R·E

BOUND BY
W. & J. MACKAY & CO.
AT THEIR
Bookbinding Works,
CHATHAM.

PROFESSIONAL PAPERS

OF THE

CORPS OF ROYAL ENGINEERS.

EDITED BY

CAPTAIN C. B. MAYNE, R.E.

ROYAL ENGINEERS INSTITUTE.

OCCASIONAL PAPERS.

VOL. XX.

1894.

ALL RIGHTS RESERVED.

Chatham:

PRINTED BY W. & J. MACKAY & CO., 176, HIGH STREET.

PUBLISHED BY THE ROYAL ENGINEERS INSTITUTE, CHATHAM.

AGENTS: W. & J. MACKAY & CO., CHATHAM.

1894.

Price 10s. 6d. nett.

*** The R.E. Institute is not responsible for the statements made or opinions expressed in this Volume.

PREFACE.

VOLUME XX. of the *Occasional Papers* for 1894 presents to the reader a very varied list of subjects.

The volume opens with an interesting paper on *The History of the Royal Prussian Engineer Committee during the first 25 years of its existence*, translated by Capt. M. Nathan, R.E., and which is enriched by a Translator's Note giving a comparison between the English and Prussian systems of Engineer organization and working.

Of the two papers relating to Surveying, that by Lieut.-Col. H. H. Godwin-Austen on *Exploration Survey Work* shows the value of the plane table for reconnaissance surveys in mountainous and hilly country, and of the prismatic compass in close confined country. It further affords a good illustration of the use of latitude observations, which are so easily made, as a check on rough rapid work. The other paper, by Major C. R. Conder, R.E., on *The Trigonometrical Survey of Palestine*, will be found to be full of practical advice and wise words that should appeal to all who serve in foreign countries, and not merely to those engaged in surveys. It illustrates a saying attributed to Robert Stephenson, "The hardest engineering is the engineering of men."

Of the military papers, the compilation of Major H. D'Arch Breton, R.E., on *The Contest for North America, 1750—1760*, illustrates the oft-repeated lessons of the necessity for a single commander in the field, the evil of half-hearted measures, the weakening effect of divided councils on the part of the legislators who provide the sinews of war, the necessity for a strong central government and for a safe line of communication, the great value of sea power, the great moral effect of surprises and ambushes, and other similar points. All of these form important factors in that combination of secondary formative causes which go to make up the life and energy and activity of a nation, whether in peace or war, and which so largely influences the issue of success or failure. Passing from these general considerations, we are brought by Capt. F. N. Maude's thoughtful paper, *Twenty Years of Tactical Evolution in Germany*, face to face with the stern conditions which govern on the battlefield. This paper is one requiring thought and careful reading to appreciate its value, and it points out that the loss of control and consequent confusion that occur in battle, especially in those that have taken place during the past three decades, have been chiefly due to want of discipline, and not merely to the efficacy of the enemy's fire. It is also pointed out that the real decision in battles is made at the medium ranges, the subsequent retreat or victorious advance being but the outward and visible sign that this decision has been arrived at one way or the other. The deduction from this fact is the importance of using such formations, at the medium ranges in battle, as will ensure a maximum of fire power, that is, as will prvoide the strongest fire line possible capable of being kept under control. But at the same time the "persuasive influence" of an advance to the bayonet assault must always be kept in view, as also the fact that the fire-fight is for the purpose of preparing the way for it. Consequently we find that for the medium ranges and under, single rank formations, combined with a high training of the individual soldier, are advocated as a principle for the fighting in the future. In Capt. Tresidder's valuable paper, *Notes on Armour Plates and their Behaviour under Fire*, we pass to the peculiar province of the Engineer. This paper has already attracted much attention. Capt. Tresidder has endeavoured to show in detail what takes place in the very small fraction of time that elapses between the impact of a shot at a plate and the complete absorption of its energy, and the explanation of such an expert cannot fail to be of deep interest to those who desire to understand the nature of the actions and reactions that take place between a swift-moving projectile and the armour employed to resist it. The *Notes on Bridging*, by Major F. J. Aylmer, V.C., afford a good illustration of what can be done by determination and ready wit in making use of material lying near at hand for the purpose of bridging considerable spans under field conditions of engineering.

As regards the three remaining papers on Civil Engineering and sanitary matters, that on *Foundations in Sand*, by such an authority as Mr. John Newman, cannot but prove of value to all engaged in engineering works. Major W. F. N. Noel describes, in his paper on the *Derbyshire Royal Infirmary*, the latest ideas as regards hospital construction, a subject which yields to none in degree of importance in social questions relating to the health and care of the seriously sick. And in the paper on *The International System of Sewage Disposal as adopted at Cahir Barracks*, Major W. H. Goldney describes one among the many systems now advocated for the disposal and removal of the waste matters of the animal physiological economy which would otherwise prove a source of danger to the public health if not so removed and rendered innocuous.

As regards the future issue of the *Professional Papers* of the Corps, the Committee of the R.E. Institute have decided to publish them in three forms, viz.: (*a*), *The Occasional Paper Series;* (*b*), *The Foreign Translation Series;* and (*c*), *The Confidential Series;* instead of in two forms—the first and third—as at present. The rules for the issue of the Foreign Translation Series are to be the same as those for the Occasional Paper Series. The Foreign Translation Series is to contain translations of various foreign papers on subjects of interest to R.E. officers, and its pages will also contain a summary for each year of the progress that has been made abroad in the various branches of the work that officers of the Corps are called upon to perform. It is anticipated that this Foreign Translation Series will thus prove of great value to its readers by enabling them to keep abreast of the times.

But in order that the whole of the *R.E. Professional Papers* may be of the greatest service possible to the Corps, the co-operation of every member is necessary.

This co-operation has of late years been much neglected, and it is to be hoped that in the future individual officers, both at home and abroad, will find time to communicate any interesting results of their experiences in carrying on the work on which they be employed, or to contribute for the Corps at large any useful information which they may have acquired in the course of their various duties. Information suitable to any one or all of the three sub-divisions of the *R.E. Professional Papers* is required.

In this matter it is well to recall, in conclusion, the words written by the late Sir William, then Lieutenant, Denison in his preface to the first volume of the *Professional Papers* in 1837 :—

"The number and variety of the duties upon which we are employed, while they present many obstacles to the attainment of an accurate knowledge of our profession, seem at the same time to point out a system of co-operation as the surest mode of overcoming them.

"If every individual would contribute the results of his experiences, however trifling, and throw his quota of information into the general stock, he might, in return, draw from that stock rules and examples for his guidance under all circumstances, deduced from the collective experiences of his brother officers.

"But, to accumulate this experience, and to make it applicable to the various duties which we have to perform, the talents and industry of numbers must be brought into action, and each individual should avail himself of every opportunity of acquiring information, as well for his own particular benefit as for that of the Corps at large.

"There is pleasure in the mere exercise of the intellectual faculties, there is pleasure in the acquisition of knowledge for its own sake; but when knowledge is combined with utility, when it is available for the benefit of others, the pleasure is infinitely increased."

C. B. MAYNE, Capt., R.E.,
Secretary, R.E. Institute.

Chatham,
5th December, 1894.

CONTENTS OF VOLUME XX.

---

5. The Inspector of Engineers of the district in which proposed fortifications were situated.

6. The Inspector of Artillery stationed at Berlin.

7. The Head of the Engineer Division at the War Office.

The Army Orders summarize as follows the duties and procedure of the Commission :—

In all questions concerning the fortification of new positions, the extension of existing defences, or the addition of important outworks, the wishes of the Headquarter authorities will be communicated to the Chief of the Corps of Engineers, and by him to the 2nd Inspector-General.

The latter has to draw up the first statement of the project and embody it in a minute with his opinions as regards the general lines to be followed.

This minute will be submitted to the Engineer Commission for discussion.

The decision of the Commission on the first general project, when War Office approval of it has been obtained by the Chief of the Corps of Engineers, will serve as the basis of the complete project, which will now be put in hand. The 2nd Inspector-General of Fortifications will give the necessary instructions for the preparation of this project at the place itself, in consultation with the Engineer Inspectors concerned, and the local Engineer officers.

The completed design will be submitted by the 2nd Inspector-General of Fortifications, with his opinion, to the Chief of the Corps of Engineers, who will summon a meeting of the Engineer Commission and lay before it the elaborated project for examination from a general military and fortification point of view, after which the project, together with the decision of the Commission with regard to it, will be submitted to the War Office by the Chief of the Corps of Engineers for final decision.

With the exception of a few alterations in the officers employed on it, this Engineer Commission lasted till the 23rd December, 1867, when it was dissolved by orders from Headquarters, and the Defence Commission and the Engineer Committee constituted in place of it.

The Engineer Committee became for the Engineer and Pioneer Services what the Artillery Proof Commission had long been, and still is, for the Artillery.

Formation and Organization of the Engineer Committee.

By a Cabinet order of the 23rd December, 1867, a different organization of the Corps of Engineers was sanctioned, "in order that the Corps should be in a position to carry out all the duties assigned to it." The order further laid down as follows with regard to the establishment of the Engineer Committee and its functions:—

The existing Engineer Commission will be dissolved. In its place a Defence Commission will be appointed, under the presidency of H.R.H. the Crown Prince, the permanent members being the Chief of the General Staff of the Army, the Inspector-General of Artillery, the Chief of the Corps of Engineers, and—to represent the Minister of War—the Director of the General Department of War.

Besides the Defence Commission, an Engineer Committee will be formed directly under the Inspector-General. The duties of this Committee will be:—

(*a*). To draw up all general projects for new fortifications, and to examine into all detailed plans relating either to new works or to essential alterations in those already existing.

(*b*). To settle the pattern of all the *matériel* and implements of the Pioneer Battalion required for field bridging, field telegraphy, etc.

(*c*). To work out the regulations and field service instructions for the Engineer and Pioneer Services.

(*d*). To carry out scientific and practical trials in technical matters affecting the Engineers and Pioneers, and to see to the introduction of technical improvements into the service.

(*e*). To keep up to date information concerning foreign fortifications, both in regard to their military organization and the purposes they are intended to fulfil, as well as in regard to the application of new technical ideas in foreign countries.

This Engineer Committee is under the presidency of the Inspector-General of the Corps of Engineers and Fortifications, and consists of the four Inspectors of Engineers, who are all stationed in Berlin for this purpose, the Inspector of the fourth fortification district, and of two Staff officers specially appointed as members.

Eight Captains and First Lieutenants are also attached to it as assistants for secretariat and record work.

It is only as a member of the Engineer Committee that the examination and criticism of designs forms part of the duties of an Engineer Inspector.

To give effect to the foregoing, the establishment of the Corps of

Engineers had to be correspondingly increased. The altered organization and the new establishment were approved by the War Office on the 29th December, 1867.

On the same date the War Office issued the preliminary orders with regard to the relations of the Engineer Committee to the War Office, to the Inspector-General of Fortifications and Corps of Engineers, and to the lesser Engineer authorities. They were in the main as follows:—

1. All the work of the Engineer Committee will go to it through the Inspector-General of the Corps of Engineers, either on his own initiative or by direction of the War Office (General Department of War); similarly, the Engineer Committee will address all suggestions to the Inspector-General, who will then send the suggestions, reports, proceedings, etc., accompanied by his own opinion, to the War Office. If explanations and further details of the matters under consideration are required, the Engineer Committee can call for them directly from the lower authorities concerned.

2. If local examination is requisite for the consideration or preparation of fortification projects, War Office authority to undertake it must be obtained. If under special circumstances it is advisable to hold the meetings of the Engineer Committee in the place under consideration, the local Engineer officer and the Fortress Inspector concerned should attend, but only to advise, and not to have any voice as regards the decision.

3. Proposals for carrying out new works or alterations, which are usually submitted to the General Department of War in the annual report of the Fortress Inspector, are passed to the Engineer Committee if they involve a substantial change in existing fortifications, or if an examination of the subject appears necessary or desirable.

