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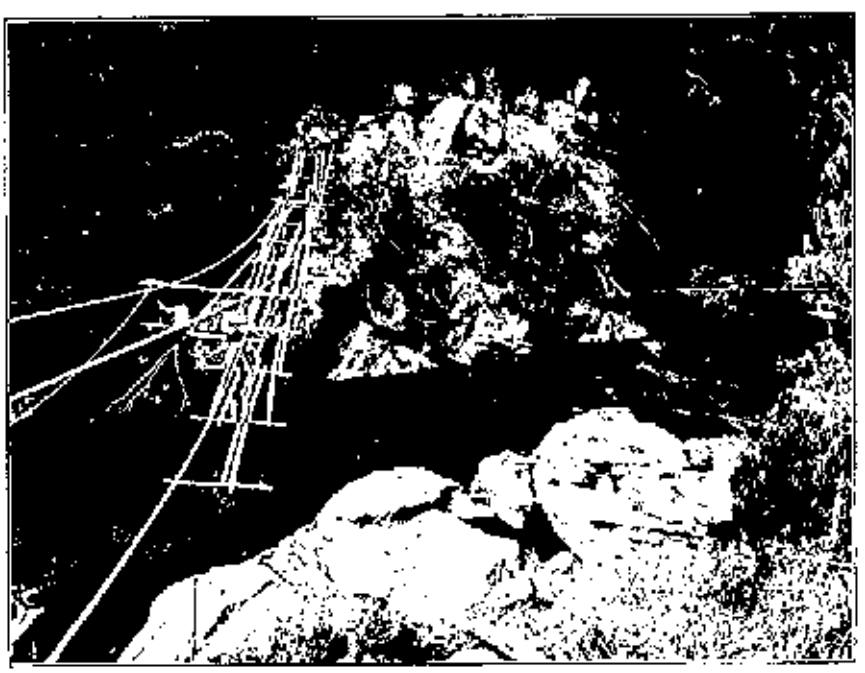
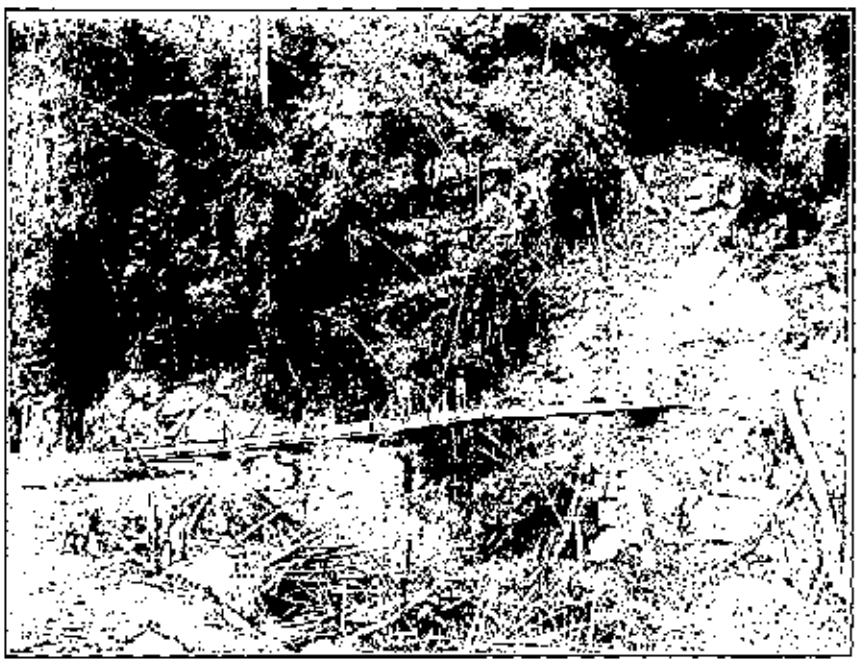


Photo 2.—Ta Mu Kha Bridge under construction.



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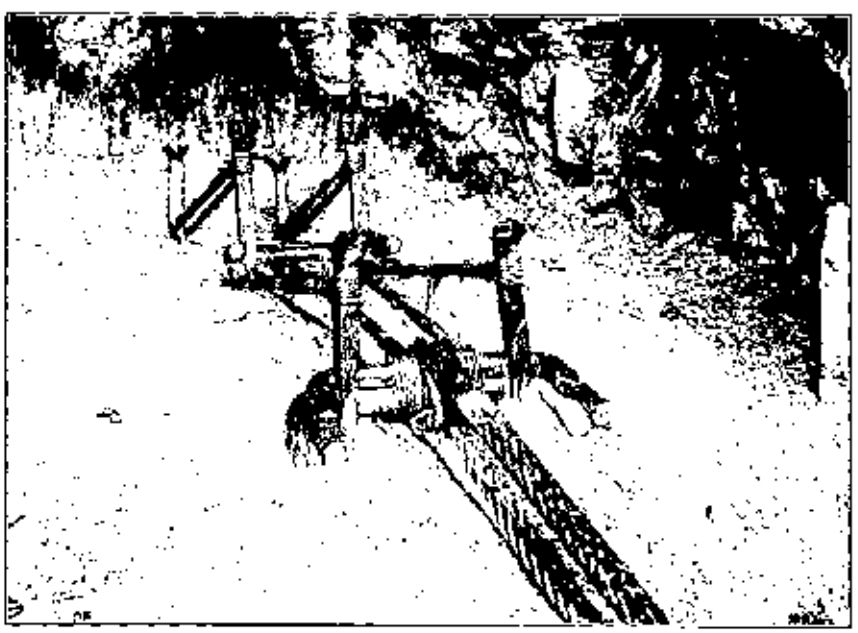


Photo 4.—Rock Anchorage with Crowbars.
Showing one end of one Suspension Cable.

BRIDGING WITH THE BURMA SAPPERS.

By Br. Major R. L. McCLINTOCK, D.S.O., R.E.

IN the autumn of 1910 a force of about 400 Military Police, supported by a regiment of native infantry, was despatched to investigate and provide an "effective occupation" of the district of Hpimaw, an inconsiderable Kachin village near the Burmo-Chinese frontier, some 140 miles north-east of Myitkyina (see *Plate* I.). The latter had previously been entirely unadministered, and very rarely visited by a European.

With the advanced guard, which left for Hpimaw about the end of November, went Lieut. Harris, R.E., and 25 rank and file of the Burma Sappers and Miners.

With the adventures of this "Hpimaw Column" it is not my business to treat, but the village in question having eventually been reached and occupied by it, the authorities finally decided to withdraw the force again to Myitkyina, leaving a police post at a place called Ruckchong in the vicinity.

To maintain communication with this post during the rains, which are both early and torrential in these Kachin hills, it became necessary to provide a road. The native track by which the column had laboriously advanced to Hpimaw had proved very difficult for transport as it ran direct from crest to crest of the successive mountain ranges, sometimes at gradients of 1 in 4, and as the surface was mainly clay it became totally impassable in wet weather.

Accordingly in January, 1911, the Burma P.W.D. was called upon to construct a good 7′ wide mule track with a ruling gradient of 1 in 15, from Myitkyina to the new post. This track was to follow the valley of the N'maikha River, thus skirting round the worst of the hills. The river in question is the larger of the two streams which, uniting some miles north of Myitkyina, form the Irawaddy, and even in the dry season is a furious, unfordable, unnavigable torrent. The country through which it tears its way is nothing but a succession of steep mountain spurs covered with dense bush, running more or less parallel to each other down to the N'maikha. Those who have served in West Africa and on the North-West Frontier can best picture it by imagining the bush of the middle Niger transplanted

on to the khuds of Waziristan. The jungle is so thick that it is impossible to camp without first clearing a patch of ground, and the slopes so steep that it is usually also necessary to level a site for each tent.

As the mountain spurs abutting on the N'maikha alternate with tributaries feeding it, the latter had to be bridged to give passage to the new road. The local native (the Kachin, a wild but harmless race of diminutive stature) is uncommonly good at the erection of temporary bamboo bridges over these streams which serve well enough in the dry season, and by these the column had moved out. The rains, however, had to be taken into account, and in the rains these rivers rise 20' or 30' in a few hours, and become raging torrents whirling along forest trees and rolling down boulders as large as houses in their wild career. For the purpose of this bridging work the services of the remainder of the Burma S. and M. were placed at the disposal of the P.W.D.

As the whole of the operations connected with Hpimaw were being conducted by the Civil Government and not by the military authorities, the Government of India would not sanction the S. and M. going on ordinary field service conditions (*i.e.* all their expenses being debited to military grants) but had recourse to a system peculiar to India, in which a company of S. and M. is "permitted" to take up work for a private employer or another Government department. This system, briefly, is that the military authorities cut the S. and M. Company the working pay of the men (and make certain other disallowances affecting both the rank and file and the officers) while the O.C. of the unit has to make a bargain with his employer—be it private firm, Government railways, P.W.D., etc., etc.—to secure such terms as will at least ensure his men against loss in the transaction. If he can in addition make a little profit, it usually is devoted to giving the rank and file a trifle extra working pay.

This system is usually an excellent one as it provides most useful technical training of all sorts for the men combined with a saving to military funds, but for its success it is essential that the O.C. should be allowed a perfectly free hand in making his bargain with his civil employer. In certain cases, however, when the work is of an urgent and semi-military nature, he is apt to find himself strongly urged by his military superiors to lose no time in getting to work, while his prospective departmental employer (being naturally anxious to get the services of the S. and M. as cheaply as possible) exhibits a certain coyness about coming to what the O.C. considers fair terms. Such was the present case, and considerable correspondence took place before the P.W.D. agreed to such conditions as the O.C. considered would place all ranks in the same financial position as if the work had been an ordinary field service job. The position of an O.C. between the Scylla of appearing to

delay or shirk useful and urgent work, and the Charybdis of letting his unit in for a heavy pecuniary loss is neither a pleasant nor a dignified one.

However, satisfactory terms having at length been conceded by their civil employers, the company at the strength of 1 British and 3 native officers, 2 British sergeants and 100 rank and file, left Mandalay on the 15th February and arrived at Tumpang Kha on the 24th of the same month. This was about the furthest point of the then administered territory, and all the bridging work lay in front.

It was already late in the year to begin so large a work, as the rains were reported to be due about the 10th May, after which no work is possible owing to the excessively malarious nature of the jungles, and also to the extreme difficulty of moving about the country. Considerable delay in getting to work was, however, experienced at this point, as not only was the actual alignment of the road still unsettled, but all tools and material for the bridges had yet to be obtained from Rangoon. Also, the column had absorbed practically the whole of the available transport of the district, and there was very little means of moving the Sappers and their rations to the site of their work. Fortunately the alignment was decided on shortly after the arrival of the S. and M. at Tumpang Kha, so that the actual earthwork of the trace could be put in hand, but the lack of tools and material, to say nothing of transport, delayed the commencement of the big bridges for nearly three weeks more.

The distribution of the work between the P.W.D. and the S. and M., arranged during this halt at Tumpang Kha, was briefly as follows. The P.W.D. was to carry out all the earthwork of the new trace with coolie labour, and to undertake all minor bridges of 60′ clear span and under. There is an excellent standard type girder (made of wood and wire cable) employed by the P.W.D. in the Myitkyina district which will cover spans up to 60′, but has not so far been adapted to anything greater. The S. and M. were consequently allotted the job of all bridges in excess of 60′ clear span. There were four of these, the Ta Mu, Hnawmaw, Ritney and Narzar Khas. In addition there were three much larger rivers, the Tumpang, Shingaw and Chipwé Khas, which it was decided were too big to be tackled this year. To negotiate these "flying ferries" were employed, made from 3″ wire cable stretched high above the flood, and sustaining a raft of two large "dug-out" boats bearing a platform. The S. and M. took part only in the construction of that at Tumpang Kha.

During this enforced wait the Sappers did not remain idle but executed a quantity of minor bridging work, constructed the dug-outs for the Tumpang Kha ferry, and supervised and assisted the

huge gangs of P.W.D. coolies, now rapidly accumulating and representing almost every race from Pathans to Chinese, employed on the earthwork of the new road trace.

Lieut. Harris and his 25 men rejoined headquarters from the front on 8th March, bringing the strength up to 2 British and 3 native officers, 2 British sergeants, and 125 rank and file.

It was not until 14th March—a month after leaving Mandalay—that the O.C. was enabled to move with the right-half company to the site of the first big bridge, the Ta Mu Kha (*Photos* 1 and 2), and begin preparing the anchorages for a suspension bridge of 160' roadway span. The steel cables for this bridge arrived on elephants on 3rd April, and the bridge was finally completed on the 14th idem.

In the meantime Lieut. Harris and the left-half company had been able to move on past them to the Hnawmaw Kha (suspension, 152' span) and had arrived there on 1st April.

On completion of the Ta Mu Kha bridge, the right-half company had moved past them again on the 15th April to the Narzar Kha (suspension 105' span, *Photo* 3) and having finished this by 2nd May, moved back again to undertake the Ritney Kha, a suspension bridge of similar span. As the left-half company was just at that moment at a standstill for want of woodwork, the bulk of the company was able to concentrate on the Ritney bridge, completing it by the 9th May, the Hnawmaw bridge also coming to an end the following day. As these four suspension bridges completed the special task assigned to the S. and M., the left-half company started down country at once. The work had only just been finished in time, as between their departure and that of the right-half company, delayed about a week for want of transport, the rains actually commenced, rendering the six days' march to Myitkyina anything but a pleasant experience. The malarious reputation of the district also received full justification, as, on return to Mandalay, practically the whole company—European and native—went down with fever of the malignant Tertian type.

The company had thus completed four suspension bridges of between 100' and 200' span between 14th March and 10th May (57 days), besides having executed a large amount of general bridging and road work prior to the former date.

This output of work may not seem very great to those who are accustomed to operations on the fieldworks ground, where it is only necessary to send across to the store to obtain anything required from a chess to a 3" cable. In the jungle, however, where not only had approaches to be dug and huge stone abutments to be erected for the shore ends of each bridge, but where every solitary roadbearer and chess required in its construction had to be sawn from a tree felled on the spot, and where not even a nail was procurable within a week's march, things perforce moved more slowly.

The natural difficulties, too, were considerable. The banks of the rivers at the bridge sites sloped as a rule from 30° to 45° and were covered with dense bush, which had to be completely cleared before the site could even be finally chosen. Forcing one's way through such bush, in which every member of the vegetable world seems armed with fish-hook or spear, and in which every insect stings or bites, is by no means pleasant work. So venomous, in fact, were the flies that a large percentage of the daily sick roll was contributed by men suffering from severe ulcers caused by fly-bite, and the sensation of getting a handful of red tree-ants down the neck is one that will linger "while memory holds her seat." I may here remark that the working dress of the company had hitherto been "shorts," but these were found quite unsuitable for wear in such a fly country, and the men were glad to cut the arms off their jerseys and make a sort of mitten out of them to protect their bare knees.

The steep slopes of the banks were greatly to our advantage in that they enabled us to dispense entirely with artificial piers for all the suspension bridges and anchor the cables directly to the banks at a suitable height instead. On the other hand, levelling a sufficient plateau for an anchorage (and place for the men to stand to work, for which at least 15′ × 20′ is required) on such slopes, usually meant shifting over 2,000 cubic feet of earth for each end of the bridge. Nor were the banks as a rule either of sound rock, in which crowbar anchorages could be used, or of good earth easy to get out for the log pattern of anchorage. Normally they were found to be either a compost of boulders bedded in clay, or a mass of soft disintegrating granite, too full of fissures to blast, but extremely troublesome to chip out with the pick. As a result, more than half the time taken over each bridge went in the preparation of the anchorages.

The main cause of delay, however, was the fact that all the transoms, roadbearers and chesses had to be made at site from trees felled and cut up by the company sawyers. Owing to the system of "taungya" cultivation in use by the Kachins (which briefly consists in felling and burning a portion of the jungle every year, the whole being dealt with once in about fifteen years) although bush was only too plentiful, good trees suitable for the saw-pit were scarce, and the scantlings had often to be carried over a mile from the pit to their destination. The company could only muster enough sawyers to run five saws at once and the services of some civilian sawyers had to be called in to lend a hand with the roadway of the Hnawmaw bridge.

Technical Notes on the Work.

1. *Type of Bridge Employed.*

Three out of the four suspension bridges were made on the "half-loop," or as we were wont to call it, the "single-ender" principle.

This system lends itself specially to cases where the banks are so steep that it is possible to dispense entirely with artificial piers by anchoring the cables direct to the slopes at a suitable height for the dip and span.

As a "single-ender" is calculated as being half a "double-ender" (*i.e.* ordinary pattern with two piers) of twice the span, it will be evident that for any particular bridge the height of the single pier will be double the height of the piers of a "double-ender." Consequently, if the piers are dispensed with and bank anchorages used instead, the anchorage of the "single-ender" will be twice as high up the bank as that for a double-ender would be. Consequently, also, it will be proportionately further back from the shore end of the bridge. Thus there will be considerably more room for the road to reach the shore end of the bridge without dangerously undercutting the anchorage up above it in the bank. Of course an alternative to cutting the road out of the slope is to bring it up to the bridge on a stone abutment built up against the edge of the gap, but this is always tedious, and, in the case of deep gaps, impracticable.

To take an example (*vide Figs.* 1 and 2) suppose a gap of 120', a dip of 1 in 10, and the banks to slope at 45°.

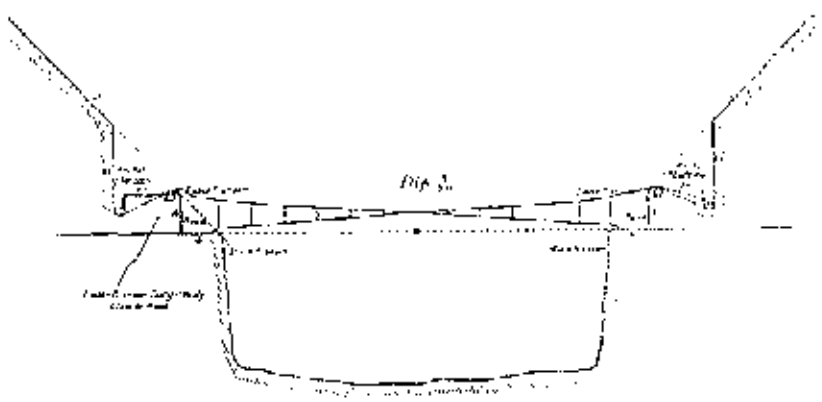


FIG. 1.—*"Double Ender" Suspension Bridge Anchored. Earth Banks.*

If a double-ender is constructed, each "anchor plateau" will come 12' above the horizontal, and its cutting line next the bridge will be 12' back from the edge of the gap. If a roadway 12' wide has to be taken to the shore end of the bridge by cutting back into the slope, the back wall of this road will (even if left vertical) come directly beneath this cutting line. This means that the "cable transom" must either be taken still further back (which means very greatly extending the cut of the "anchor plateau"), or be put almost over the top of the back wall of the road, which is a very unsafe position, as the pressure of the cables on the "cable transom" naturally tends to break down this wall.

