig. $11, h$ is misplaced, it should be under $m$.
86 , " $x$, the end of the beam B should be on a level with E.
130 , note 72 , the figure should not be square, nor should $A B$ be parallel to the horizon; the side AD being $=1, \mathrm{DB}$ is $=1.0926$.

This opportunity also is taken to point out that the scale of Plate 9 , in vol. iii. Professional Volumes, page 108 (Model Towers, adopted by Napoleon), is erroneous; it is double the size it ought to be.

The Binder is requested to observe, that the earlier sheets have been accidentally printed as if forming the commencement of the second volume, instead of the first of a new series.

[^24]
[^0]:    * In a former paper, vol. i., page 103, I assumed that in the ricochet shot would have effect at 5 or 6 feet under the surface; by more recent experiments it is found that, at the greatest angle at which they will rebound, they do not penetrate above 2 feet. A 13-inch shell, falling from its full range in 10 feet water, is found on the sand as if laid there by hand. A musket ball fired horizontally into water, penetrates a very short way. It would be interesting to carry out these experiments so as to ascertain the precise limits of resistance of water in each case.

[^1]:    * Against a line-of-battle ship the height should not be less than 60 feet.

[^2]:    * See the instructive and very curious translation with which this officer has favoured us in the Second Number of "Corps Papers."
    $\dagger$ See note on caponnière, appended, No. 1.

[^3]:    * The "effective length" is what remains after deducting the loss by the thickness of the parapets of the face and curtain. It has been taken from the plates as published, without reference to correction for particular polygons.
    $\dagger$ Vauban is not mentioned, as few would now-a-days adopt his 1st or 2nd tracing; and the "system proposed" is too nearly related to his 3 rd tracing to claim much, or any, originality.

[^4]:    * In consequence of the divergence of AK and A E , the defilade will probably require K to be sigher than A, as $a, b$, Figs. 10, 11, p. 295, Aide M'́moire.
    + See Note 5.

[^5]:    " Victoria," Hong Kong,
    28th December, 1849.

[^6]:    * See Note A. in Appendix.

[^7]:    * See Note B. in Appendix

[^8]:    * It has since been terminated in the Bushman Land, much further from the coast.

[^9]:    * This applies only to the Cape Town District.

[^10]:    * Forwarded for the information of his Excellency the Commander-in-Chief, by Lieut.Colonel Cole, Commanding Royal Engineeers, 1st Dec. 1848.

[^11]:    Victoria, Hong Kong,
    19th September, 1850.

[^12]:    VOL. II.

[^13]:    * The extent of the main line of the Ganges Canal, according to the design as detailed in Colonel Cautley's printed Report of 1845 , is 453 miles. But this reached to the very extremity of the Doab at Allahabad, where the Ganges and Jumna meet. The line, as in execution, will terminate in the neighbourhood of Cawnpor.

[^14]:    * The cliff is composed of a very compact chalk, 121 lbs to the cubic foot, dipping to the north at an inclination of about $15^{\circ}$, and intersected by veins of flint at intervals of about 15 or 20 feet. Its height was at the site of the western mine 203 feet, and at the other 22514 feet, above high-water mark. The section at the first of these spots was nearly vertieal ; for the whole height at the second it was only so for about 140 or 150 feet.

[^15]:    * This method originated in a suggestion of Colonel Lewis, founded upon a mode he had practised of obtaining light in a magazine, by reflection from the painted copper door of the building.

[^16]:    * See page 66, 10th Professional Volume.

[^17]:    * See page 70, 10th Professional Volume.

[^18]:    * The remarks on fortification were written in 1817: as, however, the subject to which they relate has of late years exeited considerable publie attention, the Editors, with General Thackeray's permission, have introduced in this paper a reprint of the Memoir.

[^19]:    * Discussion of the Meteorological Observations taken in India. Phil. Trans. 1850, p. 375.

[^20]:    * Sabine, Report of the British Associstion, 1845, pp. 73-82.

[^21]:    * Fifth Report of the British Association, 1835.

[^22]:    * Lieut.-Colonel Sykes's Discussion of Meteorological Observations taken in India.

[^23]:    * Inserted by desire of the Inspector-General of Fortifications.
    + Entire rows of bricks laid transversely, alternating with entire rows laid lengthways.

[^24]:    G. Woodfall and Son, Printers, Angel Court, Skinner Street, London.