4. If it is a matter concerning the application of works to a locality where no Engineer officer is yet stationed, or if it is judged advisable that the initiative with regard to the drawing up of a defence project should come from the Engineer Committee, at the instance of the War Office, the Committee must itself undertake the preparation of the general plan, together with the estimates; or it must give such detailed directions as will enable the officer appointed for the purpose to prepare the designs locally.

5. If the Engineer Committee consider a project submitted to them unsuitable for execution, they are not to content themselves with mere criticism, but must alter it, or make an entirely new

project, so that the complete elaboration, etc., can be carried out without delay.

6. If the preliminary plans are approved, the Engineer Committee will receive notice of the approval of the estimate through the Inspector-General.

7. The general projects for defence armament, before being decided upon, must also be laid before the Engineer Committee for examination and alteration, if necessary.

8. All general decisions with regard to fortification details and constructions are to be examined or elaborated by the Engineer Committee before they are issued in the name of the War Office (General Department of War). This also applies to the laying down of general principles for the treatment of fortification and armament projects, regulations, field service instructions, administration arrangements, etc.

9. All changes in military bridging *matériel*, as well as in the organization of bridging trains, must be submitted for trial by the Engineer Committee before they are adopted by the Headquarter authorities or the War Office. This also applies to the regulations concerning the Pioneer Service, which have to be approved by Headquarters. But it is left to the discretion of the Inspector-General of the Corps of Engineers whether to obtain the assistance of the Engineer Committee in matters relating to other technicalities of the Pioneer Service, and in general questions of scientific or technical engineering.

The members of the Engineer Committee were appointed by order of the Inspector-General, dated the 21st January, 1868, and they were directed to report in Berlin on the 1st February, 1868, and to commence their duties on that day.

The Engineer Committee has sat in Berlin since its first appointment.

In accordance with the principles laid down by the Inspector-General in the order of the 1st February, 1868, for the working of the Engineer Committee, it was divided into four divisions, called the 1st, 2nd, 3rd and 4th Divisions, consisting of members and assistants under the sub-presidency of the Inspectors of the 1st, 2nd, 3rd or 4th Engineer Districts. As regards actual constructions, the work of the divisions was distributed as follows :—

Division 1.—Fortification projects, etc., for the districts of the 1st and 2nd Fortress Inspections.

Division 2.—The same for those of the 3rd and 4th Fortress Inspections.

Division 3.—The same for those of the 5th and 6th Fortress Inspections.

Division 4.—The same for those of the 7th and 8th Fortress Inspections.

As regards organization, regulations, etc., the work was distributed thus :—

Division 1.—General questions relating to building technicalities, particularly earthworks, masonry, and carpentering. Details of all branches of these subjects. Study of progress and improvements in civil engineering. Type designs, based on experiments, of casemates of all descriptions, permanent mining galleries, magazines and shelters, fortress bridges, lightning conductors, etc.

Division 2.—Ironwork, especially in its application to armour-plates, cupolas, and bomb-proof cover. Study of foreign experiments and publications on this subject. Type designs based on experiments.

Division 3.—Manufacture and preparation of all *matériel* and tools for general Pioneer Service, for sappers and miners, for siege trains, field telegraph detachments, field railway detachments; also torpedoes. Study of scientific and technical progress bearing on this branch of the service, as well as of experience and improvements in foreign armies, and the introduction of such improvements into the German army. Regulations and instructions as regards this branch of the service.

Division 4.—Construction of all field-bridging *matériel* and organization of bridging trains. Study of organization and *matériel* of foreign States. Regulations and orders relating to this branch of the service. Study of foreign fortifications as regards the purposes they are intended to fulfil and their interior organization. Study of publications relating thereto. Collection and arrangement of the materials thus acquired. Preparation of plans of foreign fortresses. Editing such proceedings of the Engineer Committee as it may be decided to publish. Publication of technical instructions.

The office staff consisted of :—

1 Non-commissioned officer for registration.

4 N.C.O.'s as clerks.

4 N.C.O.'s as draughtsmen.

2 orderlies were also in attendance.

By command of Lieutenant-General von Kameke, Inspector-

General of the Corps of Engineers, the first general meeting of the Committee was held on Friday, March 27th.

Collaboration with the Artillery Proof Commission.

In accordance with an order of the General Department of War, of the 27th May, 1868, the collaboration between the Engineer Committee and the Artillery Proof Commission was regulated as follows:—

1. All the agenda of the Artillery Proof Commission will be communicated by them to the Inspector-General of the Corps of Engineers and to the Engineer Committee, so that the latter may not only be up to date in general information concerning Artillery questions, but should also have the opportunity of sending an officer to attend the meetings at which important Artillery subjects connected with fortification are discussed. The same procedure will be followed with regard to the programme for firing trials, at which the resisting power of targets, the construction of platforms for guns, etc., are to be considered, so that officers whose work may be affected thereby may attend the trials.

2. In the same way the Engineer Committee will send the agenda of their meetings to the Inspector-General of Artillery and the Artillery Proof Commission.

3. The Artillery Proof Commission will appoint one of their members as Artillery Adviser to the Engineer Committee; he will attend those meetings at which the President considers Artillery co-operation desirable; those members of the Committee whose duty it is to investigate Artillery questions connected with fortification can obtain from him the necessary Artillery opinion.

4. Should the Artillery Proof Commission require technical Engineer assistance in any matter, an officer of the Engineer Committee will attend the Artillery Proof Commission at their request.

5. The respective representatives of the Artillery Proof Commission and the Engineer Committee have no vote at the meetings which they attend in this capacity.

6. The programmes for firing trials against targets, the designs for which have emanated from the Engineer Committee, will be drawn up with the co-operation of the Artillery Adviser.

In the instructions issued in the year 1889 for the Artillery Proof Commission, the above arrangements were adopted, with the addition of a seventh paragraph to the effect that:—Should the Artillery Proof Commission be required to express an opinion in conjunction with the Engineer Committee, it is specially to be mentioned in the opinion that the wishes of the Engineer Committee have been acceded to, or the reasons why they have been departed from.

Administration of the Funds of the Engineer Committee.

By an order of the General Department of War, dated March 7th, 1870, a separate Administration was appointed from the 1st April, 1870, to take over the management of the funds assigned for the experiments of the Engineer Committee. This Administration consisted of :—

1. The senior member of the Engineer Committee not holding the rank of Inspector, who officiated as Treasurer.
2. The office superintendent of the Engineer Committee as second member of the Administration.
3. The registrar of the Engineer Committee as accountant; for this purpose he was struck off the strength of his regiment, and appointed assistant at the Fortification Office.

The four Inspectors of Fortification checked the expenditure as regards technical *matériel*, and the pay department of the 3rd Army Corps as regards calculation. It was finally checked in the Accounts Office of the North German Alliance.

The regulations of the 10th December, 1863, as regards expenditure on fortifications, with certain alterations ordered by the Ministry of War, were adopted for the administration of the funds of the Engineer Committee.

Suspension of Operations Owing to the War of 1870–71.

The memorable order of the Cabinet of the 15th July, 1870, for the mobilization of the Army, suspended the action of the Engineer Committee, as well as that of other military departments and institutions. On the 19th July, 1870, the War Office decreed the dissolution of the Engineer Committee during the continuance of the state of mobilization.

The officers were placed at the disposal of the Inspector-General of the Corps of Engineers for other services, and started on the 16th July, 1870, in their new capacity, to take part, with few exceptions, in the glorious battles and sieges of the army in the field.

Before the dissolution of the Engineer Committee all current business was, as far as possible, hastily completed; the incompleted business remained in custody of the office.

The office and records, particularly those drawings and plans, etc., of foreign fortifications belonging to Division 4, were guarded at the Inspector-General's Office by an officer who, at the same time, fulfilled the duties of Treasurer to the Engineer Committee.

But the principal work of this officer was to elaborate the plans and memoranda about French fortifications necessary for the war. For this work the office staff remained, and during the whole war the work was carried on continuously by different officers.

By an order of the Inspector-General of the 12th March, 1871, the archives of the Engineer Committee were temporarily taken over by an officer who had returned to Berlin from the staff of the Engineer-in-Chief for the south attack on Paris. In order that the work of the Engineer Committee might be resumed, at any rate on a limited scale, it was re-established on the 6th April by a decree of the same authority to the extent of *one* division, a divisional president and five officers being appointed.

The Engineer Committee was able to resume its complete duties on the 25th April, 1871, and for this purpose the re-formation of the three other divisions was decreed, the division presidents being appointed, and the staff of officers detailed.

One of the principle duties of the Engineer Committee at that time was the disposal of the *matériel* from the French fortresses.

On the 7th July, 1871, it was again decreed that the Engineer Committee should consist of four divisions, the divisional presidents being appointed, and the staff of officers detailed. All those officers belonging to the Engineer Committee who had gone to the war were decorated—Major Schumann with the Iron Cross, 1st Class; Captains Wagner, May, Olten, and 1st Lieutenant Wagner with the Iron Cross, 2nd Class.

Change of Organization.

By a Cabinet order of the 13th March, 1873, a different organization of the Corps of Engineers was approved, involving also an alteration in the organization of the Engineer Committee. The part of the order affecting the Engineer Committee is as follows:—

"The Engineer Committee, which was established at the same time as the Defence Commission, on the 23rd December, 1867, will continue to exist, and, as before, be under the direct control of the

Inspector-General. It will be divided into two divisions of two sections each.

"A Major-General or a Lieutenant-General, with the rank and authority of an Inspector of Engineers, will be at the head of the Committee as President. Each division will have at its head a Colonel or Lieutenant-Colonel with the rank and authority of a Fortress Inspector.

"The Chief of the Division will superintend one section, and a Staff Officer, under his control, the other section."

In addition, six Captains and three First Lieutenants were appointed to the Committee as assistants.

The Engineer Committee consisted, therefore, of one General, two Colonels, two Staff Officers, six Captains, and three First Lieutenants.

The regulations for the Engineer Committee remained the same as those laid down by the Cabinet order of the 23rd December, 1867.

As an addendum to the Cabinet order of March 13th, 1873, an order of the Inspector-General was published on the 21st April, 1873, by which the officers of the Engineer Committee were to continue on the establishment of the Corps; the Staff officers were still to belong to the Staff of the Corps of Engineers, and the Captains and First Lieutenants to the different Engineer Inspections. They were to be regarded, however, as seconded and under the command of the President and the Chief of the Division only.

The new organization took effect from the 1st May, 1873.

On the 23rd May, 1873, the Inspector-General agreed to a newly-elaborated method of procedure consequent on the altered organization of the Engineer Committee.

SECTION FOR FOREIGN FORTIFICATIONS.

On the 22nd August, 1874, the General Department of War ordered the organization of an Intelligence and Plan Department for Foreign Fortifications, the work of which had been previously done by the Engineer Committee, and also arranged for a Section for Foreign Fortifications in the Engineer Committee. The latter was to consist of:—A Staff officer or senior Captain as chief, one or two Engineer officers, one Artillery officer, and, if necessary, an officer of the General Staff.

The President of the Engineer Committee chose the chief from among its members, and told off the two Engineer officers to the Section for Foreign Fortifications.

By order of the General Department of War, of the 8th December, 1874, the co-operation of an Artillery officer was decreed, and by order of the Headquarters Staff, dated the 4th January, 1875, and of the Inspector-General of the Corps of Engineers, dated the 7th January, 1875, direct communication between the 3rd Division of the Headquarters Staff and the Chief of the Section for Foreign Fortifications was approved.

Administration of Depôt and Funds.

By a Cabinet order of the 20th October, 1874, the introduction of a special administration of depôt and funds for the Engineer Committee was approved. It came into force on the 1st January under the title of "Administration of Depôt and Funds of the Engineer Committee." It possessed its own seal, and its duties were :—

To receive or to obtain those articles necessary for the experiments of the Engineer Committee and to take charge of them ; to look after the keeping in repair of the buildings of the Engineer service, etc. ; and also to make payments for the Engineer Committee.

The administration was placed under the special superintendence of the chief of one of the two divisions, with ultimate reference to the President.