If, however, the bridge was constructed as a "single-ender," the anchor plateau at the high end comes 24' above the horizontal, and consequently 24' back from the edge of the gap. Thus the inner cutting line of the anchor plateau comes 12' back from the back wall of the road, instead of just over the top of it, a much safer position for the cable transom.

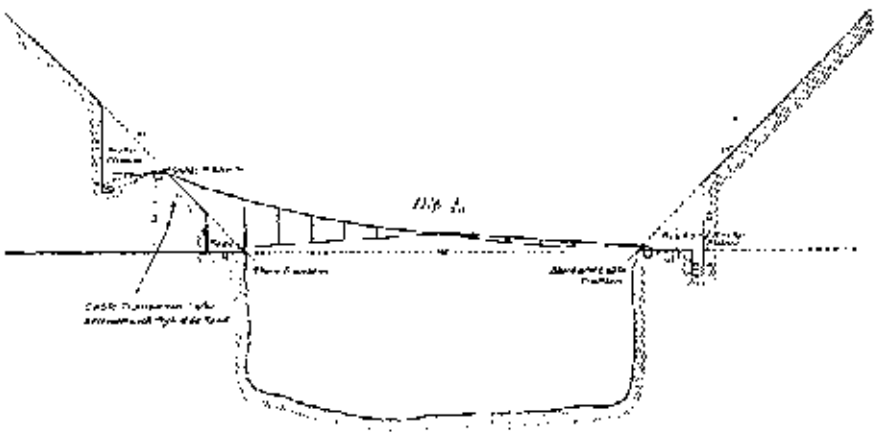


FIG. 2.—*"Single Ender" Suspension Bank Anchored. Earth Banks.*

As regards the anchor plateau at the "low" end of the bridge there is also a saving, as the one excavation does duty both for the road and for the anchor plateau.

2. *Modification of Calculations due to Unloaded Spans.*

Owing to the sloping banks, the span between anchorages (that is, span between imaginary pier heads) was always greater than the actual roadway span. In the case of the Hnawmaw bridge these were 230' and 152' respectively. This meant that about four bays at each end of the bridge remained unloaded. As the loaded portion naturally took a lower position in these circumstances than it would have done had the whole cable been uniformly loaded, this upset the ordinary calculations for the sling lengths considerably. However, a method of calculation was evolved which gave the correction in the case of a "double-ender" with an equal number of unloaded spans at each end. The question of a "single-ender" with three or four spans at the "high" end unloaded was more complex, and, though a graphic solution was finally evolved which gave approximate results, the slings at that end usually required adjustment to bring them the correct length.

This is a point which requires attention in these bank-anchored bridges.

3. *Anchorages.*

Two sorts only were employed: crowbar anchorages when sound rock could be found, and the ordinary buried log anchorage when it was a case of soft rock or earth.

Of the latter variety I have nothing to say, except that it was unfortunate that they were unavoidable, owing to their lack of permanency. I am informed by the local P.W.D. that in the Kachin Hills wood rots so quickly underground that a couple of years is all the life that can be expected from any bridge thus constructed. Logs of reinforced concrete and bundles of short lengths of railway metals were both considered as alternatives, but proved equally impracticable for want of transport to fetch the cement or rails to site.

As regards crowbar anchorages, I attach a sketch (*Plate* II.) and a photograph (*Photo* 4) of the type found by experience to be most suitable. I may remark that the *Manual of Military Engineering*, Vol. III., does not supply a very great deal of information on this most important subject. From *M.M.E.*, *Plate* I., *Fig.* 7, and para. 32, it might be imagined that two crowbars, of 1" diameter placed one behind the other, are sufficient for any stress which a 3" wire cable will stand. In my experience this is not the case. I believe the anchorage as above illustrated is just about strong enough for a 200' bridge devised for loaded pack animals.

In conclusion I may remark that in the course of the four bridges the company erected about 11,725 cubic feet of dry stone abutments and excavated some 17,400 cubic feet of earth and rock, besides undertaking a good deal of blasting to assist the road work enolits.

GIRDER BRIDGES FOR MILITARY ENGINEERS.

By Capt. E. N. Mozley, R.E.

PART I.

CRITICISM AND RECOMMENDATIONS.

A. General Considerations.

1. *Reasons for Infrequent Use.*—It is not often that the girder bridge or truss is used by military engineers. The chief reasons for this neglect have probably been the following :—

(*a*). The limitation of span over which girders can be used, and the fact that gaps of a kind for which neither trestle nor floating bridges are possible do not often occur in nature.

(*b*). Alleged complexity of design, calculation and workmanship.

(*c*). Difficulty of launching.

These objections require consideration.

(*a*). *Limitation of Span.*—As regards the first :—It may at once be said that where intermediate foundations can be made use of, either on land or water, no types of bridge, other than those carried on trestles or floating piers, would be adopted. And thus we are at once confined to a small minority of sites for which a single span type is suitable. Then again, for spans over 100′ the suspension bridge is alone possible in the field, as timber bridges over a single span are practically confined to that limit in war time, and the extensive use of iron, essential in long spans, is possible for the soldier only in the form of suspension cables.

Another cause which limits girders to 100′ is this :—The least proportion of depth to span in a girder to ensure reasonable stiffness may be taken as 1 in. Now the depth of field girders cannot much exceed 7′, the limit of reach of a man standing ; if any greater depth is attempted it is a matter of inordinate difficulty to raise the girders from the ground into a vertical plane and keep the top flanges from distorting. Finally girders longer than 100′ become very heavy, and the preparations for launching are so extensive that the chief advantage of these bridges, viz. their secrecy and the speed of that part of their construction which is in view of the enemy, is lost.

(*b*). *Complexity of Design.*—The first objection is therefore conceded. But the second is less reasonable. No engineer should be

alarmed at the prospect of having to design and calculate a girder, and, moreover, if these bridges were more frequently practised, standard types would be chosen, the soundness of design of which had been tested by the experience of others. Nor is there any real reason to hesitate on account of the careful workmanship involved. It will be found that the type of girder advocated in this article as the most serviceable, is analogous to the plate girder, and requires only nails for fastenings. Even the open truss patterns, requiring bolts and nuts or oak trenails at the panel points, need but little skilled labour, and an 88' lattice girder bridge, of which a description is given below, was easily put together by untrained cadets under the superintendence of a R.E. N.C.O., whose trade was that of a painter.

It is no doubt the case that girder bridges require a great deal more care in the construction of the girders, than do cantilever or even suspension bridges at any stage of their erection. But the great argument in favour of girder bridges—*their speed of construction once the enemy can see where the crossing is to be attempted*—will generally allow plenty of time in building the girders, prior to bringing them up to the gap.

(*c*). *Difficulty of Launching.*—There remains the third objection—the difficulty of launching. This has perhaps been solved by the adoption of the suspension cable method of which an account is given below.

2. *Advantages of this Type of Bridge.*—The great advantage which the girder bridge possesses is secrecy. It alone of all bridges except those on floating piers can be built elsewhere than at the site it is to span; and therefore, although the *total* time of construction of a girder bridge at a given site is as great as that for other types, yet the time during which the work is under the view of a possible enemy is very much less than in any other single span bridge. It may be reduced to three hours or even less for a 90' or 100' span under favourable circumstances, where a cantilever, suspension, tension or frame bridge could not be built in less than 12 hours. This advantage may be of supreme importance when the crossing of a rapid river or deep gap, watched by the enemy, is to be attempted, and gives to this type of bridge a definite place in military engineering.

The other advantages of girder bridges are:

(1). Steadiness and stiffness.

(2). Small size of material required.

(3). Independence of the ground at the site.

(4). That accurate workmanship under fire is not required.

As compared with suspension bridges, girder bridges are steadier, require no cables and little if any wire except for launching, and are independent of anchorages or of a careful adjustment on the site.

As compared with cantilever bridges they are steadier, require no such quantity of large timbers and are independent of anchorages.

As compared with frame bridges they require no long spars, are independent of accurately cut footings and of accurate section taking and frame locking on the site. They are also suitable for longer spans.

It may be said at once that it is most difficult to build and launch girder bridges strong enough to carry infantry in fours or cavalry in half-sections, except for comparatively short spans, on account of their weight. It is better to build several light bridges close to each other for traffic such as cavalry in single file or perhaps infantry two deep, thus obtaining the undoubted advantage of not putting all your eggs into one basket and also saving much time in launching.

B. Descriptions of Bridges Constructed.

The writer's experience in building girder bridges includes the following examples :—

(1). A 51' bridge to carry cavalry in single file.

(2). An 80' " " infantry in fours. (This bridge included a central trestle and two different types of girders).

(3). A 49' bridge to carry cavalry in single file. (Including 2 types).

(4). A 57' " " "

(5). A 78' " " "

(6). An 88' " " "

A detailed description of these bridges is given in Part II. and a tabular statement of their details at the end of the article.

C. Type Recommended for General Use.

From an analysis of these bridges it is suggested that the best type of girder is the "plate," as in (3) and (5), (the bridge to consist of two separate girders joined before launching), and the best method of launching is by means of rollers and light suspension cables as in (6).

1. *Reasons for Choice.*—The plate type with the web secured to the flanges by long wire nails is preferred to open trusses for the following reasons :—

(*a*). Planks of small and even thickness are easier to obtain than those of larger and of various scantlings. The former are necessary for plate girders, the latter for open girders. Nails are easier to obtain than bolts and nuts (except on lines of communication or where forges are plentiful).

(*b*). Nails are safer than bolts and nuts, as is also a continuous series of planks than a truss, in each case on the principle that no single nail or plank in the plate girder will wreck the bridge if it fails, whereas in the open type, stresses are carried along chains of planks and bolts and the failure of a single plank or bolt may destroy the bridge. It is in fact the well-known superiority of riveted girders

over pinned trusses. Good workmanship is therefore not so essential in the plate type.

(*c*). Plate girders are simpler and quicker to put together than open girders. A certain complexity surrounds the assembling of lattice or even Warren girders, and it is generally found that some forcing has to be employed to run the bolts or trenails through all the planks at a panel point.

(*d*). Nails are quicker and easier to work with than bolts and nuts, and thus time is saved and skilled labour rendered less necessary.

(*e*). In the plate type the weight of the bridge during launching can be reduced by omitting every alternate plank from the web. This cannot be done with open girders.

2. *Example.* The following design for a 100' girder bridge, which is probably the limit of span for this type, is given as a simple instance of the plate girder:—(*Fig.* 1 shows the cross section).

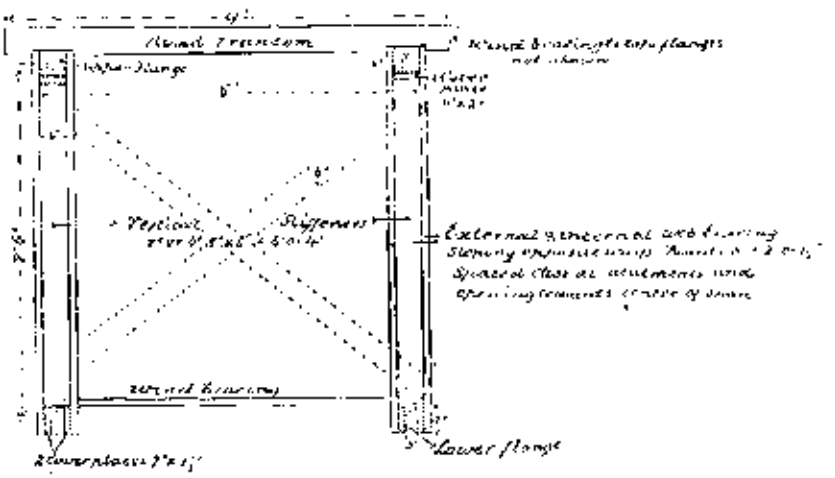


FIG. 1.

Bridge to carry cavalry in single file. Roadway 60 lbs. per foot-run.

Weight of both girders and wind bracing estimated at 12,000 lbs.

Roadway carried by two plate girders, 8' centre to centre.

Depth of girders, 7' 6", centre to centre of flanges.

Maximum distributed load on one girder, $\frac{1}{2}(196 \times \frac{3}{4} + 60 + 120)\ 100 = 23{,}700$ lbs.

Maximum safe stress of timber taken as 1,200 lbs. in compression and 2,000 lbs. in tension, per square inch.

$$\text{MFF} = \frac{\text{WL}}{8} = \frac{23{,}700 \times 100}{8} = 296250 \text{ foot-pounds} = M = rad$$

$$= \begin{cases} \text{Compression flange } 1200 \times a \times \frac{7}{2}. \\ \text{Tension flange } 2000 \times a \times \frac{7}{2}. \end{cases}$$

$\therefore$ area of top flange must be 33 square inches.

" of bottom flange must be 20 square inches.

The depth of the timbers of the lower flange should be considerable to prevent them being crushed by handspikes while launching, and also in order that the web planks should not protrude below the lower flange.

Make the depth 7" and the width 5".

The upper flange should be square—say 6" × 6".

The lower flange will then be 5" narrower than the upper flange; if the cover planks for the lower flange be 1½" planks, placed at each side of the joints, and having a combined cross section equal to the flange, they will give to the flange a total width of 6". (The cover plates should be continued the whole length of the lower flanges).

The cover plates of the upper flange will be placed above and below the joints and may be 6" × 2" planks 8' long, extending 4' each side of the joint.

Stiffeners.—Every 6' along the girder will be placed a vertical 6" × 6" plank, perpendicular to the flanges and held in place by fillets as in *Fig.* 2. These stiffeners partially support the road transoms and should not therefore open out towards the centre as in iron bridges. The dimension parallel to the axis of the bridge could probably be reduced to 3" or 4".

The stiffeners will butt on the lower flange and on the upper flange, or its cover plates.

If the roadway is carried on the lower flanges, the end stiffeners may be 6" × 6". If it is carried on the upper flanges the ends of the girders must be shaped as in *Fig.* 3. In such cases the end web planks must be very stout.

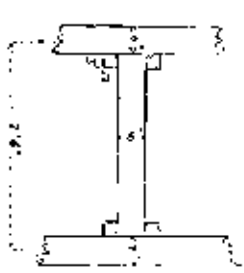


Fig. 2.

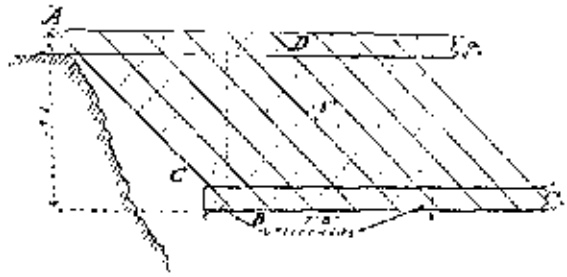


Fig. 3.

The shearing stress on each girder at the abutment, if a gun were close to that abutment and the rest of the bridge were crowded with cavalry, would be about 13,000 lbs., and, since the web is 7' 6" deep, the vertical and horizontal shearing stresses per foot-run are in each case 1,733 lbs. Now each girder is to have two systems of web planks (running diagonally at 45°, in opposite directions), each of which systems therefore sustains a horizontal shearing stress of 866 lbs. per foot-run. A 6" wire nail, connecting a 1" plank to a spar, draws at

800 lbs.[1] Therefore if we use 8" web planks and nail each end of each plank to the flange with three wire nails we shall have a factor of safety of about 3.

Web planks will be adjacent to each other at the abutments and will open out gradually to 3' central intervals in the middle of the girder, in accordance with the decreasing shearing stresses.

Cover Plates between Parts of Lower Flange.—These have to transfer a stress, varying from 39,500 lbs. at the centre to about 25,000 lbs. at the joint nearest the abutment. There are three alternative methods of transferring this stress across the joints :—

(*a*). By means of a wire sling of the requisite number of returns passing through transverse auger holes 18" from the joint, or preferably through several auger holes between 1 and 3' from the joint on each side, since a single auger hole gets bitten into, if it has to carry the whole stress.

(*b*). The requisite number of large wire nails driven through each cover plate into the flange on both sides of the joint.

(*c*). The requisite number of bolts and nuts passing through auger holes bored through both cover plates and flange on both sides of the joint.

Any one of these methods involves a considerable amount of iron-work, *e.g.* the weight of nails or wire to transfer the stress across the centre joint of the lower flange of the girder under consideration would be 15 lbs. and 20 lbs. respectively.

The second method can only be employed if the timber is sound, as the large number of nails required is liable to split it.

The first method has the disadvantage that when the load comes on the bridge the wire stretches, the joints open a little and the bridge loses its camber.

The third method takes longest and bolts and nuts are not always obtainable.

The short cover plates to the joints of the top flanges may be nailed to the flanges.

The alignment of every top flange joint would be preserved by means of a hard wood dowel, placed in axial holes bored into the ends of the two butting timbers. The dowel should be a little shorter than the sum of the depths of the holes at the joint to allow the surfaces to touch.

Wind Bracing.—Top Flange.—In addition to the cross transoms (pieces 10' × 6" × 6" at every panel point), there would be a series of horizontal diagonal bracing, placed lattice-wise, nailed to the top surfaces of the flanges. Planks 8" × 1" or 6" × 1½" may be used.

The bottom flanges would be temporarily braced together during launching by cross planks nailed to the flanges. Subsequently a

[1] From the writer's experiments.

system of horizontal diagonal bracing similar to that of the upper flange would be nailed on above or below the lower flanges.

The road transoms would be notched across the flanges and spiked to them. They need not be fixed till the bridge is in site, if it is desired to save weight in launching.

Fig. 3 shows the diagonal web bracing on one side of a girder by continuous lines and that on the opposite side dotted. Vertical stiffeners also shown dotted.

The web must be doubled on both sides of each girder for a short distance from each abutment. *E.g.*:—In *Fig.* 3 there will be a series of planks parallel to AB on each side of each girder for perhaps 10′, the series parallel to CD being nailed in each case on the outside of the series parallel to AB. At the other end of the girders the position is of course reversed.

A system of transverse vertical diagonal bracing, from the top of each stiffener of one girder to the bottom of each stiffener of the other, and *vice versâ*, would be nailed in pairs at intervals along the length of the girder to prevent the bridge being racked or distorted during launching (shown dotted in *Fig.* 1).

D. Placing the Roadway on Girder Bridges.

Girder bridges have a great advantage over all others in that the roadway can be laid much more quickly. The top flanges of the girders supply a gangway along which the material can be carried. The road transoms are placed at panel points (or over the stiffeners in plate girders), *i.e.* from 6′ to 8′ apart. Each bay of roadway (transom to transom) will be made up under cover, the chesses being nailed to the roadbearers and the ribands to the chesses. If possible the roadway should be 2′ narrower than the central interval between the girders. Each complete bay will then be carried on to the bridge by four to eight men, who hold lashings underneath it and walk along the flanges, and will lay it in its place. If necessary the bays may be connected by nailing strips of wood from riband to riband on the outside. The whole operation (exclusive of putting the bays together under cover) should not take more than 10 or 15 minutes for a 90 or 100′ bridge if plenty of men are available. This is an important saving of time if under the enemy's observation and fire.

E. Possible Arrangement for Strengthening a Girder Bridge after Placing it in Position.

Fig. 4 represents a girder bridge of 90′ span. As soon as the bridge is across and the roadway laid, proceed as follows:—(The process here described is carried on simultaneously from each bank).