In the administration of depôt and funds, which was to rank as that of a fortress, the Division Chief was to take the position of a Fortress Inspector, whilst the superintendent of the depôt was to assume the duties and privileges of a Fortress Engineer officer.

Organization and Distribution of Duties of the Engineer Committee of 1875.

The organization of the *personnel* of the Engineer Committee was settled as follows, in accordance with the procedure regulations issued on the 9th April, 1875 :—

As President at the head of the Engineer Committee, a Major-General or Lieutenant-General with the rank and authority of an Inspector of Engineers.

At the head of each of the two divisions into which the Engineer Committee is divided, a Colonel or Lieutenant-Colonel as Division Chief, with the rank and authority of a Fortress Inspector.

Besides these, the Engineer Committee consisted of two Staff officers, six Captains, and three First Lieutenants. In the regulations one of the two Staff officers or a senior Captain was to officiate as Superintendent of the Section for Foreign Fortifications, to which also two officers of the Engineer Committee, besides an officer of the Headquarters Staff and an Artillery officer, were told off.

One of the officers was to be Adjutant to the President, and act as office superintendent and manager of the Administration of Depôt and Funds.

The superintendence of all business and its distribution between the sections was in the hands of the President. In his absence his place was taken by the senior Division Chief.

The Division Chiefs superintended the work assigned them by the President. The work was arranged as follows :—

Division I.—Projects for the fortifications of the first and second Engineer Inspections, with the exception of the Coast Defences.

Special designs of permanent and provisionary works in inland fortifications.

General decisions as regards earthworks, masonry, and carpentry.

Organization of Engineer siege and bridging trains, as well as questions relating to the field equipment of the Pioneers and field telegraph *matériel*.

Rules and regulations concerning the Pioneer Service.

Torpedo service as far as concerns the Corps of Engineers.

Division II.—Projects for the fortifications of the 3rd and 4th Engineer Inspections, and also for the coast defences of the North and Baltic Seas.

Typical designs for coast defences.

Projects for iron constructions and the technical details regarding the application of iron in fortifications.

The consideration of inventions dealing with aerial navigation.

The divisions were further to study the literature dealing with their special technical subjects, and the dispositions with regard to them in foreign armies.

By direction of the President, the divisions furnished an account of their proceedings for insertion in the "Report" published by the Engineer Committee for the use of officers of the Engineers.

The President was responsible for the publication of the "Proceedings."

Special duties were assigned to the *Section for Foreign Fortifications.*

The particular duties of the Adjutant were :—

The charge of all records, drawings, plans, models, as well as the works in the press which do not belong to Division III., the direction of subordinate clerks, draughtsmen, and orderlies.

In all current correspondence, as well as in communications with the Corps to which the clerks, etc., belong, he signed for the President. The Adjutant officiated as Secretary at the meetings.

Change of Name of the Section for Foreign Fortifications.

By order of the General Department of War of the 29th of November, 1875, the name "Section for Foreign Fortifications" was altered into "Section IV."*

Torpedoes and Submarine Mining.

Originally the Engineer Committee only took part in the work of the Torpedo Division, which was established by an order of the Cabinet of the 21st September, 1871, in so far as they were called upon to give opinions concerning submarine mine-fields. When, however, this division was dissolved by an order of the Cabinet of the 25th March, 1873, the Engineer Committee became intimately connected with the whole torpedo question. It may be here remarked that at that time a submarine mine was included in the term torpedo.

A Commission for torpedo experiments and trials, under direction of the Admiralty, was created by the same order. It consisted of officers of the Navy and Engineers, the latter being chosen from among the officers of the Engineer Committee.

The duty of this Commission was to perfect torpedo *matériel*, to undertake experiments, and to practise the laying down of torpedo defences.

Additional officers and non-commissioned officers from the Engineer and Pioneer Corps were attached to the Commission for these experiments, so as to enable the officers of Engineers and Garrison Pioneer detachments of coast places to render efficient co-operation in torpedo defence.

When the Engineer officers were not required in connection with these subjects, they worked in other branches of the Engineer Committee.

* It was presumably placed in Division II., and the organization of each Division into two sections, in accordance with the arrangements of March 13th, 1873, reverted to.

The mixed Commission existed only till the commencement of the year 1878, as an order of the Cabinet of the 28th February of that year decreed that the laying of submarine mine obstructions in those ports under the administration of the War Office should be taken over by the Pioneers.

The Commission for torpedo experiments and trials was, therefore, dissolved. Submarine mining, as far as it was dealt with by the land forces, was placed under the Inspector-General of the Corps of Engineers, and a special commission, consisting of a Staff officer and two Captains, was formed to deal with the subject within the Engineer Committee.

Its function was the continuous development of submarine mining.

The practical training of Pioneers in submarine mining was to take place yearly at certain places on the coast.

Besides the officers of the Engineer Committee, these practices were attended by the number of Pioneer officers, non-commissioned officers and men required for laying out the mines, besides some foremen. Also the Engineer officers of the district were, when possible, to attend the practices.

The members of the Commission belonged to Division II. of the Engineer Committee.

The Commission was thus directly under control of the Chief of Division II., and the officers were, as formerly, employed on other work of the Committee at the discretion of the Division Chief.

The Pioneer Battalions, Nos. 1, 2, 9, and 10, especially the 3rd Companies, were told off to attend the yearly submarine mining practices. The result of this was, however, that in peace, as well as in case of mobilization, the battalions concerned were much impeded and interrupted in their other training. It was, therefore, much in the interest of the battalions when, on the 21st November, 1883, the Admiralty announced that it was in a position, both as regarded *matériel* and *personnel*, to take over gradually the submarine protection of Prussian coast defences.

The Admiralty, however, was only able to do this by degrees, as men for laying and maintaining the submarine mines became available. Pillau, Neufahrwasser, and Swinemünde, and the defences of the Weser, were the first to be taken over by the Navy on the 1st April, 1887. On the 1st April, 1888, the defences of the Elbe were taken over.

At present the Pioneers only have charge of the submarine mining at one place, and since 1889 the Engineer Committee has had nothing to do with it.

Appointment to the Technical College.

It was recognized at Headquarters that it was only possible, for the direction of the Engineer and Pioneer Corps, to give to individual officers an extended theoretical training in those technical branches which are subject to essential periodical alterations.

By an order of the General Department of War of the 9th July, 1879, it was arranged that two officers should yearly be ordered to the Technical College, a favour which had been accorded to the Artillery since the year 1871.

The conditions of the Corps of Engineers, however, made it desirable that only one officer yearly should be so ordered, and so up to the present time it has only twice happened that four officers have been at the College together. To make up for this deficiency on the part of the Corps of Engineers, the War Office considered the appointment to the College of an officer of the railway regiment, and six officers of this regiment have already visited the Technical College, so that up to date 22 Engineer officers have enjoyed the privilege of thus extending their technical knowledge.

When attending the College, the officers were directed to devote themselves principally to constructive engineering, but also to attend such lectures and practices as might directly or indirectly be useful for military purposes, such as mathematics, physics, chemistry, electricity, etc.

The officers concerned are borne on the establishments of the different Engineer Inspections and attached to the Engineer Committee.

The direction of all matters concerning the studies, and particularly the arrangement of the course of study, is in the hands of the President of the Engineer Committee. The officers are also under him as regards discipline and leave. The President, on his part, selects a Division Chief to whom the appointed officers have to refer all personal and official questions.

The President of the Engineer Committee, as a rule, assigns yearly a difficult problem to be worked out by the appointed Engineer officers, partly in order to be able to judge their scientific progress, partly for the furtherance of technical questions that may be under consideration.

During the vacation, that is between the summer and winter courses, in the months of August and September, till a short time ago, the officers, with few exceptions, were ordered to different regiments, mostly to Garrison Artillery and Pioneer Battalions. During the last year it has, however, been decided to employ the officers after the first year's course on the Engineer Committee; after the second course to appoint them to a Pioneer Battalion of the Guards, or, in exceptional cases, to another corps; and after the third, to give leave of a suitable length for a journey to study, for the expenses of which, however, no allowance is given.

Hitherto, three officers have been permitted, during the vacation, to make journeys to England for purposes of study, for which facilities have been given by the Inspector-General of the Corps of Engineers and Pioneers.

Explosives Commission.

The arrangement, which lasted till the year 1880, by which questions concerning explosives were dealt with by three different bodies, the Artillery Proof Commission, the Engineer Committee, and the Railway Regiment, without their being permanently in communication with each other, had many disadvantages.

Each department, in pursuit of its own purposes, was not able to make full use of the experience already gained by the other departments to the extent that was desirable, so that it became imperative to commit the settling of such questions to one branch.

Accordingly, on the 24th May, 1880, the War Office decided as follows:—

In order to facilitate the solution of special questions relating to military explosives, a Commission placed for administrative purposes under the Engineer Committee was formed of specially-named officers of the Artillery Proof Commission, the Railway Regiment, and the Engineer Committee, under the presidency of the Chief of Division I. of the last-named body.

It had to keep in view the whole subject of explosives in its scientific as well as technical bearings, to study and collate all proposals and experiments, theoretical and practical, as well as to consider their application to military purposes.

The choice of means to effect this purpose was substantially left to the Commission, and it was merely indicated to them that besides studying home and foreign literature bearing on the subject, the proceedings of the Patent Office should be followed, and under certain circumstances the advice should be asked of authorities in the explosives trade, Professors of the Technical College, the Artillery and Engineering College, and the University, and of leading manufacturers.

The Commission itself has to conduct but few experiments, but must keep itself well informed of those taking place which bear upon its investigations, and attend those of general interest so far as these are not directed towards special issues. It should suggest reference of any question that may arise to the special department concerned for the carrying out of experiments.

The Commission is yearly allowed a sum not exceeding 1,000 marks to defray the expenses of journals and pamphlets of technical chemistry, of obtaining the opinions of technical and scientific authorities, of trials carried out by the latter for the Commission, and of journeys to view technical laboratories, chemical manufactories, and similar institutions.

The officers appointed to the Commission, one each from the respective departments, are chosen by their commanding officers, viz., the President of the Engineer Committee, the President of the Artillery Proof Commission, and the officer commanding the Railway Regiment.

Communication with the Audit Department.

By an order of the General Department of War, dated the 14th October, 1881, and with the concurrence of the Inspector-General, dated the 20th October, 1881, the President of the Engineer Committee was empowered to send all final contracts for the supplies and work of the Engineer Committee direct to the legal adviser of the Inspector-General for examination—each communication to be signed "By order of the Inspector-General of the Corps of Engineers and of Fortifications."

Admission of the Bavarian Member of the "Reichs Rayon" Commission to the General Meetings of the Engineer Committee.

On the 11th April, 1882, the General Department of War ordered that the Bavarian member of the Imperial Rayon Commission should be informed by the Engineer Committee as to subjects under discussion relating to engineering, and should attend such general sittings of the Engineer Committee as the President of the latter should in each individual case determine.

Special Commission to Discuss the Question of Lightning Conductors.

The War Office having communicated with the office of the Chaplains', Education and Medical Departments, on the 20th December, 1883, ordered that a Special Commission to consider the question of lightning conductors should meet on the 14th January, 1884.

The Commission consists at present of the following specialists:—

Chief Councillor Professor Dr. v. Helmholtz, Professor Dr. Neesen, Dr. Aron and Dr. Holtz, and of a Division Chief, a member of the Engineer Committee, and two officers of the Artillery Proof Commission, under the Presidency of the Division Chief, to whom also is intrusted the procedure of the Committee.

Till recently the late Privy Councillor Dr. W. v. Siemens also belonged to the Commission.

In consideration of the rank of the specialists belonging to the Commission, the President of the Engineer Committee has now temporarily taken over the Presidency of the Special Commission.

Quorum.

By an order of the Cabinet of the 3rd August, 1885, a different organization of Engineers was decreed. It affected the Engineer Committee only in so far that the President and the Staff officers alone became necessary to form a quorum, and that the Chief of the Corps of Engineers and Pioneers was authorized to appoint to it other Generals or Staff officers in special cases.

The appointment of permanent members of the Engineer Committee was now made by order of the Cabinet.

Change of Name of Section IV.

By order of the War Office, dated the 12th December, 1885, it was enacted that Section IV. of the Engineer Committee should be under the direct control of the President, with one Staff officer as director, and should in future be known as Division III. of the Engineer Committee.

School of Fortification.

In order to give the fortification officers opportunity to devote themselves more to the study of the military side of fortification and the development of other branches of their varied employment in war, it was taken into consideration to relieve them of the superintendence of such works as did not directly serve the defence of fortresses. To assist in this superintendence, an order of the Cabinet, dated the 3rd August, 1885, decreed a new organization of the fortification *personnel* and the establishment of a School of Fortification.

This alteration had for its object the creation of a specially efficient *personnel* for the building of fortifications, and an extension of the powers of the former secretaries of Fortress Inspections or fortification secretaries, and office assistants (now chief surveyors of fortification or surveyors of fortifications of the 1st or 2nd class), so that these could assist in the actual building of fortifications, and could independently conduct the works of lesser importance, such as maintenance of government dwellings, repairs to works, etc., and thus partly take the place as local officers of the officers of Engineers.

The School of Fortification was to prepare the candidates for appointments on the fortification *personnel* for their duties, in the same manner as the Artillery officers are prepared at the Firemasters' School.

In order to effect the purpose as soon as possible, and also so as to enable the subordinates of the fortification *personnel*, as far as they were fitted, to have a share in the advantages which were contemplated for the fortress *personnel*, three abridged courses were arranged, to which were summoned such fortification office assistants and surveyors as had declared themselves willing to attend the School of Fortification, and were considered by their superiors to be fitted for it.

By order of the War Office, dated the 26th May, 1886, the School of Fortification was placed under the direction of the President of the Engineer Committee in all matters relating to the service and official business. An Engineer Inspector was assigned to him by order of the Cabinet of the 26th June, 1886, with powers of punishment and granting leave. The School of Fortification is subject to the Inspector-General of the Corps of Engineers and of Fortifications.

Otherwise, the School is an independent institution, under the management of a Staff officer of Engineers as Director; it occupies the former barracks of the Rifles of the Guard.

Appointment of a Bavarian Engineer Officer to the Engineer Committee.

A decree of the General Department of War, dated the 11th August, 1889, promulgated an agreement with the Royal Bavarian War Office by which a Bavarian Engineer officer (Captain or Staff officer) was to be appointed to the Engineer Committee from the 1st October, 1889, to maintain the connection between the Bavarian Corps of Engineers and the Engineer and Pioneer Service of the Royal Prussian Army.

The officer enters the Engineer Committee as a member, and is attached to one division, but is given the opportunity of gaining information in the others.

The appointment is not to be for less than two years, and may be extended, if circumstances should make it appear desirable.

Separation of Division III.

By an order of the Cabinet, dated the 19th December, 1889, published by decree of the War Office of the 21st February, 1890, it was enacted that the existing Division III. of the Engineer Committee should cease to exist, and that its duties should henceforward be undertaken by the Headquarter Staff.

The Superintendent of the former Division III. of the Engineer Committee, as well as the two officers belonging to it as members and the officer appointed to it from the Garrison Artillery, were, therefore, transferred to the new Division IV. of the General Staff.

After the conversion of Division III., the Secretary of the 4th Fortress Inspection was assigned to the Chief of Division I. as assistant accountant in place of the Secretary of Division III. of the Engineer Committee.

The subordinate officials of the former Division III. of the Engineer Committee—one registrar, one clerk, one lithographer, three draughtsmen, and one printer with the printing apparatus—were placed at the disposal and on the strength of the General Staff.

With reference to the foregoing, the General Department of War, on the 7th February, 1891, published an extract from Chapter 39 of the Establishment for 1891–92, by which the former number of the Engineer Committee was reduced by three (from 14 to 11).

The Establishment of the Engineer Committee since the 1st April, 1891, has consisted, therefore, of :—

1 General.
2 Staff officers, with the rank of regiment commanders.
1 Staff officer.
7 Captains.

The office *personnel* consists of :—

2 Office Superintendents.
1 Surveyor.
5 Non-Commissioned officers as clerks.
4 Non-Commissioned officers as draughtsmen.
3 Orderlies.
2 Civilian draughtsmen.

Personal Details.

It appears from the special list that a total number of 143 officers have served on the Engineer Committee up to date, viz. :—

129 appointed once	= 129
12 appointed twice	= 24
1 appointed three times	= 3
1 appointed four times	= 4
143	= 160

25 officers have since died.
42 ,, ,, retired.
76 ,, are still on the list.

The appointments to the Engineer Committee have been of very varied duration. The average has been about three years.

II.—WORK OF THE ENGINEER COMMITTEE.

It is not the intention of this pamphlet, nor would it indeed be practicable, to set forth all the work undertaken by the Engineer Committee since it first came into existence.

The following is, therefore, only a brief enumeration of the principal services performed.

In accordance with the distribution of work provided for in the procedure, the action of the Engineer Committee has included the following services:—

FORTIFICATION.

The general projects for the new forts at Königsberg, Pillau, Thorn, Posen, Küstrin, Strassburg, Metz, Mayence and Cologne.

The improvements in gunnery arising from the invention of new means of propulsion and explosives led to the necessity of strengthening, and in some cases modifying, the fortifications to resist these means of destruction. All experiments connected with the subject were carried out by the Engineer Committee in conjunction with the Artillery Proof Commission, and on the basis of these experiments type designs for the alteration or strengthening of existing defences, and for new fortifications, were drawn out.

Instructions for the fortification of the field of battle and designs for shelters were published, as well as types of works for the intervals in provisional and permanent fortification, and also for armoured and coast batteries with splinter-proof shelters.

Instructions for earth and masonry work, and the technical orders relating thereto, were newly drawn out on the basis of experiments.

The total number of technical instructions drawn up has amounted to 32, including 7 revisions.

Principles were aid down for working out fortification armament projects and armament programmes in the years 1869 and 1870, and the consideration of the fortress armaments and coast defences of the North and Baltic Seas was also undertaken.

ARMOUR-PLATES AND OTHER IRON STRUCTURES.

All questions concerning armour-plates were treated by the Engineer Committee.

The experiments were conducted by them in conjunction with the Artillery Proof Commission, and they have made the designs for all the armour-plated constructions that have as yet been erected.

In the year 1868, the first cast-iron shield was put up on the range at Tegel, from the design of Gruson. In 1869–70, firing trials took place.

In the year 1870, at the instance of the late Major Schumann, who took particular interest in the development of the armour-plate question, and whose services in this connection are appreciated by the Engineer Committee, experiments were made with a wrought-iron turret at the range at Tegel. They gave satisfactory results, and justified the Special Commission in recommending the employ ment of armour-plates on this system.

Further trials were made in 1873 and 1874 with a cast-iron turret for inland fortifications, and also with a cast-iron shield for a coast battery of 21-c.m. guns. As a result of these trials, the introduction of cast-iron shields in fortifications was ordered about the year 1875, and, under the direction of the Engineer Committee, the construction and erection of a number of armour-plated shields for inland and coast defences gradually followed.

In the year 1881–82, trials were made at the range at Cummersdorf with a shielded mounting, designed by Schumann, for a 15-c.m. gun, which led to the adoption of this system.

If the use of armour-plating in German defences had hitherto been comparatively limited. it was not owing to any want of appreciation of the efficiency of this means of defence, but because the rapid improvements in technical matters and the corresponding changes in ordnance made it wise not to be precipitate. This was very necessary in Germany, as money had to be economically expended.

Thanks to this restraint, the State has been saved much expense for constructions which have been quickly superseded by new discoveries.

Latterly the question of armour-plates has again occupied more attention, and experiments are now in progress to decide on the most suitable pattern of armour-plate for certain artillery purposes; experiments are also being carried out with fixed shielded mountings for machine guns.

A number of armour-plated turrets on the principle of the approved shielded mountings of Schumann have already been constructed and placed in some frontier fortresses.

In the years 1886–87 and 1888–89, designs were made for fixed bomb-proof and revolving splinter-proof armour-plated observing stations for look-outs. Shields of both descriptions have accordingly been erected in the larger fortifications, particularly a large number of the splinter-proof constructions in the year 1892.

Experiments were carried out and regulations compiled concerning sliding and drawing shutters for loopholes and observation holes, and for the protection of casemate windows with splinter-proof shutters and sandbag screens.

Units of bomb-proof shelter and splinter-proof sheet-iron cover for provisional fortification were constructed, and their application to certain works projected for time of war arranged for; instructions were issued as regards their erectio

Contracts were entered into by the Engineer Committee for the various above-mentioned experimental constructions, as well as for the supply of all descriptions of iron shields which it was decided, as a result of the experiments, to erect in fortresses. The various articles supplied were inspected and taken over.

The details of the construction of sheet-iron arched hutments were further developed, as a result of this subject being handed over to the Engineer Committee.

Firing Trials.

The Engineer Committee has always co-operated in all trials of the Artillery Proof Commission which dealt with Engineer technical details, such as firing trials at iron plates of the former bomb-proof pattern with 3·7-c.m. revolving guns and 8-c.m. flanking guns in caponiers, trials from and against masonry parapets, and trials to test efficiency of breastworks, earth-cover, bomb-proof casemates, tiers of fire, parados, etc.

The erection of the different constructions to be tried and of various other targets on the ranges at Cummersdorf and Jüterbog was, and still is, in the hands of the Engineer Committee.

Engineer Parks.

For many years the Engineer Committee has been occupied with the organization of Engineer Parks.

Only one Engineer siege train existed till the year 1877, and that had become much disorganized after the war. As at that time the Artillery possessed two complete siege trains in readiness, it was considered necessary to organize two Engineer siege trains. This was effected towards the end of 1878.

Both trains were organized after the same plan in a manner that each one complete possessed the appliances for the siege of a large fortress, whilst a further division of each into three sections made it possible to detach any third part as a small Engineer siege train for the attack of a small fortress. Each of these sections, again, was divided into a first and second part; the first was made more transportable by the addition of vehicles, and was furnished with implements for the first investment. The rest of the implements for carrying out a regular siege formed the second part, and were carried to the front from the terminal station on the railway by means of such conveyances as could be collected on the spot.

This division of the Engineer siege *matériel* could no longer be maintained when the necessity arose for keeping one part available for special purposes on the outbreak of war, and for making it mobile. Special Engineer siege trains, which were organized partly from the former complete trains, and partly from new creations, were then formed, the remainder of the stores available from the former system being combined together in one big Engineer siege train.

All projects for new organizations which were from time to time required, the re-modelling of existing trains with a view to their assimilation to each other, the distribution of the requisite new *matériel*, the ordering and in part the receipt of articles, the working up of equipment orders and regulations for these trains, were in the hands of the Engineer Committee. A new decision will probably soon be arrived at concerning them.

Torpedoes and Submarine Mining.

Till the taking over of submarine mining by the Navy, part of the work of the Torpedo Trial and Proof Commission, or the Submarine Mining Commission, was in charge of a few members of the Engineer Committee. Their duties were the progressive development of submarine mining, the examination of all important inventions and new ideas on that subject, the elaboration or revision of orders and instructions, the elaboration and perfection of designs for obstructions, the keeping up to date of the charts concerned as far as they affected these designs, and, finally, the inspection of the *matériel* for submarine mine-fields.

Explosives.

In accordance with the general instructions to the Engineer Committee, it dealt for a considerable time with all the more important questions of explosives as far as they bear upon the duties of the Pioneers, and in particular the Committee took an active part in the great alterations caused by the introduction of high explosives. Not only did the arrangement of, and participation in, the practical experiments bearing on the subject fall to their share, but also the working out of the necessary new instructions, and, during the first few years, also the acquisition of explosive *matériel* (guncotton) from private factories.