Get two poles AB as long as possible (up to 35 or 40'), the diameter need not be very large. To the two tips B lash a cross-piece the tips being as far apart in the clear as the width of the bridge out to out. To each end of this cross-piece (outside of the pole AB) make fast a chain or wire (eventually CBD), doubled so that the bight hangs towards D and the two single ends towards C.

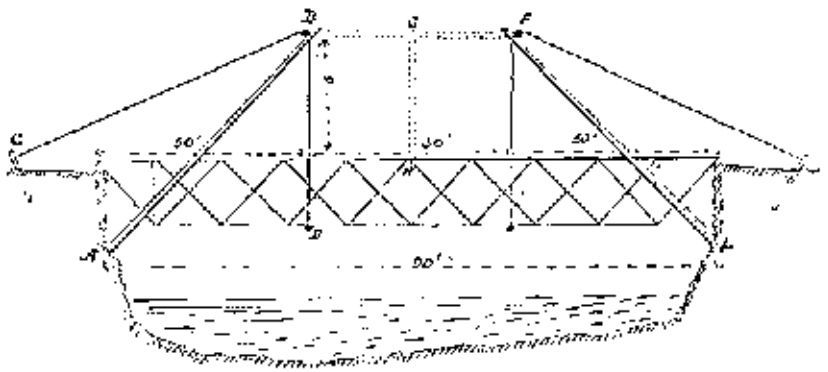


FIG. 4.

Carry this 3-pole frame on to the bridge. Lower the butts A until they get good seatings and then, by means of pike poles and the chains CB haul up the frame until AB is at a slope of not less than 45°. Make fast the bight of the chain at D round a previously placed cross-piece under the lower flanges. Make fast C to a holdfast and windlass up CB and BD. If long enough material is available, E and F may be joined by planks or poles on each side (shown dotted in the figure) and braced to the girder at GH. Finally the poles AB should be lashed to the girders.

(To be continued).

A SIMPLE APPARATUS FOR SOUNDING RIVERS AND PONDS OF MODERATE WIDTH.

By Brig.-Gen. C. Penrose, c.b., R.E.

The apparatus described below was used by the writer in New South Wales many years ago to sound, and take sections of, large public water tanks for sheep and stock in the "back-blocks" of the colony.

The apparatus acted so well and enabled the work to be done so quickly, that it is thought it might very likely be useful to officers who have to rapidly sound and get sections of moderate widths of water-way, even when boats are available.

A. Float.
BB'. Float Lines.
C. Sounding Line.
D. ,, Lead.
E. Measuring Staff or Tape.

Use.—Get one man across the water with line B', by swimming or otherwise, from X to Y. Pass sounding line through float A on bank X and attach plummet.

Pay out line B and haul on B' and take soundings every 5, 10 or 15' getting width of stream at same time.

In taking the soundings haul the sounding line up smartly until the lead hits the float and then lower away sharply, measuring the amount let out with a rod marked in feet and inches. This can be done two or three times for each sounding very rapidly.

If the current is very rapid it will be necessary to hold the ends of the lines BB' some distance upstream so as to get the float on the section line.

The sounding line must be fine and run very easily through the hole in the float, and a heavier lead will be required in deep and rapid water.

The float lines BB' must of course be very well stretched before they are marked off and used.

The form and material of the float for rapid streams is probably of importance.

The sounding line should be kept on a fishing reel and be treated with the care given to a fishing line.

The distance from the surface of the water to bottom of plummet must be added to each sounding as recorded on the measuring rod, *unless* allowed for in marking the rod.

A METHOD OF BUILDING SEA WALLS.

By Capt. T. E. Kelsall, R.E.

The following method of building a sea wall in shallow water is believed to be new. It was suggested by Staff-Sergt. Henry, R.E., M.F.W., and recently carried out successfully at Ragged Staff reclamation, Gibraltar.

A reinforced concrete retaining wall had to be built along the sea face of the reclamation. Owing to the presence of boring mussels, and also to ensure sound work, it was considered advisable to keep this reinforced work above low-water mark by building it on a foundation of solid concrete. This foundation had to be in 4′ to 5′ of water at low tide. At first concrete was deposited in the water behind sheeting, being tipped on to the bottom through a timber tube placed vertically in the water and reaching nearly to the bottom. It was hoped by this means to get the concrete to the bottom in sufficiently good condition to set properly, but the results were unsatisfactory.

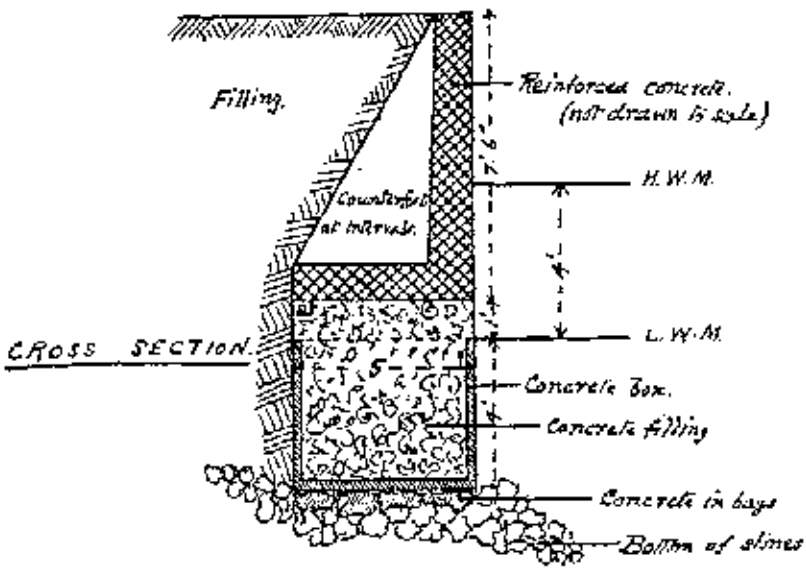
The new method referred to was then adopted. It consisted in making concrete boxes and floating them to the required position, where they were sunk by filling with concrete.

The boxes were 10′ long, 5′ wide, and 4′ deep, with sides about 2″ thick. The first one made was not reinforced, but when floated, the water pressure broke in the bottom. Subsequent boxes therefore had the bottom reinforced with hoop iron off cement barrels, and these proved sufficiently strong. They were made in timber casings placed on an existing level surface, which at low tide was about 6″ above water level but at high tide was covered by about 3′ 6″ of water. A small hole left in the side of the box at floor level allowed the water to enter as the tide rose. Had this not been done the water outside would have forced its way through the unset concrete, which would have been spoilt. After two days the sheeting was removed, the hole plugged at low tide, and as the water rose the box floated.

The line of foundation was dredged to the required depth by means of a large toothed scoop, worked by a windlass from a staging. As the bottom consisted of stones of various sizes, a level bed had to be formed of an average depth of about 1′ by depositing concrete in bags. These were rammed from above water, their finished surface being about 4′ below low-water level.

The boxes were then floated so as to lie with their length in the line of the wall, and each having been got into its correct position in plan, was sunk on to the level bed by filling with concrete. Sheeting having been erected, another foot of concrete was added on top at low tide.

The rough sketch below illustrates the method.



One box had a 2′ concrete pipe through it to form the outlet for a drain. This pipe was fixed after the box was made but before it was floated.

It is intended shortly to try an extension of the above method in connection with the uprights for a reinforced concrete pier in deeper water. The difficulties in this case will be considerably greater, and it will be interesting to see if they can be successfully overcome.

THE BRITISH MILITARY MISSION IN EGYPT, 1798—1802.

(Concluded).

In the August number of the *R.E. Journal* certain instructions and letters were given, referring to the Military Mission in Egypt between the years 1798—1802. To these are now added Major Holloway's account of the Turkish operations from December, 1800, to their completion in July, 1801, and a report by Major Hope, R.A., on the Dardanelles, giving a detailed description of the fortifications in 1799.

(7).

Report of Lt.-Col. Holloway, R.E., on the Operations of the Supreme Vizier between the 3rd December, 1800, and the 16th July, 1801.

GRAND CAIRO, EGYPT,
1st August, 1801.

A concise Statement of the operations of His Highness Youssouff Zia Pacha The Supreme Vizier, from the 3rd December, 1800, the time He received Information of a British Force being in the Mediterranean for the purpose of co-operating with His Highness in the expulsion of the Common Enemy from Egypt, until the 16th July, 1801, when He made His Publick Entry into Cairo, as extracted by Lieutenant Colonel Holloway from his own Journal.

The Difficulties necessarily attendant on the March of an Army in a Country like that thro' which the Ottoman Troops have lately passed, have been considerably increased by a variety of unforseen Circumstances which have occured peculiarly unfavorable to their Progress; and could only have been overcome by that Energy and Perseverance, which have been manifested on the Occasion.

Towards the end of last Year the Army of His Highness The Grand Vizier, which had remained encamped at Jaffa from the time of its Retreat to that Place from Egypt, was in a Condition very unfit for a second Expedition. The Plague, which had prevailed during the Summer and Autumn, and was still raging with great violence, had very materially reduced its numbers; a dreadful Mortality afflicted the Cattle belonging to it; the Magazines of Stores, Provisions, and particularly of Forage, were by no means abundant; and the great

Scarcity of Money had created Discontents among the Troops, which at times threatened the most alarming Consequences. Add to which that the tempestuous Weather at that Season of the Year, and the unsheltered Anchorage at Jaffa, rendered all Supplies by Sea (from which quarter they were chiefly to be expected) extremely precarious.

Such was the State of the Ottoman Army, (when on the 3rd December) advices were brought to the Grand Vizier by Lt. Colonel Murray Assistant Quarter Master General, of the Approach of a considerable British Force for the purpose of assisting the Turks in the Expulsion of the common Enemy from Egypt; and such continued to be the State of that Army, when M. General Moore (on the 9th Janry., 1801) came to the Imperial Camp from Marmorin, where the British Force had arrived, in order to concert with His Highness a Plan for the Co-operation of the Ottoman Army; and it was arranged that this Army should leave Jaffa on the receipt of an Intimation to that effect from the British Commander-in-Chief.

After the departure of M. General Moore (on the 14th Janry.) Preparations for Marching were begun: The Commander of their Artillary was directed to follow the suggestions previously given by Major Hope of the Royal Artillery and every means of assistance which the adjacent Country could possibly afford, was obtained without delay. The want of Forage for the Cattle was however a serious evil, as the Country offered no Remedy; but a temporary abatement in the weather at length enabled some Vessels laden with that Article, to land part of their Cargoes as well as some fresh troops brought from Albania.

The Grand Vizier perceiving the uncertainty of future Supplies during the Stormy Season, now became anxious to avail himself of that which he had just obtained, to move his Army to El Arish, where it had been determined for some time before to form Magazines. He accordingly ordered such Vessels as might in future arrive with Stores, to be sent to that place, and, without having heard from the Commander-in-Chief, left Jaffa on the 25th Feburry., and encamped that day 12 miles from thence near the Village of Zabna. The same day however the *Termagant* Sloop of War arrived, bringing intelligence that the British Fleet was preparing to leave Marmorin for the Coast of Egypt, and also the expected Intimation for the Ottoman Army to move forward.

In spite of the Resolutions with which The Grand Vizier had quitted Jaffa, he found himself unable to proceed further than Zabna. The heavy rains had rendered the Roads in many places impassable to Artillery. The Plague, which after having carried off more than seven thousand of his Troops at Jaffa, had ceased in that Neighbourhood, was now raging with redoubled violence among the Troops composing his advanced Army at El Arish; the discontents owing to

the Scarcity of Money again appeared; and lastly his Supply of Barley became expended during this unavoidable detention, and occasioned great distress.

Fortunately at this period Money arrived from Constantinople, and a further Supply of Barley. His Highness caused the Roads to be repaired, and on the 12th March, was again enabled to proceed; tho' on that day's march He lost upwards of Two hundred Camels owing to the Severity of the Weather.

While at Zabna the Ottoman Army was joined by about five hundred Men well armed and provided, being part of 5,000 ordered by Djizzar Pacha, who had entered into an Accomodation with the Porte, and was to grant this Reinforcement, as a Mark of the Sincerity of his Intentions.

On the 15th March the Army arrived at Gaza. It was here thought prudent to remain until the Plague should subside at El Arish. It ceased in a few days, after having in less than a Month reduced the Force at that Place from upwards of four thousand to about 1,500. Among its principal Victims were Ismael Pacha who Commanded at El Arish and several Persons of distinction, particularly Hassan Bey Djidda-oui, from whose zeal and enterprising Spirit The Grand Vizier and the Ottoman Ministry had formed very high Expectations.

His Highness availed himself of this delay at Gaza to settle an Arrangement with Lt. Colonel Holloway who Commanded the British Military Mission, for the future March of his Army across the Desert. It was accordingly determined that the Army should March in three divisions; the first under Tahir Pacha, as an advanced Guard, to consist of about three thousand Cavalry with 5 light Guns: the second under the immediate Command of Mehemmed Pacha, lately appointed Seraskier of the Army, to consist of about eight thousand Cavalry and Infantry with 8 pieces of light Ordnance; and the third under the Grand Vizier himself, to be composed of the Ottoman Ministers and their Suites, with the remaining part of the Army and Artillery.

It was further arranged that a British Officer from the Military Mission should be selected to accompany each of the two first divisions with Instructions from Lt. Colonel Holloway, and to give such Assistance and Advice as from their proffesional Judgement they might be enabled to afford the Pacha's, who in their turn were directed to consult with these Officers respectively on all Military Occurences.

On the 22nd March the division under Tahir Pacha proceeded to El Arish accompanied by Captn. Leake of the Royal Artillery. On the 28th The Grand Vizier with the Remainder of the Army advanced for that Place, and on the March received the account of the landing of the British Troops at Aboukir, and of the three successive Victories

gained by them over the Enemy; which inspired universal Joy and was announced to the Ottoman Army by a Salute of 21 Guns from the Artillery.

His Highness arrived at El Arish the 30th March; and in conformity to the Arrangements made at Gaza, again sent forward (on the 2nd April) the division under Tahir Pacha, accompanied by Captain Leake, and on the 5th, the division under Mehemmed Pacha, who was accompanied by Captain Lacy of the Royal Engineers.

By Captain Leake, Lieut. Colonel Holloway sent with the Authority of the Grand Vizier Summons for the Garrisons of Teneih and Salaheik, which were however evacuated by the Enemy on the Approach of Tahir Pacha; tho' not until they had destroyed some of the works, and the Barracks of the latter, which was a Fort of considerable strength.

While the Ships were unloading at El Arish, a violent Storm came on, by which they were driven out to Sea, and the greatest part of their Cargoes, particularly the Barley, which had been landed on the Beach, was washed away. The distress occasioned by this misfortune is scarcely to be described; for four days the Animals which were very numerous in the Camp, were without Forage or Food of any kind, being situated two days march (nearly 40 Miles) in a barren Desert, which afforded not the smallest means of Sustenance for them. On the 5th and 6th days Biscuit and Rice were issued for them, after which some of the Vessels returned, tho' too late to save great numbers, which had perished with hunger.

To this Calamity succeeded another equally unexpected and disastrous. The Arabs, in consequence of some discontents suddenly deserted with their Camels, and deprived the Grand Vizier of the means of moving forward; nor could all the Exertions of His Highness aided by the Influence of the Sheikh of El Arish, procure Camels sufficient for more than a very small part of the division which remained with him. With these however He proceeded, accompanied by His Excellency The Reis Effendi, a few of their Attendants and some of the Troops. Those of the Military Mission who were of this Party were Lt. Colonel Holloway who Commanded the Mission, Major Hope, Commanding the Royal Artillery, Doctor Wittman, Mr. Wightman, Secretary, and Mr. Pink, Draftsman.

From the scarcity of Beasts of Burthen, such Articles only, as were indispensably necessary were taken by Land; and consisted chiefly of Barley and Water for the Cattle, Rusk and Water for the Men, being the sole food allowed to every description of Persons from the highest to the lowest, and a very reduced Proportion of Tent Equipage together with some Ammunition for the Field Pieces which His Highness took with him; the Remainder of the Baggage, Stores, etc., had been previously embarked on board Vessels at El Arish to

be conveyed by water to Tenieh. The Officers of the Porte, with the Troops, Attendants, etc., and also those of the Military Mission, who were left behind in consequence of the Circumstances above stated, had directions to follow His Highness as soon as a sufficient number of Beasts of Burthen could be procured for them.

The Grand Vizier with the small Party which accompanied him, arrived at Catieh after four days' march, a distance of about 70 Miles. This may certainly be considered the worst part of the Desert, from the impossibility of procuring Water, after leaving the Wells of Messudie, 2½ hours (8 miles) beyond El Arish, until arriving at Catieh, where it is but very indifferent, tho' it may answer in Cases of necessity. The Road is for the most part hard and level tho' in some places the Sand is very deep and uneven and extremely difficult not only for Artillery but even for Horses, etc. It was marked by the Carcasses of Beasts and here and there of Men, who had drop't from Excess of heat and Fatigue added to the Misery of extreme Thirst: many were also observed laying on the burning Sand, and to all appearances expiring from the same Causes.

Under these truly distressing circumstances The Vizier afforded an Example of Firmness and humanity worthy of his exalted Station, being almost always seen on horseback sharing the general Fatigues and Hardships, and relieving as much as possible from his own few Comforts the miserable Objects that presented themselves.

While at Catieh (on the 23rd April) Lt.-Colonel Holloway sent by the Authority of the Grand Vizier, a Summons for the Fort of Lesbe at Damietta which was conveyed by Mr. Pink accompanied by a Turkish Secretary from the Reis Effendi who brought back an Answer from the Commandant, refusing the Terms offered.

Having halted at Catieh two days to give the Troops rest, and to allow time for the Stragglers to come up, His Highness continued his March, and on 27th April, arrived at Salahieh, being 18 hours (about 54 Miles) from Catieh. The Road between Catieh and Salahieh is in general more difficult than that to the former Place, tho' perhaps less to be dreaded, as water is to be procured on the second days March. It is intersected by a small Branch of the Nile, over which had been built a large Stone Bridge; this the Enemy destroyed on hearing of the Approach of the Ottoman Army in order to impede its Progress. The Grand Vizier on being informed of this halted the Night of the 25th April within a short distance of the Place; and sent on a party of Dehlis to make it passable, which they effected in a few hours. By this means the Party was not stopped a moment on its March, and arrived at Salahieh in less time by one day than the advanced divisions under Tahir and Mehemmed Pacha, who had taken a circuitous Route to avoid this obsticle. These Divisions had quitted Salahieh before the arrival of His Highness, and proceeded to Belbeis.

On the 30th April, having been duly authorised by the Grand Vizier, Lt. Colonel Holloway sent Major Hope of the Royal Artillery accompanied by Amiteli Effendi the Secretary to the Sublime Porte, with a proposal to the Garrison of Cairo for entering into a Treaty for the surrender of that Place to the combined British and Ottoman arms which was rejected by General Belliard the French Commandant.

On the 5th May that part of the Ottoman Army and of the Military Mission which had been left behind at El Arish arrived at Salahieh.