Since the year 1880, a part of this work, hitherto done by the Committee alone, has devolved on the Special Explosive Commission.

Quite recently, the trials preliminary to the introduction of the new ammunition C/88 have taken place with the co-operation of this Commission.

It is further a part of the duties of the Engineer Committee in connection with explosives to make or examine the projects for the placing of permanent mines in important railway and road bridges, tunnels, etc., and to lay down the principles governing such matters. The number of decisions that have been arrived at on this subject (about 200), and a compilation by the Committee of all mining designs of the sort, show the activity which the Engineer Committee have for many years exercised in this department.

Since the year 1868 the experiments with the Siemens dynamo-electric mine-firing apparatus have been carried out by the Committee.

In the year 1872 this apparatus was definitely introduced into the field equipment of the Pioneers. It was obtained by the Engineer Committee, and the instructions for the use of the apparatus and the fuze belonging to it were drawn up. Since 1889 the Engineer Committee took part in the consideration of the introduction of the fuze *n*/A.

Latterly, experiments have been carried out with a low tension fuze in conjunction with the Pioneer Battalion of the Guards.

Regulations and Instructions.

The following works have been edited, some of them in several editions, by the Engineer Committee :—

"Handbook for Pioneers."

"Regulations for Pontooning and for Sappers and Miners."

All Instructions and Equipment Orders for the different Pioneer Corps.

The preparation or alteration of the official drawings of train *matériel* for Pioneers devolves on the Committee, in conjunction with the Artillery Construction Office. It has also co-operated in the compilation of instructions for the attack and defence of fortresses to the extent of carefully examining the drawings prepared for these instructions.

Lightning Conductors.

As early as the year 1868 the General Department of War ordered the compilation of instructions for the practical application of lightning conductors.

Accordingly, in the year 1869 appeared technical Order V. concerning the fixing, and in the year 1875, after detailed trials, technical Order XXII. concerning the testing, of lightning conductors. The conclusions that had been arrived at from a consideration of numerous cases of buildings that had been struck by lightning, were, however, contradicted by the physicist, Dr. Holz, in his pamphlet which appeared in the year 1879. Consequently it was necessary to revise both instructions a few years later.

This gave rise to the new technical Order V., which, in continuation of the two previously-mentioned instructions, dealt both with the fixing and testing of lightning conductors.

Accidents by lightning to covered powder magazines at Reisse and Strassburg in the year 1882 led to new discussions concerning the most practical method of applying lightning conductors, and on the settlement of this question, in the year 1884, there was formed the special Commission already mentioned in the first part of this pamphlet, consisting of specialists, and members of the Artillery Proof Commission and the Engineer Committee.

On the proposals of this Commission are based "Instructions (B 8) for the Fixing and Testing of Lightning Conductors upon Store Magazines," which appeared in the year 1890. These are at present undergoing a second revision, and the new instructions will embody the views and experiences which have been gained in the meantime.

Lighting.

Experiments with electric light were made by the Pioneer Battalion of the Guards as early as the year 1866. On the formation of the Engineer Committee the further development of the subject was transferred to them. The experiments carried out by a special Commission, partly in co-operation with the Artillery Proof Commission, embraced not only the electric light but also the so-called Drummond lime-light. They led to the introduction of an electric lighting apparatus, manufactured by Siemens' and Halske, into the Engineer siege train in the year 1878. In the following years this apparatus was perfected according to the latest technical improvements. The treatment of questions concerning electric lighting was transferred to the Inspector of Military Telegraphy in the year 1883.

The treatment of other means of illumination for the attack or defence of fortresses remained in the hands of the Engineer Committee, and for this purpose the following methods were from time to time tried, and some of them introduced :—

Moveable protected petroleum lamps for the illumination of fortification works and especially of trenches, lanterns for patrols, and rocket troughs (after the Very pattern) for the firing of magnesium rockets for signalling purposes or for illumination of the immediate foreground of a fort in a close attack. The introduction of the last-mentioned means of illumination on a larger scale may be expected after the success of the trials at last year's Mayence manœuvres.

Aerial Navigation.

In the year 1868 the Engineer Committee was commissioned to give an opinion on the design of a flying machine which had been received at the War Office.

The Inspector-General, on the 4th February, 1872, decreed that the further development of the balloon question, which had hitherto been in the hands of a single Engineer officer, should be dealt with in future by Section IV. of the Engineer Committee.

As a result of this, a large number of suggestions and inventions concerning flying machines of all sorts were sent to the Engineer Committee for trial, until a ballooning section was attached to the Railway Regiment by a Cabinet order of the 29th April, 1866.

Alarm Arrangements.

In the year 1887, at the instance of the Inspector-General, suggestions were received for the establishment of alarm arrangements in forts and intermediate works, and, with the consent of the War Office, such arrangements were experimentally carried out during the following years.

They consisted of electric bells, mechanical bell pulls, telephones, and speaking tubes. The introduction of contrivances which are at all complicated has been postponed for the present.

Section or Division for Foreign Fortifications.

It is, for obvious reasons, not possible to give a more detailed account of the extensive sphere of action of the former Section IV., subsequently Division III., of the Engineer Committee. But it may be mentioned here that during the war of 1870–1, the necessary plans and memoranda concerning the French fortifications proceeded from this division, and were worked out, drawn, and printed by it.

In this manner the Army received nearly 4,000 copies each of 39 memoranda, and 16,000 sheets of 84 general and detailed plans dealing with 54 French fortresses from Weissenburg to Paris, and from Cherbourg to Lyons.

Members of the Examination Commissions.

It remains to be emphasized that officers of the Committee were also members of the Examination Commission of the Corps of Engineers and Pioneers till its dissolution in the year 1892, and are members of the Examination Commission of the combined Artillery and Engineer School, and also of the Senior Military Examination Commission, and that, therefore, their time is much occupied by setting examination exercises and looking over completed work, as well as by lengthy journeys to the military schools.

Printing.

Besides the printing by the former Section III., which consisted exclusively of matters relating to its own proceedings since the year 1877, the following works have been printed by the Engineer Committee, which only has at its disposal one large and one small stone hand-press :—

One hundred and ninety sections and general plans of fortresses in 41,000 black and white sheets. The sections have, for the most part, been reproduced in colours, and this requires passing each copy through the press 15 or 16 times more than a black or white drawing.

Besides these, a large number of drawings have been printed, representing mining arrangements for bridges, dwelling arrangements of barracks, submarine mining stores, type designs for fortifications, examples of temporary intermediate works; also instructions, orders, and projects, supplements to technical instructions and information concerning foreign Engineer and Pioneer services, besides the many minor details required by the various Commissions, and the constant requirements for current business.

Administration of Funds.

The Administration of Funds, which has existed since 1870, has, up to date, expended about six million marks for trial constructions, armour-plates, signal stations, explosives and materials for the Engineer siege trains, etc.

TRANSLATOR'S NOTE.

The duties of the Royal Prussian Engineer Committee in Germany correspond in this country to those of the Royal Engineer Committee, the Royal Artillery and Royal Engineer Works Committee, and in part to those of the design and iron structures branches of the office of the Inspector-General of Fortifications. The work formerly done by the Prussian Committee with respect to Submarine Mining defences is in this country entrusted to the Submarine defences branch of the office of the Inspector-General of Fortifications, to the Royal Engineer Committee, and to a small extent to the War Office Torpedo Committee.

The *Royal Engineer Committee* was constituted entirely of Engineer Officers for the first time in 1865, about two years prior to the constitution on its present basis of the Royal Prussian Engineer Committee. Its work has been confined to the consideration of proposals respecting the improvement in patterns of Stores, Equipments and Material used by the Royal Engineers in military operations and appertaining exclusively or principally to that Corps.

The subjects dealt with are included under the following headings :—

Submarine Mining.
Telegraph Equipment.
R.E. Field and Siege Equipment.
Bridging.
Railways.
Electric Lighting.
Surveying Instruments.
Photographic and Lithographic Equipment.
Miscellaneous.

The Royal Engineer Committee do not deal with the application of the stores they select to special operations or individual schemes of defence. They have, however, prepared most of the designs and specifications for engineer stores for military operations that have been introduced into the service since the constitution of the Committee.

Originally the Committee consisted entirely of officers belonging to the establishment of the School of Military Engineering at Chatham. In 1871 a secretary, clerk, and draughtsman to be employed exclusively on their work were first appointed. From 1873 to 1876 there was also an assistant secretary. Various changes in the constitution and procedure of the Committee have been effected from time to time. It now consists of :—

The Commandant, School of Military Engineering	President.
The Deputy Inspector-General of Fortifications (*I.G.F.*). The Assistant Adjutant-General, R.E. The Inspector of Submarine Defences The five Instructors, School of Military Engineering The Inspecting Officer, R.E. Stores	Members.
The W.D. Chemist The O.C.'s 1st and 2nd Div. Telegraph Batn. The O.C. Bridging Battalion An Officer, Indian Store Department The Assistant Inspector of Submarine Defences.	Assistant Members.

An officer specially appointed as secretary.

The Committee receives its instructions from, and reports to, the Inspector-General of Fortifications.

The Royal Artillery and Royal Engineer Works Committee was constituted on the 19th March, 1884, to bring the Engineer and Artillery duties with regard to the defences of the Empire into more intimate relations for the settlement of details. It took the place of four then existing committees dealing with questions of coast defence, and later, in 1881, the work of three other committees was handed over to it. The subjects it has dealt with have been nearly entirely in connection with coast defences, and comprise the following :—

(1). The revision of the armaments of all ports and harbours of the United Kingdom and the Colonies (exclusive of the self-governing colonies and of India) at which defences exist or have been proposed.

(2). Mountings and emplacements for heavy, medium quick-firing and machine guns.

(3). Workshops, laboratories, stores, etc.

(4). Electric lighting.

(5). Range and position-finding.

(6). Organization and command.

The Committee was originally constituted of officers of the

Artillery and Fortification branches of the War Office, and one naval officer. The heads of the manufacturing departments of the Royal Arsenal were associate members to attend when required. An Engineer officer was appointed Secretary. The constitution of the Committee varied slightly till 1891, when the larger questions with respect to gun mountings were withdrawn from its consideration and the heads of the manufacturing departments of the Arsenal ceased to be associate members. Now the Inspectors of Submarine Defences and Iron Structures are associate members. The Secretary is an Engineer officer specially appointed, and an officer of the Artillery branch of the War Office acts as Assistant Secretary. The Committee is presided over by the Deputy Inspector-General of Fortifications (*I.G.F.*), and the Assistant Director of Artillery is the Vice-President.

Questions are referred to the Royal Artillery and Royal Engineer Works Committee jointly by the Director of Artillery and the Inspector-General of Fortifications, and the Committee report to these officers, who deal finally with the recommendations, except in the cases of proposed alterations in armament. Prior to 1890 these proposed alterations were submitted by the Director of Artillery and the Inspector-General of Fortifications, to the Defence Committee under the presidency of His Royal Highness the Commander-in-Chief, and, if approved, were recommended by that Committee to the Secretary of State for War. Since that date the recommendations of the Royal Artillery and Royal Engineer Works Committee, if adopted by the Inspector-General of Fortifications and the Director of Artillery, have been embodied by them in a quarterly statement submitted, if concurred in, by His Royal Highness to the Secretary of State for War for approval.

The *Fortification Design Branch* of the office of the Inspector-General of Fortifications now consists of Royal Engineer officers, draughtsmen and a modeller, employed in preparing designs for new works, and examining and devising those for alterations prepared by local Engineer officers. The Design Branch officers have also some administrative work outside the sphere of the duties of the Prussian Committee. The branch is directly under the Deputy Inspector-General of Fortifications (*I.G.F*).

The *Iron Structures Branch* consists of Royal Engineer officers, clerks and draughtsmen. They carry out duties similar to those of the Prussian Committee with reference to iron structures, and in addition administrative and certain executive duties not undertaken by that Committee. The branch is directly under the Deputy Inspector-General of Fortifications ($I.G.F_1$.).