On the 6th May, in consequence of the Refusal of the Garrison of the Fort of Lesbe at Damietta to surrender, by the advice of Lt. Col. Holloway The Grand Vizier detached against that Place Ibrahim Pacha of Aleppo, with three thousand Men, who when on the point of attacking that Fort, discovered that it had been abandoned by the Enemy during the night, which gave him possession of it on the Morning of the 13th.

On the 7th May The Grand Vizier advanced to Corin 6 hours (18 Miles) from Salahieh and having understood that some discontents prevailed among the Troops under Mehemmed Pacha tending to Insubordination, He proceeded the following morning to Belbeis where they were encamped, accompanied by His Excellency The Reis Effendi, Lt. Col. Holloway, Major Hope, and Mr. Wightman, Secretary, with a few Attendants, his Presence immediately restored Order and Tranquillity among the Men.

The Camp at Belbeis had been intrenched, and a Redoubt built under the direction of Captain Lacy of the Royal Engineers, and further precautions were likewise taken against suprise, by pushing Patrols to the Neighbourhood of Cairo to observe the Enemy's Motions.

On the 11th May that part of the Ottoman Army and of the Military Mission left at Corin, joined the Grand Vizier at Belbeis.

On the 12th May Intelligence arrived at the Camp of the Capture of Rahmanie, and the Retreat of the Enemy to Cairo, and on the Morning of the 13th Information was brought that He was approaching to attack the Vizier, which being afterwards confirmed His Highness who had frequently during the Day consulted Lt. Col. Holloway, towards the Evening ordered Tahir Pacha with three thousand Cavalry and three Pieces of Artillery to repair to meet the Enemy, and if a favorable opportunity should occur during the Obscurity of the Night to attack him. Tahir Pacha met the Enemy about three Leagues from Belbeis, who, on perceiving him halted as did also the Pacha. In this state both Parties remained during the Night and until 8 o'clock the next morning, when Tahir Pacha, having been reinforced with 1,500 more Cavalry, attacked the Enemy. Mehemmed Pacha soon after came up to his assistance,

with about 5,000 Men and 5 Pieces of Cannon, and lastly the Grand Vizier himself, whose presence had the happiest Effects. The Enemy harrassed on all sides by the Turks, quitted Position after Position, at length seemed determined on a Retreat: the Turks followed them closely and in about seven hours from the Commencement of the Battle had driven him as many Miles from the Spot where it took place. His Highness then thought it prudent to Halt his Troops: and the enemy returned close to Cairo that Night. The loss on either side was inconsiderable, the Number of the Enemy in the Field, has since been known to amount to more than 5,200 including 600 Cavalry, with 26 Pieces of Artillery.

On the 18th May the Grand Vizier with the whole of his Army left Belbeis and halted that Night at the Village of Mashtoul, a little to the Westward of El Hanka. On the following day His Highness moved to Benalhasser, situated on the Eastern Bank of the Damietta Branch of the Nile, about 8 hours from Cairo, for the Convenience of communicating with General Hutchinson, The Commander-in-Chief of the British Army, and His Excellency The Captain Pacha, then encamped at Alkam on the Western Bank of the Rosetta Branch.

On the 20th May The Grand Vizier was joined by a detachment of British Troops sent him as a Corps of Reserve, under the Command of Colonel Stewart, consisting of the 30th and 89th Regiments, with some Cavalry and Artillery.

On the 24th May The Captain Pacha and General Hutchinson arrived at the Imperial Ottoman Camp at Benalhasser to concert with His Highness The Grand Vizier the future operations of the Campaign, when it was ultimately decided that the Combined Forces should immediately advance to attack Cairo. The Captain Pacha and General Hutchinson left the Camp on the 28th May to carry into Effect the Resolutions that had been agreed upon, and at the request of the latter His Highness ordered a Reinforcement of 500 of his Cavalry to join the British Army.

On the 1st June The Grand Vizier marched from Benalhasser, keeping the Eastern Branch of the Nile; the Forces under General Hutchinson and the Captain Pacha advanced along the Western Branch. From this period the Combined Armies proceeded, by slow Marches, halting for some days on the way, to give time for completing the necessary Arrangements, such as getting up the heavy Artillery and besieging Stores; and laying a Bridge of Boats across the Nile for an easy Communication between the two Armies. At length on the 20th of June General Hutchinson and the Captain Pacha encamped before Gizé, and The Vizier on the opposite side of the River before Cairo, the advanced Divisions being within Gunshot of several of the Forts. By these Movements the Enemy's Works became invested.

At this time it is supposed the Army of His Highness The Grand Vizier consisted of about 20,000 Men, 12,000 of which were Cavalry, 1,000 Artillery and 7,000 Infantry, with 40 Pieces of Ordnance.

On the 23rd June the Enemy demanded a suspension of Arms which was granted by the Combined Armies for 48 Hours, during which time a Convention was resolved on between the respective Commanders, by which the Enemy was to surrender the City of Cairo and its Dependencies to the Combined Forces, and to evacuate Egypt. The Treaty was ratified on the 28th, and Hostages given on both sides. The Fort Shal Mouski on the East Bank of the Nile was given up and one of the Gates of Gizé on the West Bank to the Combined Forces; and the Enemy were enabled to finally evacuate Cairo on the 15th July and proceeded towards the Coast accompanied by most of the British Troops from Cairo, and by those of the Captain Pacha reinforced by a Detachment from the Vizier's Army. The Day following His Highness The Grand Vizier made his public Entry into the City under a General Discharge of Artillery, and amidst the acclamations of the Inhabitants.

On a View of the foregoing Statement, the Effects produced by the endeavours of His Highness The Grand Vizier and the Ottoman Army under His Command during the Campaign will appear as follows.

That this Army has performed a March of 240 Miles, 160 of them across a Desert and that under a Combination of the most unfavorable Circumstances; that it has driven the Enemy from Tenieh, Salahieh and Damietta, and taken possession of those Posts; that it has met in the Field a considerable number of French Troops having a numerous train of Artillery and aided by all the advantages which military Science and Discipline could give them, that it has engaged them for several Hours, has compelled them to abandon their Object and to make a retreat, at a Moment too, when the contrary Event would have had the most disastrous Consequences for the Common Cause; that it has been enabled from these Successes to effect a Junction with the British Army, and by various means to contribute by an effectual Co-operation towards the regaining of Cairo; and to the removal of the greatest part of the Enemy's Force from the Province of Egypt.

Lt. Colonel Holloway would feel himself wanting in an Act of Justice, were he to pass over unnoticed the Exertions of His Excellency Mahmoud Raif The Reis Effendi during the Events of the Campaign. His knowledge of European Customs and of a Language generally understood, added to his indefatigable attention to Public Business has created a facility of Communication which has been of the greatest Utility.

(8).

Report by Major Hope, R.A., on the Defences of the Dardanelles.

BUYUKDERE,

1st September, 1799.

To BRIGADIER GENERAL KOEHLER,

Commanding His Brittanic Majesty's Forces, etc., etc., etc.

SIR,

In compliance with your Orders, I have in conjunction with Major Holloway, Commanding Royal Engineers; visited and examined the Defences, Batteries, Magazines, etc., at the Dardanelles.

When we consider the important and great National object they have to perform, nothing less than the preventing an Enemy's Fleet, from forcing a Passage to the Capital of the Ottoman Empire; which would never be attempted, or undertaken, but by a Force of great magnitude, we do not think the present Works, were calculated upon so extensive a Plan, as the momentous object entitles them to, and much fear, would not, under the present improved State of the Art of War, be found adequate to the great purpose for which they were built.

The Castles at the Entrance of the Dardanelles, (Cumcalli, on the Asia Side; and Setilbahar on the Europe) are as well situated as the width of the Channel will admit of, being 4,087 yards across, a distance rather too great for Artillery to act with precision, nevertheless, an Enemy should be met as early as possible, and impeded Step by Step, we therefore think it was judicious to take up these two points.

The next point taken up, is for a Battery of Nineteen Guns, called Eskisar, on a high Cliff on the Europe side, to the Eastward of the Castle, and although a long and plunging range, will bring on with the Castle of Setilbahar, an intersecting fire upon the entrance of the Straits; it should therefore be maintained and Armed with Ten or Twelve good Guns, 24 Pounders. The Channel from this widens so much, that no further opposition can be made, until the point de Barbier presents itself, where a Battery for Six heavy Guns should be made; as well as one of the same number, and nature on the opposite Shore; these two Batteries would establish a good and certain intersecting Fire; and being prepared for firing red hot Shot, which all Sea Batteries should be; would impede the progress of an Enemy's Fleet, and make them very cautious how they approached the Upper Castles Sultania and Keletbahar. These Castles are situated upon the narrowest part of the Dardanelles, but the position of the Castle of Keletbahar, is not so well chosen as it might have been, had it been placed on the point to the Westward of it; where it would have had a much better command of the Channel.

It behoves the Turkish Government seriously to exert every effort, and means in their power to improve and strengthen these Castles, by

all the power of Art and Science. For, if an Enemy once passes the Grand Barrier there would remain no obstacle whatever of sufficient importance to check or prevent his accomplishing the object of his Design and making his way to Constantinople.

In obedience to your directions, I shall state the various defects at present existing in the four Castles and Batteries, and recommend such alterations, and improvements in the Artillery Department, as would be most advisable in my opinion to be adopted for the better security and defence of the Dardanelles.

The Guns, a few excepted, appear to me unserviceable, being flawed, full of cavities, some cracked, and pieces blown out of others. The Metal does not appear to be of a good quality, well purified, nor properly proportioned, being very brittle, and liable to constant accidents upon firing, an instance of which we were witnesses to; on the Island of Tenedos, the Guns, are most of them at present placed in front of the Great Guns, or Pierriers, where in case of an attack, they would be perfectly useless. The Gun Carriages are in general too large, for the Guns mounted upon them, very heavy, and ill constructed for narrow Ramparts; without Beds, Quoins, Sponges, Ladles, etc. The Shot lay about in all directions, mixed and impiled, are old, corroded, very rugged and rough. The Magazines I have seen, require an admission of Air, and Copper Doors, otherwise are good. Powder, and every description of Ordnance Stores extremely deficient.

The chief opposition, and upon which great dependence seems to be placed at present to an Enemy's passing the Castles, are the enormous large Guns or Pierriers, some of which are nearly thirty Inches in Diameter; they lay upon Skids, under Archways, made in the Curtains and Bastions; cannot consequently be traversed, and only fired upon a moving object, when it happens to come opposite to their direction, it must however be allowed that if One of these large Stone Shot, which they project, was to strike a Vessel it would probably be her destruction; but as many of them break into pieces after leaving the Guns, they are of course, very uncertain in their effect, and not to be alone depended upon; but as it may be advisable to make use of them it is proposed to let as many remain under the Archways, in the Curtains next the Channel, with the alterations proposed by Major Holloway as there may be places for them; but must observe that the principles approved and adopted of late years, for Sea Batteries, has been to endeavour by every possible means to move the Guns with facility by Traversing Carriages, or Platforms, so as to be enabled to follow the direction of a Vessel as she sails, and to fire upon the same object as often as possible.

A Mixture of a variety of different Natures of Ordnance, being even among the best established Artillery liable to create confusion, and occasion mistakes, particularly at a time when every precaution should be taken to guard against it, that of an attack, to avoid which, I beg

leave to recommend to the Turkish Government, to Arm the Old and New proposed Works in the four Castles, with only three kinds of Ordnance, Viz., 24, 18, and 12 Pounders, or Guns nearly answering to those Calibers, in the Number and Manner stated in the returns numbered 1, 2, 3, and 4; to which I have added a list of the requisite quantity of Ordnance Stores for each nature of Ordnance, calculating upon 150 Round Shot and 20 Case or Grape per Gun for the 24 and 18 Pounders, and 50 Round Shot, and 20 of Case or Grape for the 12 Pounders Gun. The Guns should be mounted upon Carriages constructed on the principle of our Garrison Carriage; they will be better adapted to their narrow Ramparts, require fewer Men to serve them, and be easier worked.

Such Howitzers as are in my return proposed for the Castles, should be mounted upon proper Carriages, made expressly for them. The Ammunition proposed for them, is at the rate of 200 Shells per Howitzer, and the same number of Shells, etc., are proposed for the Sea Service Mortar, two of which should be in each Castle.

As it is not to be supposed that these Castles will at any time be attacked both by Sea and Land together, I have regulated the proposed number of Artillery Men, by the number and nature of the heavy Ordnance, which if kept up in time of War, will I should suppose be fully adequate to the service of the Guns on the Castles at all times.

The Number of Non Commissioned Officers, and Gunners, required for the different Castles, and Batteries will be as follows. Viz.:

	Non Comd. Officers.	Gunners.	Total.
Camcalli	20 ...	203 ...	223
Setilbahar	27 ...	270 ...	297
Sultania	30 ...	334 ...	364
Kiletbahar	15 ...	156 ...	171
Equisar Battery ...	6 ...	60 ...	66
Point de Barbier, and opposite Battery ...	6 ...	60 ...	66
	104	1083	1187

The Number of Artillery Men, and quantity of Ammunition, etc., for the Pierriers are not included in this Statement as, their exact number is not yet fixed upon.

The next object of great importance, and strongly to be recommended for the Defence and Security of the Dardanelles, is the Establishment of a Regular Corps of Artillery for the service of the above mentioned Ordnance, properly Officered, with a sufficient number of Non-Commissioned Officers. This Corps should be well trained in the Exercises of the Guns, Howitzers, and Mortars; as well as instructed in every Branch of Artillery, necessary to make

them good and expert Gunners. They should be paid and cloathed by the Government, and that regularly. Barracks or Quarters should be provided for them, and their daily rate of subsistence should be sufficient to maintain them. The pay of the Non Commissioned Officers should be more than that of the Private or Gunner.

The Ordnance Stores should be put under the charge of a Storekeeper, who is to be answerable and accountable to the Government for the Stores, he should have a Clerk and be allowed a sufficient number of Labourers to enable him to keep the Stores in good regular Order. He should keep an exact account of all the Stores he receives and Issues on account of the Service, and send a Monthly state of them to the Government. A Second Person as a Check upon the Storekeeper should also be appointed, as Clerk of the Cheque, who is to have at all times free access to the Magazines and Stores; is also to keep an account of all Stores received and issued jointly with the Storekeeper, and to report to the Government any misapplication of them that may come to his knowledge. Thirty rounds of Ammunition per Gun should be kept constantly ready and lodged in Expense Magazines near the several Batteries, Kilns, or Furnaces for heating of Shot should be erected.

As Iron Ordnance is infinitely preferable to Brass, and generally used in our Garrisons, being more durable and not liable to be injured by firing in the manner that Brass is; particularly if the Metal is not sufficiently hard and tenacious. I therefore recommend Iron Guns for the Castles and Batteries; Should the Sublime Porte judge it proper to adopt any part of the proposed alterations and improvements.

About a Mile and a half to the Westward of the Castle of Setilbahar, is a Battery for Nine Guns, in which there are at present 5 Light Field Pieces; these should be removed, and the Battery armed with heavy Guns, if it is intended that this Battery should remain; one placed on a point between it and the Castle, would answer the double purpose of forcing an Enemy's Fleet to keep a respectable Offing, and be a greater protection to the Castle.

When Major Holloway has compleated his plans and projects, for the intended Works in the rear of the Castles of Setilbahar, and Kiletbahar; I shall have the honour of laying before you some further Remarks, and Observations, as well as the necessary Returns of the Ordnance and Stores for them and the Batteries.

I have the honor to be,
Sir,
Your most obedient
humble Servant,
R. HOPE,
Commdg. British Royal Artillery
and Major.

BONYOUKDERE,
21st September, 1799.

To BRIGADIER GENERAL KOEHLER, etc., etc., etc.

SIR,

The undermentioned Articles will be required for examining, and removing the different Natures of Ordnance in the Castles at the Dardanelles, etc., Viz. :—

Gins compleat	4
Sling Carts	2
Truck Carts	2
Sledge Carts	2
Searchers	4
Relievers	4
Prickers	4
Iron Crows	6
Crab Capstans...	2
Spars	6
Skids large	12
Do. small	12
Shot Gauges sets	4
Men's Harness sets	24
Coils of different sized Rope...	3
Blocks and Tackles.	
3 In. Planks	12
Handspikes, large	12
,, small	24

Such Pickaxes, Shovels, etc., as may be wanted can be borrowed from the Engineer's Department.

I have the Honor to be,
Sir,
Your most obedient
Humble Servant,
R. HOPE,
Comdg. Royal Artillery and Major.

To BRIGADIER GENERAL KOEHLER,
Commanding H.B.M. Forces, etc., etc., etc.

Return of the Number and Nature of Ordnance for the proposed Tower and Battery on the small Island off Tenedos.

24 Pounders mounted on Garrison Carriages Compleat	15
Stores for Ditto.	
Handspikes	60
Spunges	15
Ladles	8

Wadhooks	8
Linstocks	8
Tampeons	15
Aprons of Lead	15
Powder Horns and wires	8
Punches for Vents	8
Spikes	15
Claw Hammers	6
Shot { Round	1,500
Shot { Case or Grape	300
Cartridges empty	1,900
Wads	3,800
5½ In. Shells fixed	100
Tongs and Bearers	4
Water Buckets	3
Portfires, dozens	2
Portfire sticks	4
Powder Barrels, 90 lb.	170
Bridge Barrels	1
Powder Measures from 1 lb. to 4, sets ...	1
Slow Match, cwt.	2
Tubes	500
Tube Boxes	4
Tanned Hides	2
Hair Cloths	2
Wadmill Tilts...	2
Lanthorns { Muscovy	2
Lanthorns { Dark	2
Sheepskins	6
Spunge Tacks...	600
Tarred Marline, skeins	6
Gins Compleat	2
Portfire Clippers	4

R. HOPE,
Comdg. Royl. B. Arty.
and Major.

Colonel Geo. Strahan, R.E.

MEMOIR.

COLONEL GEORGE STRAHAN, R.E.

By Col. S. G. Burrard, f.r.s., R.E., Offg. Surveyor-General of India.

George Strahan, the son of William Strahan, was born at Ashurst in Surrey in 1839. He was educated at Eton, and in 1857 he entered the Military College of the Honourable East India Company at Addiscombe. He obtained his commission in the Bengal Engineers in 1858.

His eldest brother, William, was in the Artillery and died many years ago. His three younger brothers survive him; Aubrey entered the Geological Survey of Great Britain and is now a distinguished geologist. Henry is the Mayor of Hythe, and Charles, following his elder brother's example, obtained a commission in the Bengal Engineers, and after being Surveyor-General of India has now retired from the Government service.

The subject of this memoir won the sword of honour and the prizes for mathematics and drawing at Addiscombe, and his name is on the old boating cup in the Chatham Mess. This cup was competed for in an annual four-oared race by crews of the Royal and Indian Engineers. When the Indian Engineers were amalgamated with the Royal, the competition ceased. The last race was rowed in 1861, and on the cup at Chatham he is named as having rowed number three in the Indian boat in 1859 and as having been stroke in 1860.

Strahan went to India in 1860 and joined at Calcutta. He was first posted to the Bengal Sappers and Miners at Roorkee, and subsequently to the Irrigation Branch of the Public Works Department at Hardwar, the head works of the Ganges Canal. He remained in Irrigation for 15 months and in July, 1862, was appointed to the Topographical Survey of India. He entered this branch at an important turning point in its history. From 1800 to 1825 the Topographical Survey of India had been based on military route sketches. From 1825 to 1850 topographical maps had been mainly derived by reductions from large scale revenue surveys. No Indian maps of an earlier date than 1850 give any idea of vertical relief. It was between 1850 and 1860 that topography in India made its first stride in advance. Talking of

this advance Strahan used to say in his enthusiastic way: "It was all due to Dan Robinson."* He would acknowledge that the introduction of the plane table had proved of great advantage to topographers, and that the publication of Waugh's *Instructions* and Thuillier's *Manual* in 1853 had had considerable effects, but he always insisted that Robinson was the originator of the modern system of delineating ground. If we now look back upon the old maps of India we are struck at once with Lieut. Daniel Robinson's (1 inch=1 mile) maps of the intricate country between the Indus and the Jhelum, which were made between 1851 and 1859, and which are immensely superior to all others of that date. It is no exaggeration to say that these maps constitute an epoch in the history of topographical surveying. Robinson's maps of the Indus-Jhelum country (1851—1859), and Montgomerie's maps of Kashmir (1855—1865) were the only good topographical maps of India that were in existence when Strahan joined the Survey. Even these maps fall below the modern standard in that they furnish so few values of height.

In 1862 there were four topographical parties, and on his appointment to the Survey Strahan was posted to No. 1 Party (Gwalior and Central India). In 1857–58 the absence of all maps of Central India had proved very embarrassing during the advance of Sir Hugh Rose's columns, and in 1860 Capt. Daniel Robinson, who had just completed his surveys in the Northern Punjab, was directed to initiate the topographical survey of Gwalior, Central India and Rajputana on the 1 inch=1 mile scale. This was a vast undertaking, the area embraced exceeding 200,000 square miles.

In 1860–61 Capt. Robinson commenced the triangulation and extended it over 3,300 square miles, and in 1861–62 he started the topographical work. The records of 1861–62 give the names of the military officers with the Central India Topographical Party thus:—Capt. D. G. Robinson, R.E., Superintendent; Lieut. G. Strahan, R.E., Assistant Surveyor.

The expenditure on the party in 1861–62 was 55,000 rupees. In 1862-63 there were three military officers with this party and they are shown in the records thus:—Lieut.-Colonel D. G. Robinson, R.E., Superintendent; Lieut. G. Strahan, R.E., and Lieut. R. V. Riddell, R.E., Assistant Surveyors.

In 1862 Robinson reported to the Surveyor-General as follows:—

"My instructions to Lieut. Strahan were to carry the triangulation down to latitude 25°, remeasuring the great triangles if weather would permit; if not to confine himself to covering the ground with secondary triangles based on the old stations of the Great Arc. The weather became too hazy to admit of Lieut. Strahan doing more than

* General Daniel Robinson, C.B., R.E., joined the Survey of India in 1845. He was Director-General of Telegraphs from 1865 to 1877.

fulfilling the second part of my instructions, and that he did with so much difficulty and he suffered so much from exposure that his health has been in a very bad state ever since."

In 1863 the Surveyor-General (Sir Henry Thuillier) reported as follows to Government :—"Lieut. Strahan's practical knowledge is of great value. I am happy to be able to state that he has improved in health and is likely to remain at his post. He is an officer of the highest promise and merit. Lieut. C. Strahan, R.E., joined early in November in time to accompany the Central India Party into the field, where he is now undergoing instruction and taking an active part in the operations under his brother's excellent guidance."

In 1862-63 the topographical out-turn of the party was 3,457 square miles; George Strahan himself completed all the triangulation, besides 200 square miles of plane tabling.

The Surveyor-General now represented to Government that the topographical survey of the immense area allotted to No. 1 Party would not be completed for 60 or 70 years, and in 1863 a new party, No. 7 (Rajputana), was created. Both No. 1 (Central India) and No. 7 (Rajputana) were at first placed under one Superintendent. On Colonel D. Robinson being appointed to act for General Walker as Superintendent of the Trigonometrical Survey, Capt. A. B. Melville of the Kashmir Survey was appointed to take his place in Central India and the military officers of the two parties were distributed as follows :

Capt. A. B. Melville in charge of Nos. 1 and 7 Parties.

No. 1 Party (Gwalior and Central India)—Lieut. G. Strahan, Assistant Surveyor.

No. 7 Party (Rajputana)—Lieut. C. Strahan, Assistant Surveyor.

In 1864–65 No. 7 Party (Rajputana) was formally separated from No. 1 (Central India), and was placed under the superintendence of Lieut. G. Strahan. In reporting to Government of his intention to separate the two parties, the Surveyor-General wrote :—

"Lieut. G. Strahan is an officer of great ability and excellent business habits. He has received his training in a good school. When inspecting the work executed by him last field season, I was fully satisfied with all that has been done. This officer excels as a draftsman."

In 1864 Mr. W. Stotesbury, who was for many years to come one of George Strahan's principal assistants, joined the Survey and was posted to No. 7 Party.

In 1864-65 Strahan moved his party to its new area (Jaipur and Alwar), and, as no triangulation was ready, he confined the operations for this season to triangulation. 7,300 square miles were triangulated between November and April : of these Strahan himself did 5,286 square miles.

The advent of railways has so revolutionized procedure that it may

be of interest now to recall how survey parties used formerly to take the field. During the summer of 1865 Strahan had his office at Mussoorie. Early in October he recalled his native surveyors and khalasis from leave and assembled his party at Dehra Dun. He then started with a few elephants and a hundred camels on his long journey to Rajputana. For two months the early mornings were spent in marching; camp office used to be opened daily and during office hours the triangulation of the previous season was computed, points were plotted on plane tables and all preparations for field work were made. The march continued till November when the party reached its destination. Field work was carried on till April, when the scattered members of the party met again for their long march back to the hills which they reached towards the end of May."

In after years I once heard one of Strahan's assistants (Mr. W. W. Macnair) say that "on the Rajputana Survey Colonel Strahan used to do everything at a gallop. On horseback the only pace he recognized was the gallop. His camels were unloaded and his camp was pitched at full speed; theodolites were erected, and observation taken without pause. He was so constituted, that he never wanted leisure nor rest except during sleep."

There is little doubt that the strenuous life in Rajputana and the constant necessity he felt of working against time and of pressing and urging others, formed in him habits that made it difficult for him in later life to take kindly to the patient and accurate methods of geodesy.

I do not think that George Strahan served under General Robinson after 1863, but to the end of Strahan's life Robinson was engraved upon his memory as a hero. I remember a few years ago Strahan being delighted one day at coming across Robinson's old shikaree. "Just fancy," he said, "my meeting that old chap again. I used to see him often in Dan Robinson's howdah 30 years ago."

The Survey of Jaipur and Alwar was continued throughout the winter season of 1865-66 and 1866-67. The following extract is from Strahan's report for 1866-67 :—

"The camp left Dehra on October the 1st and the whole party were assembled at Delhi on October the 15th. Five days' march brought it to the frontier of Alwar where the ground allotted to Mr. Tod lay. On the 11th day Messrs. Baness and Stotesbury were detached to their ground and on the 16th day Messrs. Tapsell and Hussey were detached. I reached Jaipur on the 19th day's march from Delhi. I then commenced the triangulation of the city preparatory to the survey on a scale of 500' 1". The traversing and computation were sufficiently advanced in a fortnight for me to commence a detailed survey. The Survey of Jaipur comprises eight plane-table sections; two of these I completed myself, as a sort of pattern

[1] Colonel Bythell's article on Surveys.—*Imperial Gazetteer.*

of what I wished done. I then left Mr. Kitchen to complete the rest. Much delay was occasioned by the necessity of sending word to the authorities every evening of the exact spots which we wished to visit next day. The first day on which I approached one of the forts in Jaipur, without having any authorized official with me, they threatened to fire unless I immediately withdrew. I had several interviews with the Maharaja, as I considered an explanation of the uses of an accurate plan of his city and territory in person, would do more to secure his co-operation than any amount of writing. He took great interest in the theodolites and other instruments which I showed him."

During the winter season of 1866-67 the Surveyor-General received an urgent request from Government to make immediate arrangements for the survey of the site of the new cantonments for European troops, which were to be erected at Pokri in the Himalayas. Sir Henry Thuillier thereupon directed Lieut. Strahan to close his regular operations and to proceed to Pokri with all his assistants as quickly as possible. At Pokri the operations consisted of making a survey of the crest of a range, 5 miles in length, scale 1″=200′, contoured at 10′ intervals. Sir H. Thuillier subsequently reported to Government as follows :—"Lieut. Strahan is entitled to much credit for the manner in which he carried out this survey. He had no assistant with him who understood levelling. The map of Pokri is interesting as being the result of the first contoured survey which has ever been made in the Himalaya Mountains."

The following extract is from Strahan's own report (dated 1867) on the Survey of Chakrata :—

"We were compelled to leave the field in Rajputana one month earlier than usual having been called upon to execute the survey of the site of the new cantonment at Pokri. The party were all assembled at Delhi on April 1st and proceeded without delay to Pokri. This change has most unfortunately delayed the out-turn of my maps. This is the more to be regretted as on reaching Pokri I found that we were there before we were required. From your letter I concluded that the site for the cantonments was fixed and nothing remained but to make a contoured survey of it. General Wheeler must have been strangely misinformed on this matter, for I found that the Committee wished me to contour the range for 8 miles to *enable them to select a site*, a task impossible to complete under four or five months. Under these circumstances I recommended a reconnaissance first, and then when the site was determined a contoured survey of it. This did not however meet with approval, and I commenced the contouring of Chilmeri Hill at Capt. Peile's request. I had completed two-thirds of this when the President of the Committee wished me to survey a ridge beyond, called Chakrata. This I completed, and was then requested to go back to Pokri and complete Chilmeri Hill, the latter being the site still in favour with Capt. Peile. This vacillation induced me to refer the matter to you.

"As this is the first contoured survey executed in the Himalayas I shall enter somewhat fully into the methods employed. I adopted two systems, one at Chilmeri and one at Chakrata. First, at Chilmeri I selected a central point and with a theodolite I marked out from it two lines at right angles. This I intended to be the basis of the survey. I then proceeded to level these lines having large pegs at every 20' vertical rise or fall. I then measured the horizontal distances between the pegs by means of wooden rods. Secondly, at Chakrata instead of having straight lines I followed the winding of the summit of the range, and I laid out cross-lines at intervals corresponding to conspicuous watersheds. This change necessitated the traversing and plotting of the central and cross lines. On the other hand keeping to the summit of the ridge diminished the labour of levelling, and is, I think, best adapted to this style of survey."

On November the 9th, 1867, Strahan left India on furlough on medical certificate. He had then been in charge of the Rajputana Survey Party for 3½ years. In his report for 1867 the Surveyor-General wrote as follows :—

"All the maps of No. 7 Party (Rajputana Survey) are admirably executed and are decidedly the best of the season. I have much pleasure in testifying to the very creditable manner in which Lieut. G. Strahan has performed his duties. I much regret that the failing health of this talented officer has deprived the Department of his services for the time."

In July, 1869, Strahan returned from England and resumed charge of his former party, No. 7 (Rajputana). Sir Henry Thuillier wrote to Government :—

"I have personally discussed the new Rajputana programme with Lieut. Strahan whose return to the Department I gladly hail."

In 1869-70 Strahan took up the Survey of Jodhpur, Udaipur, Sirohi* and Ajmere, and he made a large scale survey (6 inches = 1 mile) of the great hill of Mount Abu.

In his report for 1870 Strahan pointed out that there was too large a gap in the principal triangulation of the desert and that his own secondary triangles could not be extended over such an enormous area without risk of undue accumulation of error. At Strahan's representations General Walker decided to run two more principal series of triangles across the desert.

Strahan himself observed great numbers of secondary series of triangles across the gaps between the principal series, and he always eliminated the errors of observation by the method of least squares,

* Long after Colonel Strahan had retired from the Service, the Sirohi Durbar wrote and asked him to return, and see whether their state boundary pillars had not been moved. He returned then to his old haunts in Rajputana after an absence of 35 years.

polygon by polygon, and at the close of each series he would distribute the closing errors by the rigorous methods of geodesy. The scientific way in which he adjusted his errors has given his triangulation a high and permanent reputation.

In his report for 1870 the Surveyor-General wrote to Government as follows :—

"It gives me the greatest satisfaction to bear testimony to the zeal, ability and systematic regularity with which Capt. G. Strahan has conducted all the duties entrusted to him. I have repeatedly in my reports to Government drawn special attention to the excellent services of this able officer."

In 1870–71 the Rajputana Survey was extended over Udaipur, Kotah, Indore and the Aravalli Mountains. The topographical outturn for this year was 3,551 square miles. The triangulation done by Strahan himself was 2,493 square miles.

In 1871 the Surveyor-General reported :—

"Further important employment has been found for this party, which is peculiarly qualified to undertake surveys of difficult ground of an intricate character. The sanitarium of Simla has long needed a careful survey on a large scale. It is therefore proposed to withdraw the party from Rajputana by the end of March to Simla, where they will be able to prosecute the new survey in the hills. In this way I hope to obtain good plans of the several military stations of Jutogh, Kasauli, Dagshai, Sabathu, in addition to Simla."

Capt. Strahan was thus in the field in Rajputana from October to April ; and during May, June and September he was employed on the triangulation of Simla.

In 1871–72 the topographical programme of his party was as follows :—(*a*). Survey on 1" scale, Jodhpur in the winter. (*b*). Survey on 24" scale, Simla, in the summer.

The Surveyor-General's report on the maps of the year was :—

Rajputana.—"Delineation of the ground, good and effective."

Simla.—"The six Simla sheets completed, of which three have been fair drawn by Capt. G. Strahan and three by Mr. Stotesbury, are admirably finished specimens of hill-drawing on a large scale and faithfully represent the ground.

"The labour of drawing these sheets is very great and demands first-rate artistic ability."

In the Simla sheets an attempt was made to follow the English scale of shade. This scale of shade had been found of use in indicating the relative steepness of slopes when troops were manœuvring over the downs of South England but Strahan regarded it as unsuitable to the Himalayas.

In 1872–73 Strahan's party was employed from November to April in the Marwar State of Rajputana and from May to September on

the Survey of Simla. The party was in the field and engaged upon outdoor work for 9 months out of the 12. The Surveyor-General in 1873 reported to Government :—

"I find it difficult adequately to express again the high sense I entertain of Capt. G. Strahan's attainments and management. The Survey Department owes this talented officer much for his successful prosecution of surveys of varied character of the highest order of merit."

In 1873–74 the Survey of Rajputana was continued in the winter and that of Simla was completed in the summer. In Rajputana the survey was extended from Ajmere to the borders of the Bikanir Desert. Of this desert Strahan reported :—

"Water is brackish and only found at great depths. I measured one well over 400' deep. According to the inhabitants the sandhills do not shift their positions to any great extent and I hope that some of the principal triangulation stations which I had to build at great expense will prove permanent. I was surprised to find that a system of telegraphy by looking-glasses flashed in the sun was in use across the desert to Bikanir. It is employed by the opium merchants to ascertain whether opium is selling at a cheap or high rate at Calcutta."

The year's out-turn of topographical survey in Rajputana was 3,170 square miles; Strahan himself completed 2,160 square miles of triangulation.

In 1874 the Surveyor-General reported to Government :—"The Simla Survey has been satisfactorily finished. In addition to the elaborate large scale sheet plans, 20 in number for the Simla Survey, Capt. G. Strahan has drawn a most artistic general plan of Simla and Jutogh in brush shading, 8 inches = 1 mile. It is a matter of congratulation that the double object of the survey in Rajputana and of the laborious large scale survey of Simla has thus been successfully and efficiently accomplished. An admirable out-turn has been effected in both cases at a most moderate cost."

The month of December, 1874, is memorable in astronomical annals for the transit of Venus. This was the first transit of Venus that had occurred since 1769, and as it was to be visible from India, the Government decided to have it observed from four places. The distance of the earth from the sun was less accurately known in 1874 than it is now, and the passage of Venus across the sun's disc was expected to yield important data. There were six observers in all and they were distributed as follows :—

General J. T. Walker at Dehra Dun, Mr. Hennessey at Mussoorie, Colonel Tennant, Capt. W. M. Campbell, Lieut. Waterhouse at Roorkee, Capt. G. Strahan at Lahore.

The following is an extract from Strahan's letter to Colonel Tennant, dated December the 17th, 1874 :—

"The instrument I used for the transit was a 6" refractor. The transit instrument used for time is one belonging to the Great Trigonometrical Survey of 30" focal length. I commenced observing transits of stars on November the 21st and continued without the exception of a single night until December the 10th. There can be little doubt that the times recorded during the transit of Venus when reduced for error and rate are true within a few hundredths of a second. Having satisfied myself as to the best position of the chronometer and having made experiments on eye-pieces and apertures, I awaited the phenomenon without anxiety. The weather on the morning of the 9th was all that could be wished. Ingress was not visible so far up country as Lahore, and for about an hour after sunrise the sun's limb and the planet were trembling a good deal, but as the sun got higher the definition became better, till about 15 minutes before contact the edges of the two bodies were sharply defined. As the planet moved towards the sun's limb she appeared to push out the edge of the sun before her, the cause of which phenomenon became evident in a few seconds. The planet's edge was encircled by a ring of light nearly as bright as the sun's disc which prevented any contact from ever taking place at all. There was no appearance whatever of a black drop or ligament. An elaborate discussion of my observations would be out of place, but I am tempted to make a few remarks upon appearances so unexpected. There can be little question that they point to the existence of an atmosphere on the planet. The ring was visible up to the time of external contact and from this a rough estimate of the refractive power of the planet's atmosphere may be made. The deviation of a solar ray amounts to 1 minute, 27 seconds of arc. During the transit, I kept a careful look-out for a satellite of Venus and also for any peculiar appearances in the planet's shape but I never detected the slightest deviation from a clear hard circular edge."

In 1874–75 the Rajputana Party had to take up the Survey of Kishengarh and Shekawati. Strahan being away for the transit of Venus, the party was taken into the field from Simla by Lieut. E. P. Leach (now General Sir Edmund Leach, V.C., K.C.B.). Strahan rejoined the party in Rajputana in January and commenced a large scale survey of the towns of Ajmere and Kishengarh. The total topographical out-turn for the year was 3,741 square miles. The total annual cost of the party was Rs.64,000.

In 1875 Capt. Strahan was transferred from Rajputana to Mysore. The following extract from the Surveyor-General's report of 1876 explains the transfer :—"The services of an experienced officer having been required to start a new topographical survey of the Mysore State, Capt. G. Strahan, R.E., who had most successfully conducted the operations of the Rajputana Party for 11 years was recommended for this duty and with the sanction of Government was transferred to the charge of No. 8 Topographical Party, from October the 1st, 1875."

Lieut. Leach succeeded Capt. Strahan in charge of the Rajputana

Party and the latter's connection with Rajputana terminated. The Survey of Rajputana was continued till 1885, by which time the whole area had been mapped, with the exception of the interior of the desert.