The *Submarine Defences Branch* consists of Royal Engineer officers and clerks. They are employed on duties in connection with the Submarine mine defences of our ports and harbours, similar to those carried out by the Prussian Committee for some years prior to 1889, but have also administrative duties which were never undertaken by that Committee. The branch is directly under the Deputy Inspector-General of Fortifications ($I.G.F_1$.).

In comparing the German and our own organization, we find that the Royal Prussian Engineer Committee has no administrative and no executive functions except as regards the carrying out of experiments. It draws up all schemes of defence, examines and revises, if necessary, all designs for works, and prepares all type drawings, specifications, instructions and regulations concerning technical matters affecting the Engineers and Pioneers. With us there is no body of officers charged solely with this and no other work. With a few exceptions all the Engineer officers and assistants employed on duties corresponding with those of the Prussian Committee have also other duties of an administrative nature not undertaken by that Committee.

The Engineer Committee in Germany is under the Inspector-General of the Corps of Engineers. The corresponding Committees and branches in this country are under the Inspector-General of Fortifications and Royal Engineers, except the Royal Artillery and Royal Engineer Works Committee, which is jointly under him and the Director of Artillery.

The Artillery branch in Germany appears to have less to do with projects of defence and defence armaments than in this country.

In Germany an officer of the Engineer Committee attends meetings and experiments of the Artillery Proof Commission. In England a Royal Engineer officer is specially appointed to the Ordnance Committee.

The official instructions in military engineering in all its branches prepared in Germany by the Engineer Committee are compiled in this country at the School of Military Engineering, under an officer who is a member of the Royal Engineer Committee, but not as part of the work of that Committee. They are subsequently dealt with before promulgation by the Deputy-Adjutant-General, Royal Engineers, and the Inspector-General of Fortifications and Royal Engineers.

The study and compilation of information as regards foreign fortifications, which, till 1890, were duties of the Royal Prussian Engineer Committee, and were then transferred to the Headquarter Staff, are dealt with in this country by the Intelligence Branch of the War Office.

There appears still to be in Germany a Defence Commission composed of high officers of various branches of the service (not including the Navy), the functions of which probably correspond somewhat with those of the English Defence Committee prior to 1890, and the Joint Naval and Military Committee on Defence subsequent to that date.

The Royal Prussian Engineer Committee has expended about £300,000 in experiments in the past 22 years. During this time the Engineer expenses for experiments in England have amounted to about £130,000 on works, in addition to an amount for stores purchased on the Artillery Vote which it is difficult to estimate.

PAPER II.

THE TRIGONOMETRICAL SURVEY OF PALESTINE.

By Major C. R. Conder, D.C.L., LL.D., M.R.A.S., R.E.

My object in this address is not so much to enter into a detailed account of a survey which may, perhaps, not be of primary interest to all, or into any dry archæological disquisitions, as to place at your service such features of the work as may be of practical use to yourselves. For I have often noticed—and it is quite right that it should be so—that the lectures delivered in this Institute which have excited most interest are those from which my brother officers, and especially those who are equipping themselves for future good and distinguished service, hope to obtain the help which is to be gained by the experience of those who have gone before. Such experience as I have gained during twenty years of survey work in Asia, in Africa, and in England, I therefore offer for your consideration.

There are few better preparations for active service than that which is afforded by exploration and survey work—a fact which is quite as much recognised abroad as it is among ourselves; and fortunately in our Corps the opportunities afforded to those who wish so to prepare themselves for their most important duty are constant and numerous. I feel convinced that if the two distinguished officers whom we have recently lost—Capt. Mackay and Capt. Stairs, both of whom, I am proud to say, were at one time my subalterns—had lived to reap the fruits of their work, and had been placed later in command of men during a war, they would have made their names yet more widely known, and would have done invaluable service to their country, for they both understood the principles on which success in their profession must rest. They were energetic, self-reliant, very hard working, kind and considerate to those whom they led, and implicitly obedient to those under whom they served. In either case the fullest reliance could be placed on their judgment, and on their faithful devotion to duty ; while neither were infected with the modern disease of self-advertisement. I have no doubt that we possess, and shall continue to train up, men of their stamp ; but they both possessed unusual advantages in being very early placed in positions of responsibility under circumstances very similar to those of actual warfare.

It has been my lot to conduct a survey of even larger dimensions in Africa than that which I carried out in Asia, during the delimitation—as British Commissioner—of the boundary between the Transvaal and Bechuanaland ; but this survey was of a slighter character, to a smaller scale, and with many greater facilities than any that we enjoyed in Palestine. For the large proportion of the audience, who are looking forward to an Indian career, it will be more useful to speak of Asiatic work, because the conditions of the Palestine survey were nearer to those which they may encounter; and for these reasons I propose to confine my remarks mainly to the subject of the trigonometrical survey of Palestine.

I was sent out in command from the S.M.E. in 1872, a few months after the work was started, in consequence of the serious illness of Capt. Stuart, who had been appointed to the post, which he was obliged to resign. I maintained my connection with the work till the outbreak of the Egyptian War in 1882, and I spent six of these years in the field in Palestine, and four in the publication of the map and memoirs of the survey in England. The whole of Western Palestine from Dan to Beersheba was completed during this time on the scale of an inch to the mile, the survey being based on a regular triangulation depending on two measured bases. In 1881, and the early part of 1882, I was in command of a party which commenced the survey of Eastern Palestine on the same principles. West of the River Jordan we had surveyed 6,000 square miles. East of the Jordan we measured a base, and connected it by triangulation with our former stations on the Judean watershed, and carried out the survey and thorough examination of part of Moab and Gilead, amounting to an area of 500 square miles, before we were finally stopped by order of the Sultan. We also had experience in levelling, since we ran a line 30 miles long from the Mediterranean to the Sea of Galilee, the level of which (682 feet below the Mediterranean) was formerly uncertain within 300 feet.

The first and most important question to which I wish to draw your attention is that of the organization of the party, and of our arrangements for work, for transport, and for the feeding of the expedition. It should always be remembered, not only by explorers, but still more so by soldiers on active service, that no chain is ever stronger than its weakest link. The best-laid schemes may be frustrated by sore-footed oxen, sore-backed horses, or want of foresight in providing food, forage, or water. An expedition in which these matters of detail do not constantly engage the anxious care of the leader will soon fall to pieces. The design may be brought to nought by neglect of the health of some groom or muleteer, who is perhaps the humblest of the explorer's followers; and the responsibility for the comfort, health, and perhaps the lives of brave comrades should always hold the first place in the commander's mind as representing claims even stronger than those of the gentlemen who are sitting round council tables at home, and awaiting in comfort, and with impatience, "results" of the expenditure, to place before the public. In the long run these home claims are satisfied by the success in the field; and I feel sure that all will recognise that the only real basis of a satisfactory reputation for those concerned lies in the discovery, which is made in time, that the work has been faithfully done, that it is thorough and capable of bearing minute examination, and that it was carried out without making any unreasonable or tyrannous demands on those entrusted to the care of the leader. I have watched with interest the proceedings of other explorers, of whom we have many different types. There are those who carry fire and sword with them. Those who bully and browbeat defenceless natives. And those again of whom, as a nation, we are so proud, who, like Livingstone and Thompson, and Drummond in Africa, have observed in the wilderness, far away from the constraints of public opinion, the same principles of justice, patience, and humanity which they have learned at home, and who left behind them a name which was sweet of savour not only to their fellow Englishmen, but to the unknown savages whom they befriended in the deserts. If you desire that good work and plenty of it be done by your party, that zeal and faithfulness—on which your own reputation may depend later—be stimulated, all this lies in your own hands; and in the East especially, where tyranny and corruption are rampant, a very little justice and a very little humanity are gratefully remembered.

The party consisted of sometimes two and sometimes three non-commissioned officers of the Corps, chosen from the ordnance survey companies, under the command first of one officer and one civilian, afterwards of two R.E. officers. I claim this as a merit in the sight of our Corps, that where one blade of grass grew I made two grow, by persuading the committee of the Palestine Exploration Fund of the advantage of depending entirely on the R.E.'s, and thus securing the services of an additional R.E. officer. My latest comrade, Capt. Mantell, who accompanied me east of Jordan, is so well known to you that you will easily believe how much of our success, under the very difficult political circumstances in which the survey beyond Jordan was carried on, was due to his exertions—and I may add his courage.

The remainder of the party, which made up a total of from sixteen to twenty at different times, was entirely native. We declined to have anything to do with the ordinary dragomans or contractors. We bought our own horses, and at one time our own mules. We had our own tents and servants, and when moving camp we hired camels from the peasantry. We were thus entirely independent, and the whole party was expected to submit to military discipline—not, perhaps, exactly that of the parade, but such as is possible to maintain among rude and fierce Orientals.

The climate of Palestine is trying to Europeans, and to natives also; and our work obliged us often to camp in unhealthy places, by marshes, and in low ground. It soon became apparent that the fatigue of walking was too great, and that the work must be done entirely by mounted men. Good horses of the country were cheap, and each explorer had his own, with which he soon became familiar. In the whole course of the work neither a horse nor a mule was killed, though they were often marched thirty miles a day for days in succession. On one occasion we marched all the way from Damascus to Jerusalem, yet were fit to begin exploring work as soon as we reached the ground. Every Englishman had comfortable breeches and gaiters, and a good English saddle. I often think our success depended in great measure on these breeches. We had more than once an epidemic among the beasts, as well as fever prostrating all the party; but to minimize these chances as much as possible, we worked in the plains only in the spring time as a rule, and reserved the mountains for the hot summer and the unhealthy autumn. During January and February we were always comfortably housed, and engaged fully in indoor work.

West of Jordan we worked under the protection of the Turkish Government, with a regular firman, and accompanied by a bashi bazuk, or policeman. When, however, we began the Eastern survey, the circumstances were very different. The firman was annulled, and strict orders were sent to the Governor of Syria that we were not to be allowed to explore at all; this was due to the secret surveys conducted further north, about this time, by Russian officers. It was, therefore, only by stealth, and by the assistance of an Arab chief, who was almost an outlaw, that we were able to accomplish anything. The time spent beyond Jordan was an anxious period, during which we were hunted by the local officials, who somehow always went in the wrong direction to find us; and our final stoppage was due to the jealousy of the powerful Beni Sakhr tribe, though I often think that the French Consul and the Jesuit fathers in Moab knew more than they confessed about the message which was sent to Damascus which led to our presence being discovered. Without a knowledge of the Arabic language, which enabled us to deal directly with the Moab Arabs, we should have been quite unable to carry out this design.

I am led, therefore, to remark on the importance of learning the native languages for any explorer in wild countries—such as Palestine was when first I knew it, twenty years ago. If unable to communicate directly with guides and chiefs, the explorer is in the hands of his interpreter, who becomes the master of the situation. Even our sergeants learned enough Arabic for their purpose, and of the accomplishments of Capt. Mantell it is needless to speak. For antiquarian purposes it was necessary to learn something of other tongues, and I should have been very glad to know Turkish well, since we occasionally had to deal with a Turk. Modern Greek is also useful in the Levant, as are all the European languages. Before learning Arabic, I found Italian perhaps the most useful language for general purposes, but of late years the knowledge of English has enormously increased.

The latest expedition was the most completely organized of all. It could be taken in two, and proceed independently in two sections, each under an officer, with its cook, groom, body servant, and muleteers. This was of high importance, since it enabled us to escape the spies set to watch us, and entirely to frustrate them for a time. Generally speaking, on account of sickness, and for other reasons, it is a good thing that an expedition should be throughout in duplicate, since this more than doubles its power of action.

A word may here be added on the question of transport, which is a subject on which it is very difficult to lay down general rules. Transport entirely depends on the character of the country, and on the climate and habits of the people. In South Africa I have found it economical to have my Gladstone bag conveyed in a waggon by sixteen oxen. In Palestine we never used any wheeled vehicle at all. The men rode horses; the stores which demanded rapid transit were placed on mules, and those for which we could wait came afterwards on camels. Thus, even if the camels were delayed on the march, we had food to eat at the end of the day, and instruments for survey next morning.