Strahan had spent 13 years on the Survey of Rajputana, and had been in charge of the Rajputana Party for 11 years. In after-life he used to refer to his time in Rajputana with enthusiasm. "It is," he used to say, "the healthiest country in the world. In 13 years I never lost a man." Speaking of the rocky conical hills that protrude at intervals of 10 miles out of the flat sandy wastes of Marwar he used to say "Marwar was created for triangulation. The absence of water makes it useless for any other purpose. It must have been created for triangulation only."

In 1900 the topographical maps of India were subjected to a rigorous examination by Colonel Gore, Surveyor-General, who was reporting to Government upon the topographical requirements of the country. Of Bengal he reported that, out of 433 sheets, "285 were useless"; of Northern India he reported that "the surveyors had had little idea of surveying hill features." Referring to the Central Provinces he said, that "the maps did not satisfy modern requirements." In Madras, he said, "no attention had been paid to accuracy of details." With regard to Hyderabad, he reported, that the surveys had been commenced in 1816 and that nothing was known as to how they were executed, that they were sketchy reconnaissances. His report on the Rajputana maps was :—

"The Rajputana maps are good, sound, topographical maps of an excellently even quality, and were all published within one year of the date of the field surveys."

In 1875 the Government of India directed that immediate steps should be taken to commence the topographical survey of the Native State of Mysore. Mysore is a rocky triangular table-land, containing large areas of mountain and forest and studded with vast numbers of tanks. The topographical party was formed under Capt. G. Strahan, and as a nucleus three of his most efficient assistants, Messrs. Kitchen, Stotesbury and Macnair were transferred with him from No. 7 (Rajputana) Party to the new No. 8 Party (Mysore). The annual cost of the Mysore Survey was estimated at 80,000 rupees ; the scale of survey was to be 1 inch = 1 mile.

As there was no triangulation ready for the topographers, the party for the first field season, 1875–76, was limited to the four officers only, and all these were employed on triangulation. The out-turn of triangulation was :—Capt. G. Strahan, 1,740 square miles ; Mr. F. Kitchen, 1,160 square miles ; Mr. W. Stotesbury, 1,160 square miles ; Mr. W. W. Macnair, 1,520 square miles. Total, 5,582 square miles.

In his first report on the Mysore Survey, Strahan wrote :—

"So far the appearances of the ground lead me to suppose that both

triangulation and plane tabling can be accomplished without difficulty. There are plenty of low rocky hills suitable for stations. There may be a little trouble here and there in fixing the plane table, where cocoanut plantations abound; considerable care will have to be exercised in the delineation of the undulations of the ground."

In the following year, 1876-77, it was fully expected that the area triangulated would have been surveyed in detail, and the Mysore Party was raised to its full strength; but a great famine and drought prevailed throughout Mysore and stopped the survey operations. The Surveyor-General reported to Government :—

"Capt. Strahan much fears that very little of the ground specially prepared for topographical delineation can be visited, and it will be difficult to carry on any connected operations whether of skeleton triangulation or of topography, in any part of the province. The accounts received up to date of the state of the province are exceedingly gloomy. The usual out-turn cannot now be expected, but Capt. Strahan is making every endeavour to utilize his establishment and to feed them by judicious commissariat arrangements."

At the close of the field work the Surveyor-General reported to Government :—

"Famine prevailed throughout the Southern Peninsula; Capt. Strahan's party had to be scattered and could not carry on their work in a compact block; they could not enter the greater part of the country that had been triangulated and prepared for detail survey. Capt. Strahan selected certain localities in which it was possible to obtain water, provisions and forage. The out-turn of work for the year was 1,465 square miles of topography, 5,280 square miles of triangulation."

At the close of field work in April, 1877, Capt. Strahan took furlough and the Survey of Mysore was placed under the charge of Major (now Sir H. R.) Thuillier. In the winter of 1877-78 Major Thuillier reported :—"The prospects of Mysore are much better than could have been expected; the famine and pestilence have disappeared, pasturage and cultivation are everywhere and suffering is nowhere visible. The survey work is progressing favourably."

In 1879 Major Thuillier went on furlough and Strahan resumed charge of the Survey of Mysore. During the winter of 1879-80 the survey was extended over the Western Ghats. The rugged nature of these mountains, the density of the jungles and the absence of roads and supplies were obstacles to progress. Strahan wrote :—"Ordinary methods of working with the plane table are in many places impracticable; resort has to be had to special methods, especially to that known as plane-table traversing, in which the plane table supplies the place of an angular instrument and the measurements are made by chain. This is always slow, and when

chain lines have to be cleared through forests, progress is slow indeed."

In 1880 Mr. Chew, the senior assistant, died of malaria.

Between 1875—1881 there had been surveyed in Mysore 12,754 square miles, and according to the original estimate of area there remained for survey 14,250 square miles. But in 1881 Strahan reported that the anticipated area of 27,004 square miles was too small, and that the true area of Mysore exceeded 30,000 square miles.

In 1880-81 he carried the triangulation along the Bababun Hills, which he described as being covered by a dense mass of bamboo jungle, inhabited by elephant and bison. No greater contrast to the bare hills and plains of Rajputana can be imagined than that presented by the forests of Mysore.

In 1880 the question of a clinometer, which could be used by plane tablers, was first raised. Before that date all heights on maps were obtained from levelling or from the vertical angles of triangulation or from barometers. It had become evident to topographers that no improvement in the representation of vertical relief upon maps could be expected until the numbers of observed heights were largely increased.

In 1880 General J. T. Walker issued his clinometric shade scale. This was the first clinometer tried in India; it consisted of a cardboard quadrant with plumbline attached. Walker estimated that vertical angles could be measured by means of it within 15 minutes of arc, so that the error in height should not exceed $0{\cdot}005 \times$ (distance in feet).

At 2 miles distance the error would be 50′. "It is much better," Walker wrote, "in hilly country to have a height in error by 50′ than to have no height at all."

Strahan tested Walker's clinometer in Mysore throughout the field season 1880–81. He reported as follows:—

"The results are disappointing; high winds are prevalent in Mysore and I found by my own experience that a very gentle breeze was sufficient to render the results so wild as to be little better than what an experienced eye could obtain by guess."

Strahan then designed a new clinometer of his own, and this was tried by his assistants and found to give results better than those obtained by Walker's instrument. The following observations of a height are typical of many, which were obtained with one of Capt. Strahan's clinometers:—

Distance of Point in feet.	Resulting Height in feet.	Difference from Mean in feet.
41,270	2,560	+34
29,850	2,531	+ 5
30,200	2,488	−38

The discrepancies were considered too large ; but if we may judge from subsequent experiences Strahan was expecting too much. The distances, at which the instrument was tested, were excessive. Even the modern clinometer could not be trusted to give correct heights at a distance of 41,000′ (7½ miles).

In 1880–81 General Walker reported to Government :—" In accordance with my instructions systematic attempts were made throughout the whole work to obtain a greater number of heights than had previously been attempted and these heights were of great assistance to Major Strahan in the delineation of the fair maps. This officer who is an accomplished draftsman has produced some sheets, specially Nos. 27 and 29, in a style very superior to that of previous work."

In his report for 1881–82 Major H. R. Thuillier, who had again taken over the Mysore Survey from Strahan, wrote as follows :—

" All the surveyors were furnished with the clinometer designed by Major G. Strahan, and observed their heights therewith throughout the work, but the results were more or less unsatisfactory, especially in ground where variations of height were small. I have endeavoured to adhere to 50′ vertical intervals for the contour lines, and to follow out the method of keeping the contours closer to the streams, as introduced by Major Strahan last year in sheets 27 and 29."

In 1883 General Walker issued an order, in which he explained that a want had been felt of something better than a cardboard clinometer, and that this had led to the invention of six different patterns of clinometer.

Pattern T was intended to be placed *on the surface* of the plane table. Patterns S and R were to be held *in the hand*, elbows being rested on the plane table. Patterns B, W and X were intended to be screwed *to the side* of the plane table. It is *believed* that the letter T denotes " Thuillier's pattern," that S denotes " G. Strahan's " and that W denotes " Wahab's." This is the tradition, but there is nothing on record in any report to explain the origin of these letters. In his report for 1882 Major H. R. Thuillier refers to George Strahan's pattern but not to his own. Thuillier's pattern was found to be the most suitable and was introduced into the Survey. It is liable to an error of 20′ at a distance of 2 miles.

In October, 1881, General Walker asked Major Strahan to take Colonel Campbell's place in the geodetic party, and Strahan's connection with Mysore ceased. As Strahan was in charge of the Mysore Survey for four or five years it is interesting now to follow the criticisms that were passed upon the Mysore maps by the Survey Committee, which was appointed in 1905 to report upon the condition of maps in India.

In his exhaustive report on the Indian maps, dated 1900, the Surveyor-General, Colonel Gore, had expressed himself as follows :—

"In the year 1874 the topographical survey of Mysore was commenced and was carried through to completion being finished in 1886. It consisted of a survey of the whole country on a scale of 1 inch = 1 mile. The Mysore maps are a most excellent series, and except that they must naturally be getting out of date, they leave nothing to be desired."

The Survey Committee of 1905 condemned large numbers of the maps of India. Of Bengal it wrote that no part of India was worse off. Of Assam it wrote "the maps of Cachar and Sylhet are admitted on all sides to be useless." But of the maps of Mysore the Committee wrote as follows:—"Mysore is more fortunate in its maps than any other province of India; the survey was commenced in 1874–75 and was completed in 1886. The Public Works Department have given a most favourable account of the accuracy and utility of these maps. They found it possible to lay out a new railway line by the maps. The maps in their opinion could hardly be improved."*

In any community and in any age Strahan would have been in the front rank of map draftsmen. But the specimens of his work, that he has left behind, do not hold their own against modern drawings. Their inferiority is due to three causes; firstly, in Strahan's day, colour printing had not been introduced, and his maps of Rajputana, Simla and Mysore show outlining, lettering and hill-shading all in black; secondly, Strahan's maps were reproduced by the inferior process known as photozincography; thirdly, Strahan never had a sufficient number of values of height at his disposal to enable him to show the forms of hill masses.

Strahan felt rather bitterly about photozincography. "A draftsman," he used to say, "is not allowed to draw what looks well, he has to draw at the bidding of a zincographer. How in the world could I draw a Himalayan map to suit a zincographer? If you look at my hachures through a microscope, you will see that in my drawing they are sharp crisp lines, but the zincographer has squeezed them out and given them hairy edges."

In 1875 the city of Ajmere was surveyed on the scale of 12 inches = 1 mile. One sheet of this survey, covered entirely with hills rising to 3,000', was drawn by Strahan himself. Horizontal hachures according to the scale of shade were used. The map is artistic and shows the hill details well. It was specially published for the instruction and use of draftsmen of the Survey of India, as a specimen of hill-shading.

After the 24" sheets of Simla and Jutogh, 1872-74, had been completed, Strahan reduced them and made from them his well-known drawing of Simla on the scale of 3 inches = 1 mile. This plan is an artistic delineation of a complex Himalayan area. Strahan and Stotesbury

* The Survey Committee, however, reported that the maps of Burma and Baluchistan were the most up to date of the whole country.

drew the original Simla 2·4" sheets with horizontal hachures according to a scale of shade: but in his 5" plan of Simla, Strahan depicted the mountains by means of vertical hachures. He threw over the scale of shade and obtained effects of relief by side-light. He much preferred vertical hachures to horizontal. "Horizontal hachures," he used to say, "do not represent any actual markings on the surface of the ground, but vertical hachures indicate the directions in which rain runs off."

One day, after he had retired, he came over to the Survey Office at Dehra Dun to see a large number of Himalayan sheets that had been joined together. The hills had been depicted by approximate contour lines (form lines), and the whole drawing had assumed one flat monotonous shade due to the uniformity of these contours. No mountain relief was apparent, and it was only possible to discover the variations in height by laboriously following out particular contour lines. The surveys had been admirable, the drawings had failed. Strahan's criticism is impressed on my memory because of his reference to General Robinson. "To make these hills stand out," Strahan said, "you must darken the salient points." It was pointed out to him that the contour lines showed the *average* slopes of the ground, and that the slopes round the salient points were not in nature steeper than elsewhere. "Still," he said, "you must emphasize salient points; otherwise the hills are meaningless. Dan Robinson always insisted on this. You will find that even in his published instructions he insisted on the accentuation of salient points."

Now the moment we accept the system advocated by Robinson and Strahan, we throw overboard the principle of indicating steepness of slope by depth of shade. But Strahan's arguments were convincing. "Who wants to know angles of slope in the Himalayas?" he would ask. His view was that we were surrendering the power of making maps realistic in order to show average slopes, which no one wanted to know.

In 1881 the principal geodetic work being undertaken in India was the observation of astronomical arcs of longitude. These measurements had been initiated by General Walker, and the results obtained by Colonel Campbell and Major Heaviside had been utilized by Colonel Clarke in his famous determination of the figure of the earth. The Indian arcs of longitude from Bombay to Vizagapatam and from Mangalore to Madras, being near the equator, had largely influenced Clarke's determination. The flatness of their curvature had led Clarke, firstly, to increase the equatorial radius of the earth, and, secondly, to assume that the equator was an ellipse of small eccentricity with its minor axis terminating in Ceylon. Walker now wanted to measure the arc of longitude from Karachi on the west of India to Moulmein in Burma and to extend the network of arcs over the whole of India. In 1881 Major Strahan succeeded Colonel

W. M. Campbell in charge of one of the astronomical parties, and in the winter of 1881-82 Majors Strahan and Heaviside carried the longitude operations across North-Eastern India from Agra to Calcutta. In 1882-83 they extended their arcs to Chittagong, and in 1884 to Moulmein.

During the summer of 1885 Major Strahan was in England for six months on duty for the examination of the longitude instruments. He carried out the examination at Greenwich Observatory. The Astronomer Royal provided him with a site and allowed him electrical communication with the standard sidereal clock. Strahan completed his task in time to admit of the instruments being sent out to India in September.

In October, 1885, the astronomical parties assembled under Strahan and Heaviside at Agra. As Heaviside was contemplating furlough I was transferred from the Computing Office to Agra as assistant to the longitude observers. Throughout the winter and spring I was employed with them in extending the arcs of longitude to Multan, Peshawar, Amritsar and Dehra Dun.

My two chiefs had been trained in different schools. Colonel Heaviside had been a geodetic observer from the start and had been grounded in the geodetic school of patience and accuracy. Mr. Hennessey used to say: "Observers are born, not made, and Heaviside is a born observer." Colonel Strahan had passed many years of his life in rapidly extending triangulation and topography over Rajputana, where he had never been able to slacken speed. He was an able astronomical observer, but he brought the ardour of the Rajputana trianguiator into the astronomical observatory, and his impetuosity was a constant source of perturbation to the aged astronomical recorder, Babu Harsahai.

Heaviside used to like to arrange his stars three minutes apart so as to have plenty of time. Strahan thought that one minute was ample. When we were working at what Strahan called "a slow programme," with three minutes' interval between stars, he so disliked waiting that he would keep some computations by him and take them up while sitting at the telescope during each pause.

One of the principal difficulties of longitude work was the liability of the electrical apparatus to stop working, owing to some interruption on the telegraph line connecting the two longitude stations. Whilst the observer was engaged upon star observations in his tent, something would go wrong with the line wire or its relays or with the recording apparatus, and all the star observations would be wasted. Each of the observers had trained an intelligent tindal to watch the pens of the electric recorder and to rush from the telegraph office to the observatory tent to give instant warning when anything was wrong. Heaviside used to instruct me to receive these warnings serenely, to avoid being flustered in the observatory, and not to be

put out by the thought that the stars would not wait till the electric connections had been restored. Strahan used to deal with these interruptions differently. He would dash at 20 miles an hour from the observatory tent to the telegraph office, rapidly test the connections, signal along the line and dash back in order to save as many stars as possible. His tindal was an excellent Mahratta named Ethu. It was Ethu's business to run to the observatory tent and to warn Strahan whenever the electric recorder was failing. Ethu however used to hesitate to break his bad news, although time was everything. He would stand outside the observatory tent and cough gently. Strahan had got to know the meaning of this cough and directly it occurred he would vanish from the tent.

During the winter of 1885–86 Strahan introduced a new method of computing azimuths, and he designed a new computation form. He showed the form to me at Multan, and asked me to test it. Colonel Heaviside said to me, "Strahan will be so pleased with this new form that he will insist on doing all the computations himself. He will not let us touch them. He will be made very happy." This proved to be true. I used to see Strahan computing away for hours at his azimuth form, and he would at intervals say:—"This form answers splendidly," or "this form saves nine-tenths of the work," remarks with which his colleagues agreed.

In 1886 the Government decided to have a topographical survey made of the Nicobar Islands, and Major Strahan had to abandon the longitude measurements in which he delighted and to undertake the Nicobar Survey. During 1884-86 Capt. Hobday had made a survey of the Andaman Islands, and on his departure for furlough in May, 1886, he handed over charge of the Andaman Survey Party to Strahan. During the summer of 1886 Strahan had charge of both the longitude work and of the Andaman mapping. In November, 1886, Strahan embarked with his party for the Nicobars. Two of the Indian marine steamers, the *Kwangtung* and the *Nankauri*, with all their boats were placed at Strahan's disposal, and a large number of convicts were attached to his party. As the survey operations were sanctioned for one season only, and as all work had to be completed within six months, some departures from the usual practice of surveying were necessary. There was no triangulation ready, and there was no astronomical elements, upon which to base triangulation. Strahan had therefore to arrange to carry out the detail survey, the triangulation and the astronomical basis for the triangulation, all simultaneously. Before Major Strahan left for the Nicobars, I happened to be living with him. I was particularly impressed with his complete independence of textbooks. He was aware that in the Nicobars he would have to observe for longitude, latitude and azimuth, to measure base lines, to make tidal determinations, but I never knew him consult a book. He had so intimate a knowledge of all the various operations, that a

textbook was unnecessary. The work required to be done in six months was the following :—

(1). An accurate survey of the coast lines.
(2). A correct determination of the positions of the several Nicobar Islands on the earth's surface.
(3). As much topographical detail of the interior of the islands as could be obtained.
(4). A large scale survey of the convict settlement at Kamorta.

Strahan found that there were in all 20 islands ; of these the area of Great Nicobar was 376 square miles ; nine of the islands had areas less than 1 square mile.