Our greatest difficulties were in the desert, where barley for the horses could not be bought. A mule will only carry barley for himself and for one horse, to the amount of two or three days' supply. A horse cannot carry more than one or two meals for himself, if he is to be ridden hard. In the Judean desert my mules were very hard worked, as they went up to the hill villages for barley, and moved the camp the day after they came back. At the end of the time we were nearly starved out, having neither food nor forage, and were obliged to march in a heavy storm. In the Jordan valley, where we fed the beasts entirely on the grass, the result was that, after two months, nearly every beast in the expedition had sore back. By an arrangement of the pads they were, however, marched back to Jerusalem without making these worse; and finely-powdered sugar I found an excellent caustic in healing these sores. The camels also gave trouble, and there is no greater mistake than to suppose that a camel (unless specially trained) can travel without food, water, or rest.

The party had to live mainly on goat's flesh and unleavened bread, with game, when available, and plenty of excellent fruit and vegetables. We drank cold tea and lemonade, and a ration of wine after sunset. Quinine was served out all round in cases where fever was prevalent, and various other ills had to be doctored to the best of our knowledge. We also gave medicine to the villagers and Arabs, and I have had men come 30 miles to our camp to have their eyes touched with nitrate of silver solution for ophthalmia. The success of the work was, however, in spite of all precautions, twice nearly brought to nought by severe attacks of fever, which laid the whole party—natives as well as Europeans—on their backs at the same time. In spite of these troubles, and of conflicts and dangers which were occasionally encountered, not one man of the party, either native or European, ever voluntarily left the work. It cost the life of one—Mr. Tyrwhitt Drake—who, if he had lived, would now be widely known as a traveller and Oriental scholar.

It is now time to say something of the survey work itself. I have been told that we made a "compass sketch," and one critic believed that astronomical determinations would have given us greater accuracy. As I have said before, the survey was trigonometrical; and, having since made an astronomical survey, I have been able to compare the relative methods. Another officer expressed surprise to me on hearing that we measured a base line; but I have not learned how trigonometrical surveys are conducted without one. As I have said, we measured three—one in the Plain of Sharon, east of Jaffa; one in the Plain of Esdraelon, east of Mount Carmel; and one on the Moab plateau, east of the Dead Sea. The latter is rather a curiosity, because it is a crooked base line, the end of which is at an angle of 60° to the main part. The line was directed on a high raised mound, which formed a fine station at the north end; but as the sides of the mound were covered with the ruined walls of the city of Heshbon, it was impossible to chain to the station. We directed the line up a side valley, and measured actually another side of an equilateral triangle, which we set out very carefully with two theodolites, measuring each of the angles, and so obtaining the length by measurement, which entailed no calculation at all.

The first, or Ramleh, base was nearly four miles long, and the two measurements agreed within half a link. The second, or check, base was four and a-half miles long, and measured within three links. The Moab base was run under great difficulties, because the piles intended to keep it straight were removed by the Arabs, who dug under them to find gold. It was 3·9 miles long. The main part showed a difference of 1·3 feet between the two measurements. The deflection at the end, measured with a steel tape by Capt. Mantell and myself, agreed within 2 inches in 1,485 feet when re-measured. The bases were measured with an ordinary chain, which was corrected by a steel standard, which had been tested at Greenwich for a temperature of 75° F. The chains used were measured both before and after use, and found to have stretched slightly during the operations.

From these bases a very well-shaped triangulation was found easy to extend, with triangles varying from 5 to 15 miles side ; and in nearly all cases each of the three angles of each triangle was measured. The instruments were excellent 8-inch theodolites. The triangulation was calculated in camp by Sergt. Black, R.E., and so well done that when it was re-calculated at Southampton the change in the position of the stations was, for the most part not plottable on the 1-inch scale. The opinion of Col. Clarke, R.E., on the character of this work is of very high authority. He reported that the points, for the most part, within 30 miles of the bases, were fixed within 10 feet ; and at the extremities, or in the Jordan valley, where many observations were taken in the midst of thunder-storms and hail showers, it did not exceed 100 feet. As the latter range only represents the 53rd part of an inch on the scale of the map, it will be clear that the triangulation fulfilled all requirements.

The heights of all the trigonometrical stations were calculated by vertical angles, and are fixed, according to Col. Clarke's report, within five feet. The remaining heights were obtained by levels, by the mercurial thermometer, and by the aneroid. The latter instrument requires much attention. I did not ride a very high horse in Palestine, but I have known the aneroid to register a difference of 20 feet when I dismounted ; and an aneroid acts differently going up hill and coming down. The Jordan valley, being 1,000 feet below sea level, proved as trying to the temper of aneroids as it did to that of human beings. But we controlled these vagaries by observing the habits of the individual aneroids when placed beside his more responsible relative, the mercurial, in camp, and we read them also at the trigonometrical stations. The heights of the camp were also at times ascertained by levelling to the nearest trigonometrical point, or to the Mediterranean (which has only 18″ of tide), or to some other fixed level or bench mark.

The barometrical heights were calculated in London by Sergt. Armstrong, R.E., and I believe them to be reliable within 20 feet. These observations were made at fixed points, and occur at distances of every two or three miles over all the country surveyed.

The trigonometrical stations were marked with the broad arrow, which may be found on every high hill in Palestine, and over them we built cairns of stone, about 10 feet high, which we whitewashed, so that they showed extremely well. The longest observation taken, from the Carmel Monastery to the top of Hermon (9,200 feet above the sea), and back again from Hermon to Carmel, was some 80 miles long. By means of the true bearing of this line, and of latitude observations on Hermon, the top of that mountain, which was outside the survey, was fixed, and its height was obtained by the mercurial, and by vertical angles to our station in the anti-Lebanon.

We took many observations for latitude before the triangulation was fully developed, but they became unnecessary later. Observations of Polaris for true bearing were occasionally made, in order to make sure that we were not slewing the work, and to correct the variation of our compasses. We were once accused of having left out a ruin, and we asked the French archæologist for the compass with which he made the observations of the position of the ruin which we could not plot. The ruin proved to be there after all, and it also was found that the compass of the archæological critic in question had no needle.

The trigonometrical observations were taken three times over; and this was, on one occasion, important. I observed the south end of a rock in the sea. On the second round the rock had moved several degrees. On the occasion of the third round it had also moved; and soon after it arose from the sea and flew away. It was the south end of a huge squad of pelicans, who were basking on the Mediterranean several miles away.

When the trigonometrical round was finished we took another round, reading to the nearest minute only (not to five seconds, as for the triangulation observations), and this we called the "detail round." It included every distinct object visible, such as valley junctions, domes, minarets, solitary trees, or corners of buildings, columns, and the like; and the intersections of these observations were plotted so that within the triangles, fixed by calculation, we had a number of points depending on them, and fixed by two or three plotted intersections. I have been told that villages might have been fixed by tangential observations round them. My experience is that a village often loses its figure entirely under such treatment, and that it is much safer to fix the top of the mosque, or some such building, and, if possible, to fix buildings at opposite ends of the village, and then to put in the rest by pacing or other measurement when the village is visited. This was our general method; and for towns and large ruins we made special surveys on larger scales, which were reduced for the map.

Our system, therefore, was one of constant interpolation within our triangles, which had two great advantages: one that no cumulative error could occur; the other that the surveyor could ride from point to point, and very rarely required to take any measurement other than an angular one. It is well, however, to have a guide to hold the horse while taking angles and plotting. I had one favourite horse who objected to the prismatic compass, and used to seize me by the seat of the breeches while I was observing. We were, however, always accompanied by guides, who repeated the Arab names of the day to our native scribe in the evening in presence of the surveyor; for in our case it was absolutely necessary that the names should be correctly spelt, because the scientific identification of the modern with the old Hebrew nomenclature entirely depended on radical identity of the names.

The detail was worked in between the fixed points, with the prismatic compass as a rule, the object observed to being rarely more than three miles away. In this work all took part, unless special surveys had to be made, which usually fell to the officers' share. I have often tested the work done by the men, and of the accuracy and care shown by them all I can bear unqualified witness. The credit for the system of survey rests, indeed, in great measure with Sergt. Black, who carried on the survey before I arrived for several months without the advice from an officer. By this method we could get over about 100 square miles per month in the mountains, and when very hard pressed in Moab, by working long hours, we got as much as 250 square miles of detail survey done by four men in a month.

But a country must not be surveyed across the grain, as we very soon discovered. It must be taken in the direction of the ridges, and not at right angles to their watersheds. The spurs in Palestine run east and west. The surveyor rode, therefore, east or west till mid-day, and back west and east in the afternoon, going from five to perhaps ten miles from camp. The camp stood in one place for a fortnight or longer, or perhaps only for a week, and the camps were 15 to 20 miles apart. New-comers who tried to survey north and south from camp spent their day in climbing down valleys 500 to 1,000 feet deep, and in climbing up the other side, and were disappointed that they had not done a fifth of the work brought home by the experienced men. The reason was at once revealed to them —they had taken the country across the grain.

I have often been asked why we did not use the plane table; and a sort of enmity has been fomented by various writers between the plane table and the prismatic compass, as if these instruments were natural enemies. This is not at all the case. Each has its special uses, and sometimes neither can be used. The compass cannot be used in basaltic and ironstone regions, as I know well by experience; but, on the other hand, when I have seen a R.E. officer in Africa (where I used the plane table largely) flying suddenly over his horse's head with a plane table extended in his right hand I have felt inclined to recommend him to use the compass. The N.C.O.'s in Palestine were familiar with the compass, and it is very handy in riding. I should have had to teach them the plane table, and it is often very awkward with a fretful horse. Therefore, we used the compass in Palestine, but the plane table in Africa. In Northern Bechuanaland, though there was less basalt to interfere with the compass than there is in Stellaland, I was unable to use it for interpolation, because were no points. The *vaalbushes* are all just like each other, and there there is nothing else at all except *vaalbushes* and bustards to survey. I, therefore, here made traverses of what are called the roads of the country, the point of observation being a lance in the hand of a horseman who held the surveyor's horse. These traverses, executed by myself and Capt. Mackay and Lieut. Bythell, when plotted and fitted together with cross lines to tie them, formed a very good basis for the survey between the various villages, where there was practically nothing to survey except paths. In Palestine such a method of work would have been out of the question altogether.

The next thing to consider was the delineation of the hill features of the map, which was my special work. I have hill-shaded the whole of Palestine, except Upper Galilee, which was done by Sergt. Malings, R.E., and I also drew the Moab hills of the 500 square miles surveyed. The method employed was as follows:—Each surveyor pencilled in the hills on his trace, and took observations with an Abney's level of the principal slopes. A special trace was then made, and the hills transferred to it. During the time when the triangulation work was going on round the camp, I had occasion to ride over all the ground sufficiently to see its general character, and I drew freehand profiles of the mountain scenery from all possible points of view. I then proceeded to hachure the trace with horizontal hachures, aided by the angles marked in pencil, and by the pencilled shading and the freehand profiles. The result was shown to the surveyor, who criticized it from his special knowledge of the ground. It is to be understood that all the tops, and knolls, and spurs, on the map are actual features. They have not been generalized or characterized, but actually surveyed; and the detail is quite as minute as that of the old series Ordnance map of England, though not as minute as in the hill detail of our new series map at home.

The system I adopted in Western Palestine—of horizontal hachures without light and shade—I now consider better suited for large than for small-scale work, and in Moab I adopted the usual map-maker's system of vertical hachures, with a light from the left-hand top corner, such as is used in the 1-inch map of Ireland on the Ordnance survey. Scale of shade is quite inapplicable to 1-inch work, though I think it excellent on a 6-inch scale. The Moab hills were specially capable of picturesque treatment, and I think that not only does the map look prettier on such a system, but—which is far more important—the small features in low ground can more easily be made clearly intelligible by the vertical than by the horizontal system on the 1-inch scale. There is a prejudice against light and shade as "unscientific," but it appears to me that the main object in a small-scale map is to make it easily readable, and that the best method is that which secures this result.