The longitude of Port Blair in the Andaman Islands had been determined from lunar observations in 1861. This determination Strahan now accepted, and he measured the difference of longitude between Port Blair and his Nicobar station by means of chronometers, which he tested himself by star transits. He observed also for latitude and azimuth, and he measured base lines with bars of teak. He thought it best not to level his base-line bars but to measure their inclinations, and he invented a special device for doing this. He carried traverses round the coasts of all the islands by means of the subtense bar method which had recently been invented by Colonel Tanner. Strahan's theodolite and subtense bar had frequently to be set up in the sea with the spray dashing over them, and the bar was often partially obscured by the breakers of the never-ending swell. The following extracts are taken from Strahan's report :—

"On December the 4th, heavy rains set in, and it was impossible to proceed with the verificatory measurement of the base. I therefore commenced the traverse of the island of Nankauri. By December the 13th, the swamps had sufficiently dried up to enable me to carry out the second measurement of the base. On December the 15th, I left Kamorta for the Island of Kar Nicobar with Mr. Keating, to start him on the coast traverse. I left him there on the 17th, and then steamed round the island of Batti Malv to ascertain, if it were possible to land on it, as it would be necessary to fix its position by astronomical observations. I then returned to Kamorta and finding the observatory ready, I erected and adjusted the transit instrument. On the following day I completed the coast traverse of Nankauri Island. From December the 28th to January the 5th, I was engaged in observing transits at Port Blair and at Kamorta with a view to determining their difference of longitude. The rest of January was occupied, partly, in observing the latitude at Kamorta and partly in traversing the coast of the island, which proved a difficult job. It was rarely possible to land from the boats direct. The only practicable method was to anchor the boat outside the surf, and then either to swim or wade ashore. Except when the rollers came in, the water was only 4′ deep and the men could stagger along, but the surf went

often over their heads to the detriment of my theodolites and plane tables. This process had often to be repeated 10 or 12 times a day, and for days together not one of the party ever had a dry thread on him. Five times my boat was completely capsized in the breakers.

"I carried the triangulation across St. George's Channel which divides the Great and Little Nicobars. I succeeded in landing on Batti Malv Island and observed the sun there for latitude. I then proceeded to Kar Nicobar and secured star observations for latitude the same night. In order to get mean sea level I made a series of tidal observations at Kamorta.

"The Nicobar Islands are at such distances apart, that their shores are concealed from one another by the curvature of the earth; this necessitated more astronomical work than would otherwise have been required, as in many instances the triangulation could not be extended from one island to another."

The following extract is from the Surveyor-General's (Sir H. R. Thuillier's) report for 1887 :—

"The survey of the Nicobar Islands presented exceptional difficulties. Much credit is due to Colonel Strahan for the ability, readiness and resource, which he brought to bear on the undertaking, the conditions of which were entirely different from those met with in India."

The following inscription was subsequently erected on a stone at Kamorta :—

"*Great Trigonometrical Survey.*—The position of this stone was found from observations made by Colonel G. Strahan in 1887 to be north latitude 8° 2′ 21″·03 and east longitude 93° 31′ 55″·05."

On the completion of the Nicobar Survey in 1887 Strahan resumed the longitude operations, and in conjunction with Colonel Heaviside observed the Cape Comorin arcs. In 1888 he succeeded General Haig, as the Deputy Surveyor-General in charge of the Trigonometrical Branch of the Survey. Haig did not retire till 1889, but he did not return to duty after taking furlough in 1888.

Strahan never took kindly to administrative work, even when he was officiating as Surveyor-General. He was essentially a man of action. His temperament compelled him to constant action. He liked to be taking observations or to be improving instrumental designs. He had not the patience to study and classify results, or to discuss their meanings as Walker had done. His idea of work was construction, observation, and drawing. As an administrator he seldom went round the observatories without taking some share in the practical work going on. He could not stand by and look on at others. His assistance was always welcomed, never resented; he joined in, not to put others right, but because he loved the work. When an explorer came in from Tibet, Strahan liked to get hold of

him and to draw the map himself. He rarely went into his drawing office without turning draftsmen out of their seats and adding to their maps himself, and he would spend hours together in the workshops watching the construction of some new instrumental attachment of his own design.

Strahan was the 7th Superintendent of the Great Trigonometrical Survey. His predecessors had been

Colonel Lambton,* 23rd Regiment	1798—1818
Colonel Sir George Everest, Bengal Artillery	1818—1840
General Sir Andrew Waugh, Bengal Engineers	1840—1861
General J. T. Walker, C.B., R.E.	1861—1883
Mr. Hennessey	1884
General C. T. Haig, R.E.	1884—1889

The characteristic feature of the Trigonometrical Survey has been the unbroken continuity of its policy. Its methods, though approved by Airy, Stokes, Clarke, Helmert and Darwin, have been at times derided as hyper-accurate, unpractical and slow. But nothing has turned it from its course. The Superintendents before Strahan had been professional geodesists. It had been no effort to them to maintain a policy with which they were in hearty sympathy; but Strahan with all his love and knowledge of astronomy was first of all a man of action. It could not have been otherwise.

All the early years of his professional career had been passed in strenuous and rapid topographical work. They had impressed upon his mind a practical bent, which led him occasionally into conflict with the old geodetic traditions. Geodetic observers will spend much time in order to avoid remote risks of error. They will argue that the degree of accuracy cannot be judged from present requirements only, for future discoveries may at any time add fresh interests to old determinations; and they will make their observations very refined, in order to have a reserve of accuracy, in order to have a geodetic equivalent for what engineers call their factor of safety. These were points on which Colonel Strahan was not always in agreement with his executive officers. What degree of accuracy is necessary, what degree is desirable? Some of his ideas were foreign to the Computing Office at Dehra Dun. He would at times give vent to opinions expressing doubts, not only of the utility of geodetic accuracy, but even of the reality of it:—

"Walker and Hennessey," I have heard him say, when he was

* Selected, when a junior officer, on account of his knowledge of the stars, to lead Sir David Baird's column during the night preceding the assault on Seringapatam.

speaking of his predecessors, "were always fighting over the ninth place of decimals, and they were both probably wrong in the seventh."

Although Strahan was not in accord with the old school, whose motto had been, "accuracy before speed," and although his impetuosity occasionally led him into difficulties, he was an enthusiastic Superintendent and most loyal to his predecessors. No one could have been more strict in maintaining the traditional accuracy of the work; whatever may have been his personal opinions he relaxed no rule of his predecessors. When in 1888 Upper Burma was annexed to India he cordially supported the policy of Sir Henry R. Thuillier and of General Haig to cover the newly-acquired territories with a gridiron of first-class triangulation, a policy that had met with unexpected opposition.

As a computer Strahan was accurate and rapid, but his impetuous temperament led him to carry out computations on odds and ends of paper instead of the recognized forms, and far from having each computation done in duplicate by an independent computer, he would complete his own computations and then check them all himself.

W. H. Cole, the Cambridge Mathematician, was in charge of the Computing Office at Dehra Dun, and having for years been the colleague of Walker, he had great influence with Strahan. One day, after Cole had retired, Strahan received a copy of a paper by a Prussian geodesist on the subject of the retardation of the electric current in telegraphic longitude observations. This was a subject which Strahan had studied, and he took exception to the Prussian paper. With Strahan a paper was either right or it was wrong. I once heard a friend of his say "George Strahan only deals in superlatives." Strahan wrote a note to refute the Prussian formulæ, and dealt in it with great numbers of figures. Although he had a Computing Office at his elbow, he did all the computations himself, and in his own impetuous way he checked them himself and published his paper. The Prussian Institute made no reply, but years afterwards when Colonel Lenox-Conyngham and I were at Potsdam, the Director of the International Geodetic Association took us into his library and solemnly pointed to Strahan's paper.* Strahan had made a slip in his calculations which had vitiated his results. On its being pointed out he at once recognized his mistake and it was a great blow to him. It was more than a personal blow, for it was a vindication of the old geodetic school of Walker.

As Deputy Surveyor-General at Dehra Dun, he took up again the investigation of the errors of the longitude arcs, and he designed and made a vertical collimator consisting of a telescope floating in mercury. He also designed a new pattern of sundial for use at our

* It had been published by Colonel Strahan in Vol. XV. of the *History of the Great Trigonometrical Survey of India.*

tidal observatories. He had studied the subject of sundials, and there is a stone sundial of his construction now standing in the compound of the Survey Office at Dehra Dun. Strahan's pattern of metal sundial was specially designed for tidal observatories at places like Minicoy, Mergui and Muscat, where no reliable time is obtainable. The difficulty with the sundials of the usual pattern was that the shadows they cast were not sharp; there was a penumbra, and it was not possible to say exactly where the edge of the shadow really began. This penumbra is of course due to the sun being a disc instead of a point of light; the uncertainty in time amounted to two minutes, and this was too large for the tidal observations. Strahan met the difficulty by introducing a gnomon with a narrow slit. The sun shone through the slit and caused a thin line of light to fall on to the dial plate instead of the usual shadow. The centre of this line of light could, in spite of its penumbral edges, be estimated with considerable precision. Strahan's pattern of tidal sundial is still in use.

In 1894 Colonel Strahan retired from the service of Government. To the Survey of India his enthusiasm has proved of permanent value, for it has caused enthusiasm in others.

Not having known many professional artists I feel diffident in referring to Strahan's powers as a landscape painter, but they were certainly extraordinary. He told me that when he was fifteen, his mother gave him Ruskin's *Modern Painters*. His father thought that the book was too old for a boy. The gift, however, proved a happy idea, for it remained his inseparable companion for life. "That book," he would say, "has taught me to see nature; all I know of nature and art I have learnt from it."

Strahan used to make rapid sketches from nature and then convert them into larger pictures in his studio. When out of doors, he would always be studying nature. "One's memory," he used to say, "ought to be a storehouse of facts." He would try and learn by heart the intricate forms of clouds and hills and trees in fleeting effects of light. In the rains, he would watch mists for minutes at a time, and would then close his eyes to test whether he could remember their forms and gradations. When once they were fixed upon his memory they were always available for insertion in subsequent pictures.

Although he was a fine draftsman and could use his colours with skill, he excelled mostly in composition. His powers of composition were wonderful. I have walked along Himalayan paths with amateur and professional artists, and I have always heard from them the same complaint:—"This scenery is magnificent, but I can find no subject for a landscape: either there is no suitable foreground, or the foreground is too sharply detached from the distance. I can get no lines that lead into the picture." Strahan alone never made such a complaint, and never found any difficulty. He would see subjects for

landscape everywhere. I once acted as the secretary to a painting exhibition in India and I came to know the exhibitors. Among the latter were two professionals, a Mr. and Mrs. W., who had studied in Paris and had exhibited at the Salon. These professionals pointed out to me how full of faults Strahan's pictures were, how conventional they were, and how carelessly the foregrounds were drawn. I said to the lady professional one day :—"You and your husband are always finding fault with Colonel Strahan's work, and yet whenever I come into this exhibition you are both looking at his pictures." She said to me :—"That is true. The reason is this; although Colonel Strahan is no draftsman, and no colourist, yet he is a poet: all his paintings are poetry." One morning Strahan came into my office and said :—"Who do you think have come to my studio this morning and asked me to give them lessons? Mr. and Mrs. W.! They say they want me to teach them composition."

For 48 years Strahan exhibited at the annual exhibition at Simla. I do not think that he ever failed to win a prize. On three occasions he won the Viceroy's prize, and on other occasions he won the Commander-in-Chief's medal. He took a great deal of trouble in forming sketching clubs for instruction and in getting up picture exhibitions, and many successful amateur artists owe their initiation in landscape painting to him.

Strahan's great power lay in the choice and arrangement of his subjects. In my desire to learn the principles of composition I have noted questions down to put to Strahan. He answered me always with characteristic readiness and clearness, but I never learnt his secret from him. It was the secret of genius, and he could not impart it. I never discovered how it was that he could always find an endless number of poetic subjects, not only among Himalayan snows, but in the deserts of Rajputana, in the jungles of Mysore, on the banks of the Hooghly, in Devonshire, Norway and the New Forest.

His wonderful powers of composition were to some extent his undoing as a painter. His mind was an unfailing well of artistic ideas, that he could not repress. While at his easel painting a landscape of snowy mountains, an idea would strike him of mists clinging to hillsides and partially obscuring the deodars. He would hastily finish off the foreground of his picture in order to commence on another.

Strahan's pictures were criticized, but they sold readily and they fetched high prices. Other artists may have been more accurate and more careful, but no painter has touched the Anglo-Indian public so profoundly as George Strahan. By means of his paintings he has taught that public to appreciate the poetic beauties of Indian scenery. He has handed on to them the lessons he learnt himself from Ruskin.

Strahan was an enthusiastic violoncellist and he was the promoter

of the Philharmonic Society of Mussoorie and for many years its president and manager.

After Strahan retired in 1894 he settled in Dehra Dun and used to spend his summers in Kashmir, in mountain climbing and in exploring the snows. Mrs. Strahan shared his fondness for mountain scenery and for camp life, and their enthusiasm for Kashmir seemed to increase after every trip. Although he was retired from the Service his life was one of ceaseless activity. In 1898 he went to Bengal to observe the total eclipse of the sun, and some years later he joined a party of the Royal Astronomical Society, and went to Norway for another solar eclipse. In March, 1910, Colonel and Mrs. Strahan left India for good; he was then hale and hearty. He died at Hampstead on January the 7th, 1911, at the age of 71. He leaves a widow, two sons and two daughters.

REVIEW.

MANŒUVRE ORDERS.

By COLONEL F. TRENCH, C.V.O., D.S.O. Tenth revised edition (1911), by MAJOR B. M. BATEMAN, R.G.A.—(W. Clowes & Sons, Ltd., 23, Cockspur Street, S.W. Pp. vi. + 115, and 18 pp. on pocket card. $3\frac{3}{4}'' \times 5''$. Price, 2s.).

THE first edition of this little book was published in 1898. What to the British Army were then new ideas, requiring quotations from German sources to recommend them, are now embodied in our own regulations, and subsequent editions have accordingly been revised to bring them into conformity with the official books. Such revision is rarely entirely satisfactory; had the first edition appeared after, instead of before, our present *Field Service Regulations* and been based on them, various points would probably have been put differently and some errors avoided in the examples.

The first chapter deals with "General Principles," *i.e.* remarks on orders, points to be considered in writing them, etc., the main points of which are now embodied in *Field Service Regulations*. The second chapter describes a method of obtaining practice in writing orders by means of "Map Staff Rides." Chapter III. contains tables and data of establishments, transport, road spaces, camps and billets, and the official abbreviated titles of regiments. These data are taken from *War Establishments*, the *Field Service Regulations*, the *Field Service Pocket Book*, and other official publications. Chapters IV. to VIII. give outlines and examples of orders for marches, attack, defence, convoys, halts, bivouacs, etc. Chapters IX. and X. contain specimen orders for the defence of a locality by an extemporized volunteer force, and Martial Law Regulations. The eleventh chapter gives outline orders for the passage of a river and for a landing. Chapter XII. gives examples of the standing orders required at manœuvres and on service. Accompanying the book is a waistcoat-pocket card of outlines for use at manœuvres and war games.

The principal point that strikes one on looking through a book of this kind is, of what use is it? If the reader knows the contents already, is the book of any use to him? If he does not, would he not do better to study the official books on the subjects dealt with? To the first question it may be answered that the book contains, in a form handy for reference, information scattered in various places in several different books. To the second the reply is that the book does not profess to be a substitute

for the official books, but only to illustrate them. The *Field Service Regulations* give excellent instructions on writing orders, but they are all in general terms; the practical application of the instructions to definite conditions can best be shown by examples. Without examples to illustrate the regulations a beginner finds many minor, but none the less real, difficulties. The fact that the book has reached its tenth edition shows that there is a considerable demand for it.

While examples are undoubtedly of great assistance, the ones given do not entirely agree with the precepts they are intended to illustrate. It is surely superfluous to put in orders that an advanced guard "will protect the advance of the main body," that the main body "will follow the advanced guard," and that the "Brigade Signal Officer will establish and maintain signalling communication between units and G.O.C." All these appear in a single example of march orders (p. 47). When the commander of an advanced guard or column is named, the troops allotted to him should be detailed in order of seniority of arms, not in order of march (pp. 49, 54); the words "the head of" should not be used when naming the time at which a body of troops should reach or pass a given point (pp. 47, 50, 54); an officer to command the transport should always be named (*Field Service Regulations*, I., 28, 5).

In both the examples of attack orders, also, the author after detailing the artillery adds "Target: the enemy's artillery." *Field Service Regulations* say "Artillery commanders must closely watch the advance of the infantry, and direct their fire against what is, for the time being, the most important target, always remembering that the object of their fire is to assist the infantry advance." If the defender withholds his artillery fire (as the author evidently expects he will—see his examples of defence orders), to name the target thus in attack orders reduces the attacker's artillery to the position of spectators.

The above are only some of the more obvious points to which the author might well turn his attention; and it is to be hoped that in the next edition they may receive consideration, so that the officers who find the book useful may be able to rely upon the examples as being in accordance with accepted practice, based upon the official books.

NOTICE OF MAGAZINE.

Rivista di Artiglieria e Genio.

April, 1911.

On the Mobility of Engineer Troops and of the Method of Lightening their Tools and Equipment so as to render them more fit for Service in the Field.—Whilst in France the question of the reorganization of engineer troops is being discussed, Capt. Winkler, of the 20th Battalion of French Engineers, has published in the March and April numbers of the *Journal des Sciences Militaires* a valuable article on the above-mentioned subject.

Taking into consideration the present state of the organization of the French Engineers, and after examining the causes which do not fulfil the exigencies of modern warfare, the author points out certain improvements in the instruction of the troops, in the employment of officers and men, and especially in the formation of the engineer parks and equipment with a view to increasing the rapidity and efficacy of this arm on the field of battle.

Capt. Winkler commences his article with some general considerations on the duties of sappers in the field, and on the tactical instruction of engineers. With regard to the first of these points he premises that the means at the disposal of the artillery and infantry for removing obstacles to their advance are generally insufficient, and the author dwells on the necessity for special troops having special technical training and being equipped with suitable tools, instruments, and material.

With regard to the technical instruction of the engineers, the author says that it should be such as to teach them at all times to be conversant with the requirements of the troops in their vicinity, to act in accordance with the intentions of the officer in command, and to render devoted assistance to the other arms in the shortest time and with the greatest efficacy.

The simple instruction in fortification, which it is necessary to give to the officers and troops, is not sufficient to qualify them for those concrete situations which occur in actual war and for which there is need to find a true and ready solution. In addition to the instruction in fortification, there should be exercises of such a nature as to render them proficient not only in technical instruction but especially in tactics.

The author then proceeds to examine these questions, and to consider separately those that refer to the organization and *personnel* of the engineers, or relate to the material and parks of the companies.

Organization and Personnel.—The duties of companies of engineers attached to divisions are always very numerous, complicated, and invested generally with a character of urgency, so much so that one company is not sufficient to assure a continuous and efficacious service, and it is necessary to assign *two companies of engineers to each division of*

infantry. In all great modern armies the tendency is to increase the pioneer troops; the Japanese have a battalion of pioneer troops for each infantry division; in the German Army the new law brings the proportion of engineer troops from 4·5 battalions of pioneers to 100 infantry battalions.

In view of the breaking up of engineer companies, either for the execution of work or for tactical reasons, it is necessary that there should be an adequate number of subalterns for each company of engineers. These should in the author's opinion be not less than four, all mounted. The necessity of sufficient means for the transmission of orders and reports also requires that there should be *three cyclists and one mounted sapper*.

For carrying out certain duties at short distances from its own unit also, such as reconnaissances, passages of rivers, etc., a small group of cyclists should be assigned to the mounted sappers under the command of a non-commissioned officer, so as to co-operate not only with the officers of the reconnoitring parties, but also to execute any works preparatory to the arrival of the main body of the company.

In view of the companies being broken up for various works, the officers and non-commissioned officers of engineers should also all be trained as signallers, and each section should have two sapper signallers. The telephone should also be used and this can be done by means of four telephonists per company, equipped with two micro-telephonic stations and 3 or 4 k.m. of line.

The following dispositions are recommended:—

(1). *In Co-operation with Infantry*.—(*a*). The infantry should themselves excavate the trenches, which they are charged to defend, with their own tools aided by those from the engineer parks, and should organize the resources and the obstacles at their disposal. The engineer troops should co-operate with the infantry in constructing the trenches with strong profiles, and in undertaking all works that require special technical knowledge.

(*b*). With the precision and rapidity of fire that now obtains, the concentration of fire becomes exceedingly damaging to works with large superficial area and strong profiles, as these offer an excellent target to the fire of explosive shells, while lightly constructed trenches are far less exposed.

(*c*). Engineer troops should assist in the construction of defences at supporting points of a position, but it cannot be admitted that this is one of their chief duties. The duty of defending a point of support rests mainly with the infantry to whom the engineers bring their technical resources.

(*d*). In the attack of villages, woods, salient points of ground, etc., if obstacles impede the assault, it is necessary to have resource to the engineer detachment equipped with explosives and proper tools, to open a passage for the infantry.

(2). *In Co-operation with Artillery*.—The co-operation of artillery and engineers on the battlefield is less frequently required than that of the engineers and infantry, and would only happen in the destruction of obstacles that may impede the march, in the passage through woods, and the felling of trees to take up a position. Such co-operation is only

useful when the work can be done with the greatest rapidity, and in such cases the light groups of cyclists and mounted sappers would be of great service.

Dispositions for Material and Company Parks.—Portable spades or shovels should be used by the infantry for the excavation of trenches which have not a greater depth or profile than those required for fire when kneeling. For greater depths, the French infantry use portable tools of the same pattern as those used by the engineers, and which are carried on light wagons in the proportion of two to each regiment. For more important works the troops make use of the tools from the engineer companies or those of the engineer parks of the army corps.

The portable tools of the French engineers are allotted to each company as follows:—128 excavating tools (64 picks, 64 shovels), 72 cutting tools (billhooks, saws, small picks, scissors, etc.). These are distributed among the sections so that each can be employed independently on various works. This allotment of tools both as regards quantity, etc., is sufficient for all works of the first urgency likely to be required by a company on the battlefield.

The park of the sappers and miner companies of the French Engineers comprises 239 tools, of which 94 are excavating tools (64 shovels, 30 pick-axes), and 145 are cutting tools (knives, billhooks, scissors, etc.). This is a sufficient allotment for fortification work, and demolitions which may occur in a campaign, but the patterns of tools for the park are too heavy. With regard to explosives the park for a company contains 194 k.g. of mélinite, a quantity which is much less than the 400 k.g. carried in the German parks of pioneer companies.

The author goes on to say that the wagons for the company parks in the French Engineers are too heavy. It would be advisable to lighten these wagons, and also to distribute the material in these carriages so that each company of engineers can perform its duties in the least possible time. The adoption of light carriages with two wheels is recommended, to allow of the breaking up of the engineer companies into detachments, a question intimately connected with that of the distribution of material. Arrangements should be made for the breaking up of the companies into four sections or subdivisions, so that four wagons would be requisite, each containing the necessary tools for the men of the sections.

With regard to explosives, as their use varies in many cases they can conveniently be divided into two allotments—one of sufficient quantity for the small demolitions which are commonly required on the battlefield, the other forming the load for a special carriage for more important demolitions. This latter carriage should contain from 120 to 130 k.g. of mélinite and the miners' tools.

With regard to the tools for bridging purposes, he recommends that one special carriage should be retained for each company. There would then be six wagons per company—four for the section, one for the explosives, and one for bridging materials.

The wagons should not have a greater weight than 1,100 k.g. each, they should have two wheels, and be drawn by two horses, made up as

follows:—Empty wagons, 470 k.g.; tools and materials, 360 k.g.; 30 bags (each 8 k.g.) 240 k.g.; total, 1,070 k.g.

The wagon for explosives should weigh 1,020 k.g., and that for bridging material 1,170 k.g.

The following would be the advantages of a park for a company of engineers so arranged:—(1). It would always be able to follow the company and with the assistance of a few men could be taken over small ditches or embankments. (2). The carriages could always proceed quickly to any given locality, and in case of being left behind they could be used singly with the sections of companies for urgent works. (3). With the aid of the section carriages it is possible to lighten the haversacks carried by the men of the company, leaving them free to work as sappers. (4). In whatever manner the companies might be broken up, the various sections could be followed by the carriages.

Finally the author treats of the question of *light bridging parks* for sapper companies, and states that, notwithstanding the willingness of the men, it is not always possible to construct useful bridges across rivers or watercourses by local resources. It is necessary that the engineers should have with them the requisite materials for bridging, and such as can readily be used on the battlefield. This material should be such that it would be possible to construct with it a bridge of about 20 m. in length and that with two such units a bridge of 40 m. could be made. The wagons for this bridging material should be sufficiently light and mobile to be able to run quickly on any kind of roads.

For the various parts of the bridges, boats of metal divisible into two parts are recommended of a length of 4 m. to 4·5 m. each, and the length of the planks for the boat bridges should be 5 m. The wagons for the transport of this material should have four wheels and should be drawn by four horses, they should not weigh more than 500 k.g. when empty, or 1,500 k.g. when loaded. Nine wagons with four horses each would be required for the whole. The weight of each wagon would amount to 1,530 k.g., viz.:—Empty carriage, 500 k.g.; load of material, 750 k.g.; 3 men with equipage, 280 k.g.; total, 1,530 k.g.

With this park material 21 metres of bridge for the passage of troops can be constructed, for infantry in file, cavalry in single file, and for sections of mitrailleuses. A division having then two companies of engineers will then have the means of crossing for 42 m. of bridge.

The strength in men and horses for a sapper company of engineers assigned to an infantry division is then given as follows:—

(*a*). Companies:—1 captain and 4 subalterns mounted, and 245 N.C.O.'s and men, viz., (1), 16 sergeants, 16 corporals, 16 head workmen (*capi operai*), 165 sappers, 8 signallers, 4 telephonists, 3 cyclists; (2), 1 sergeant, 1 corporal, 1 head workman, 14 sapper cyclists and mounted men forming a light detachment.

(*b*). Company park commanded by an officer:

8 drivers; 14 horses (1 saddle and 1 reserve); 6 wagons.

(*c*). Park for light bridging:

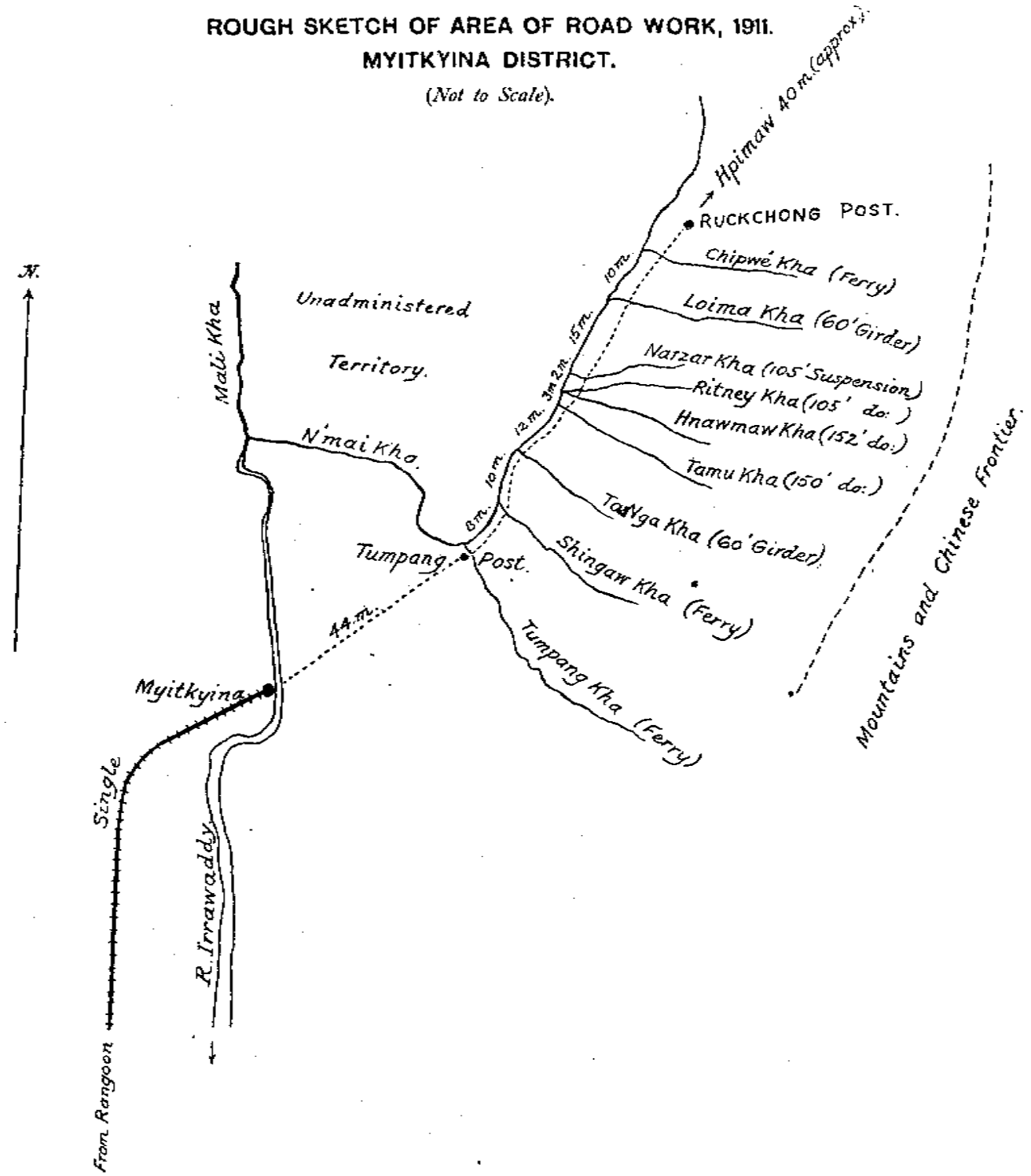
23 drivers; 41 horses (3 saddle and 2 reserve); 9 wagons.

E. T. THACKERAY.

BRIDGING WITH THE BURMA SAPPERS. PLATE I.

ROUGH SKETCH OF AREA OF ROAD WORK, 1911.
MYITKYINA DISTRICT.

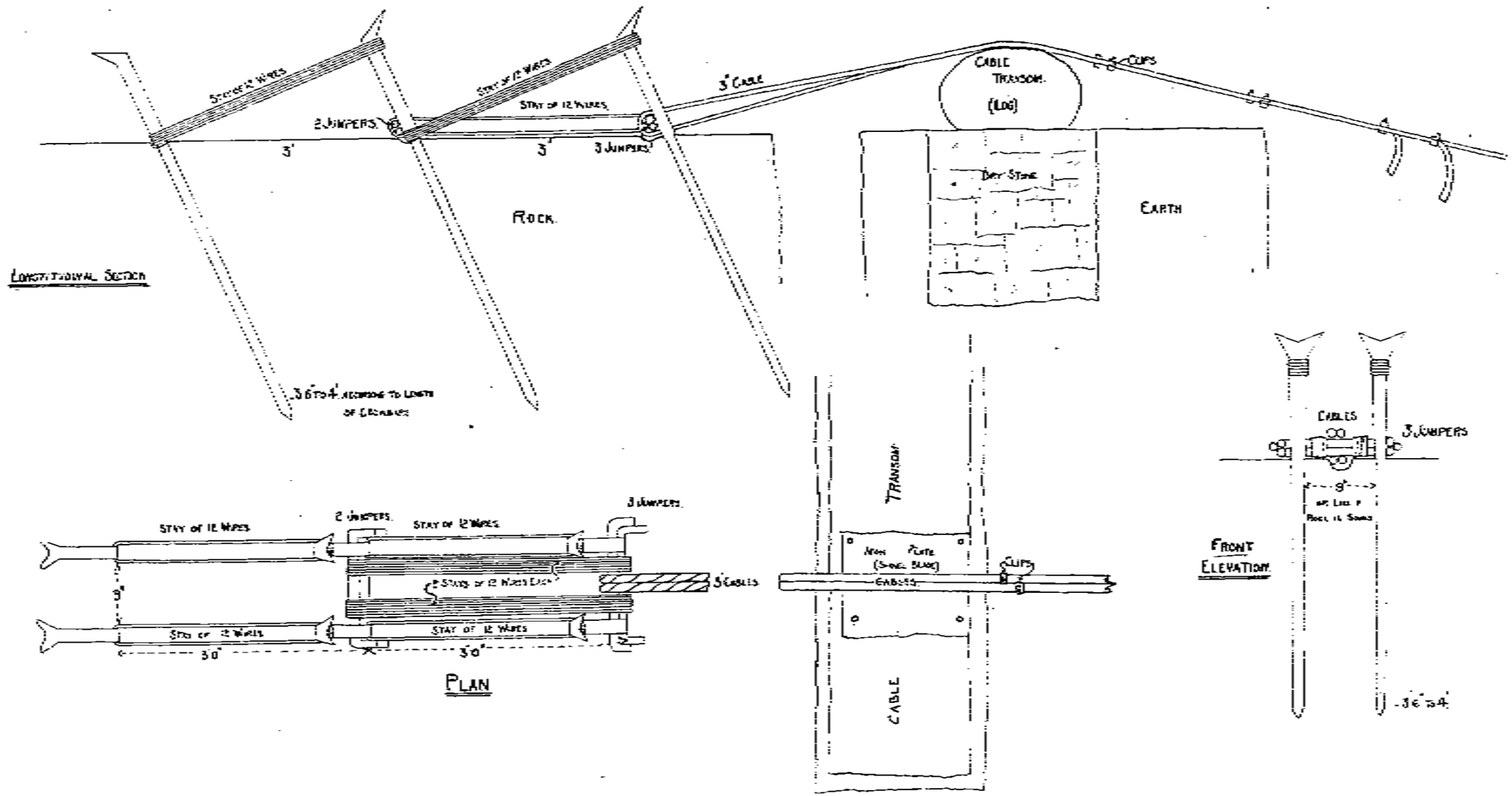
(Not to Scale).



BRIDGING WITH THE BURMA SAPPERS.

PLATE II.

DETAILS OF CROWBAR ANCHORAGE IN ROCK.



King Edward VII's Hospital for Officers.

Patron—HIS MAJESTY THE KING.
President—HIS ROYAL HIGHNESS THE DUKE OF CONNAUGHT.
Trustees—SISTER AGNES, LORD FARQUHAR, SIR WALPOLE GREENWELL, Bart., ERNEST DE LA RUE, Esq., S. ERNEST PALMER, Esq.

REPORT.

DURING 1910 241 Officers received treatment. 174 Operations were performed.
OFFICERS ADMITTED:—Royal Navy and Royal Marines, 33; Royal Indian Marine, 3; Royal Artillery, 24; Royal Engineers, 20; Cavalry, 9; Foot Guards, 1; Infantry, 74; A.S.C., 1; R.A.M.C., 2; A.V.C., 4; A.P.D., 2. INDIAN ARMY—Indian Army 7, Cavalry 11, Infantry 46, I.M.S. 1—65.
Staff, Unemployed, etc., 3.

TOTAL—241

Dr. Balance Sheet, 31st December, 1910. Cr.

	£ s. d.	£ s. d.		£ s. d.
To RECEIVED IN ADVANCE IN RESPECT OF ANNUAL CONTRIBUTIONS		202 12 0	By INVESTMENTS	40,699 5 8
,, BALANCE—Viz., Excess of Donations over Initial Outlay and Current Expenditure to 31st December, 1909	43,099 12 0		,, CASH AT BANKERS	3,578 3 4
,, Excess of Current Income over Expenditure ...	975 5 0			
		44,074 17 0		
		£44,277 9 0		£44,277 9 0

Dr. Income and Expenditure Account, Year ending 31st December, 1910. Cr.

	£ s. d.	£ s. d.		£ s. d.	£ s. d.
To RENT, RATES, TAXES, WATER AND INSURANCE		708 1 2	By SUBSCRIPTIONS APPLICABLE TO THE YEAR, VIZ.:—		
,, REPAIRS AND ALTERATIONS TO HOSPITAL ...		512 17 1	His late Majesty King Edward VII.... ...	100 0 0	
,, GENERAL MAINTENANCE EXPENSES—			H.M. King George V....	100 0 0	
Salaries and Wages ...	1,398 0 3		Sir Walpole Greenwell, Bart.	100 0 0	
Washing	272 10 5		Sir E. Cassel, Bart. ...	100 0 0	
Provisions and Household Stores	2,040 18 3		S. Neumann, Esq. ...	100 0 0	
Wines and Spirits ...	67 16 3		J. Larnach, Esq. ...	100 0 0	
Fuel and Light	246 12 0		W. Burns, Esq.	50 0 0	
Clothing-House Repairs, Telephone, and other incidental expenses ...	391 0 4		Lord Burnham	100 0 0	
		4,416 17 6	S. E. Palmer, Esq. ...	100 0 0	
,, SURGICAL DRESSINGS, MEDICINES, PATHOLOGICAL REPORTS, MASSAGE, AND SUNDRY FEES		950 1 7	Sir H. Praed, Bart. ...	10 10 0	
,, BALANCE CARRIED TO BALANCE SHEET		975 5 0	Miss Keyser	100 0 0	
			Sister Agnes	100 0 0	
			Lord Rothschild... ...	100 0 0	
			Alfred Rothschild, Esq.	100 0 0	
			Leopold Rothschild, Esq.	100 0 0	
			C. E. Keyser, Esq. ...	100 0 0	
			Mrs. Livingstone Bruce	20 0 0	
			Margaret Lady Waterlow	10 0 0	
			Mrs. Bischoffsheim ...	50 0 0	
			Lord Strathcona... ...	105 0 0	
			Sir Edward Sassoon, Bart.	50 0 0	
			Arthur Sassoon, Esq., M.V.O.	50 0 0	
			Viscount Iveagh... ...	100 0 0	
			Sir E. Hambro, Bart. ...	100 0 0	
			Baroness Eckardstein	100 0 0	
			Lord Michelham... ...	100 0 0	
			E. Gordon, Esq.... ...	2 2 0	
			C. Gordon, Esq.... ...	2 2 0	
			Mrs. G. Goddard ...	1 1 0	
			S. Gordon, Esq.... ...	2 2 0	
			Mrs. A. M. Corry ...	20 0 0	
					2,172 17 0
			,, DIVIDENDS ON INVESTMENTS		1,870 19 8
			,, SUBSCRIPTIONS AND DONATIONS PER OFFICERS OF THE NAVY AND ARMY AND RETIRED OFFICERS		3,519 5 8
		£7,563 2 4			£7,563 2 4

We have examined the above Statements of Accounts with the books and vouchers of the Hospital, and find the same to be correct.

18th February, 1911. PRICE WATERHOUSE & CO