Depth of shade should depend not only on slope, but on actual elevation above the sea, if the relative importance of the features is to be made visible at a glance. Light and shade may, of course, be easily overdone through a desire for picturesque effect, but there are certain features, such as isolated tops in valleys, which can only be made to stand up by a certain effect of light and shade. If only the slope is indicated these knolls have a tendency to look like mildew spots or duck ponds; and "science" should give way in such cases, I think, to practical utility.

The same general principle also governs the system of transliteration of names used on a map. No real scholar will trust to transliterations, however ingenious be the system of dots, dashes, commas, and accents used. He will always wish to see the name spelt in the letters of the native alphabet; and a name list will give him what he requires. In Celtic names, for instance, in Wales, it has been said that a "scientific system" should be adopted at home. My own impression is, that if the Celtic names were spelt so as to satisfy Celtic scholars, but at the same time so as to be utterly unpronounceable by anyone else, the utility of the map would be seriously damaged, because the bicyclist and the farmer could not then ask the way when using the Welsh map, and would not recognize the names on sign-posts or public announcements. The Royal Asiatic Society have lately been busy with an universal system of transliteration, which appears to me to resemble the proposal for an universal language. In Palestine we adopted Dr. Robinson's method of transliteration, not because it was equal to the system of Lane, which is the most perfect ever employed, but because it was familiar to the British public at large, and introduced the smallest amount of change in correcting the egregious spellings of former times. For scholars who wish to study the meaning of the nomenclature we have provided name lists in the Arabic characters, with translations; though these remain a grief of mind to me, because they were edited by a great scholar who has at times rejected the meaning of a word which I ascertained from the peasantry on the spot in favour of one which he knew from a dictionary. Thus *bedd* means a "millstone" in Syrian Arabic, and applies to ruins where millstones are found. My editor has at times converted it into "idol temple," which is no doubt interesting, but is not the real meaning. The word *batn*, for a "knoll," or "stomach," projecting from a hill, he also converted (in his superior wisdom) into a "water-course," which is not a known word in Palestine. In the course of his editing, however, he found out that I was right, and has thus introduced a charming confusion by sometimes following the real meaning, discovered after years of enquiry in the country, and sometimes following the dictionary. As the Syrian dialect is not literary Arabic, but the descendant of the old language of the Amorites, it is never safe to take any meaning save that given by the peasant on the spot. Arabic words, as you perhaps know, have often many meanings (as have English words), and generally signify a "lion" and a "palm tree" as well as other things. I refer to these questions here only because you may probably find them arise in other countries.

In addition to the map, we made special surveys of all important towns and ruins on larger scales, of all buildings and antiquities, with measured plans and sections of churches, castles, temples, synagogues, and rock-cut tombs. The methods varied extremely. Some were chain surveys, some were compass sketches. I have made traverses round the walls of mediæval towns, fixing church and castle by angles to the walls and towers. The harbour of Tyre Capt. Mantell and I surveyed naked, after swimming to the reef, with compass and tape in our turbans; but in all cases there was one rule observed, which is of great importance when the work cannot be plotted on the spot, and this is to have a duplicate set of measurements. It takes little extra time or trouble, and thereby you avoid the disappointment felt when you discover a missing measure, or a figure which is not clearly legible, and have to re-visit the spot. For the same reason it is important to insist that all work should be completed and penned in before the camp is moved, otherwise a delay and an unnecessary expense may be entailed when an omission or error is afterwards discovered at a distance. In the survey of the Siloam tunnel, where we lay for five hours in mud and water, holding note-books in our teeth, and bitten by the leeches, we were obliged to go back again because we found that the measurements were incomplete when the traverse was plotted.

As regards other work, geological notes, collections of folk lore, hunting for butterflies, stuffing birds, and copying inscriptions, I do not propose to speak; for these, though part of our duties, were unconnected with survey proper. The result has been the production of five quarto volumes of memoirs of the survey, in which every ruin in Palestine is described, the towns, their populations, buildings and antiquities, the sacred places, ruined castles, churches, mosques, and other buildings, the ancient cemeteries, historical and religious texts, and other details of interest detailed, and the history of every place recorded from the earliest down to the latest times. There is, I believe, no Asiatic country of which so much is now known as of Palestine.

One point of military interest I may, however, notice, namely, the use of the heliograph. It had not become well known when we were in the East, but we made rough heliographs by flashing a small mirror in the direction of the other trigonometrical party, directing the flash by putting a stick in the ground, in line with the distant hill, on which we could see the pale glimmer of the mirror of the other party. In Bechuanaland a large party of signallers was attached to my survey party, to keep up communication with the headquarters of Sir Charles Warren. I often used them for survey purposes, and could thus talk to my comrades, and interchange angles, and notices of what next to do. Many hours were so saved; and since survey stations are always suitable also for signalling, I am led to conclude that, in military expeditions, the survey and signal parties should always be in close connection with one another, if not, indeed, under a single command.

The publication of the survey was carried out under my direction in London. The plans were drawn for the Intelligence Department, and were so neatly executed that they were reproduced on the original scale by photozincography. They were afterwards reduced to about $\frac{1}{3}$ scale by photography, and engraved on copper. At that time coloured maps had not become as fashionable as they now are, but we were allowed two colours; and the brown hills, to my mind, give considerable clearness to the map. The use of more than two colours seems to me, however, a luxury which has no real necessity in a map carefully arranged in accordance with the requirements of its scale. The memoirs were much longer in making their appearance, but were all published by the end of 1884. They still require to be finally arranged and properly abstracted, to place them within reach of the reading public; but the results have already led to the publication of many new maps of Palestine, and to many changes in popular opinion as to the country and its ancient history.

As regards the cost of the work, Palestine is, no doubt (or was when we were working), a cheap country; but very rigid economy was observed, and the living expenses amounted to about one shilling per diem per man, and one shilling and sixpence per diem for a horse. I calculate that the survey cost about one penny per acre, whereas the 1-inch map at home, I believe, was calculated to cost one shilling per acre.

You may, perhaps, ask what was the object which led to the survey, and which caused the public for many years to subscribe some £4,000 to £5,000 annually for its support. The object was not only to study the ancient geography and topography of the country for the purpose of Biblical study, but also to secure a thorough examination of the whole area, since the surveyor must of necessity visit the whole of the ground. Something like 150 places mentioned in the Bible were thus discovered which were quite unknown before, to say nothing of the ancient sites mentioned by classic writers, in the Talmud, and in the early Christian and Moslem accounts of the country. Important historical inscriptions were found, and better copies obtained of others already known; and a great revolution was effected in the architectural history of the land. What former travellers had pointed out as Jewish or Phœnician ruins often proved, on minute examination, to have been built by the Romans, the Byzantines, the Crusaders, or the Arabs; but at the same time it became possible also to distinguish those remains which go back to Hebrew days. It must not be forgotten that a Saxon chapel of the ninth century in England is a rarity of early date, and that some of the existing churches in Palestine are 500 years older, but are there regarded as comparatively modern remains.

We were confidently expected to discover much more ancient things, and I have copied at Siloam an important Hebrew text which is no less than 2,600 years old, while quite recently an inscribed tablet has been dug up which was written 3,400 years ago, but which is still quite legible. Many of our more important finds were the direct result of the system of surveying the whole country, since they were made in regions which no European had previously visited. Some of our drawings and accounts of ancient remains are now all the evidence that remains of their existence, since they have of late been destroyed by greedy speculators, or by monks and others, who have erected modern buildings on the ancient sites. The Crusading frescoes, which I copied in the Jordan valley, were ruthlessly scraped from the walls a few years later by Greek monks; but they were earlier than any known remains at home, even than the paintings of the Lady Chapel of Winchester.

The study of antiquity is not merely a craze of the specialist in archæology; it is a study of the highest importance to the soldier and to the political officer. If you are ignorant of the history of a nation, of its original stock, its language, and its traditions, you cannot understand the thoughts and prejudices of the modern inhabitants. If you know nothing of their religion you run constant risk of unintentionally committing some act which is in the highest degree offensive to them. The influence which an officer may exert over Orientals depends in a very great degree on his knowledge of their peculiarities; and these peculiarities come from ideas and customs of very high antiquity, for it was not till civilization had grown up and flourished and decayed in the East that our British ancestors began to desert their skins and woad in favour of Roman civilized habits. This is equally true in India or in Persia, in Egypt or in Asia Minor, or wherever in the East you may be called to serve. The first requisite for success in dealing with Orientals is a thorough knowledge of their history and habits, such as many of our distinguished officers have attained who did not begin by despising the natives, or by dividing Arabs into the two categories of "rebels," whom they killed, and of "friendlies," whom they kicked. It must also be remembered that although the Moslem standard of moral duty is not as high as the Christian, though lying and bribery and violence and oppression are rampant in the East, still among the respectable and well-bred upper classes are to be found men as honest, as upright, and as capable as those whom we honour in the West. Several of such men as, for example, the famous Moorish chief Abd el Kader, at Damascus, it was my good fortune to meet in

Palestine. There are two things which bar the way and lead to an Englishman being shunned by Orientals. One of these is a pretence of being himself Oriental, and the other is the assumption that the native must be more ignorant and less capable than himself. As regards courtesy of manner and absolute sobriety, we may also learn very much from the Moslem of almost any class.

Another point to which I should like to draw attention is the great importance of a good knowledge of geography to the soldier or the political officer—such as some among the audience are no doubt destined to become. I believe it stands only second to knowledge of language, and perhaps at times it is even more important. Just as the course of a stream is deflected by a single rock, or even stone, so are the highways of a country dependent on the natural formation of the ground. Armies do not move faster (perhaps they move slower) in our own times than they did in the days when the ancient Egyptians conquered Palestine. They must still drink of the same springs, and avoid the same mountains and marshes. The Crusaders in the 12th century marched south by exactly the same road that the Amorites followed in 1480 B.C., and Napoleon took exactly the same route that the Pharaohs took before, and fought on the same field—when Junot won the battle of Mount Tabor—that Barak occupied in the days of the Judges. History repeats itself for a very natural reason—because the mountains are everlasting, and the streams and springs flow in the same channels and from the same sources from age to age. A railway is now to be made in Palestine on the route which I recommended 14 years ago; but it will not follow any new route, but, by the nature of the country, must be made along the ancient highway which connected Damascus with the sea in the time of Thothmes III. Napoleon said that St. Jean d'Acre was the key to Syria, and the dictum still remains true, as shown by the opinions of English engineers and railway contractors.

For such reasons the study of geography is of primary importance for any soldier who would understand not only strategy but even tactics, because the battle-ground remains the same even though the weapons are changed. The route by which the British army entered Egypt in 1882 was the route of the Exodus; and the mistake which lost Palestine to the Crusaders in 1187 A.D. would be equally fatal to any modern general who deserted the springs of Galilee to march over a waterless plain, and to meet an enemy posted beside a well watered position. In the East the distribution of the water supply regulates the possibilities of advance even more strictly than in Europe; and you will remember that General Gordon's victories in the Soudan over the slave traders, who had much superior forces, depended mainly on his holding the wells and on his thorough knowledge of the geography of the region. For such reasons the study of geography is important, and for the understanding of military history it is, of course, of primary importance.

You will perhaps allow me to give one illustration of the results which can be obtained in the study of ancient history through a knowledge of the geography—ancient and modern—of a country. In 1887 an Egyptian peasant woman at Tell Amarna, 180 miles south of Cairo, lit accidentally on the most important collection of ancient inscriptions which has as yet been found, consisting of 300 letters of the time of Joshua's conquest of Palestine, the large majority of which were written by the petty kings of Syria and Palestine to the King of Egypt. They refer to the wars of the Hittites, Amorites, and Hebrews, and it has occupied European scholars ever since to decipher and translate their contents. Now the great difficulty which has been experienced has been neither to understand the writing nor to translate it, but to know the regions and towns mentioned, of which there are no less than 130 named. The work of the Palestine survey, coupled with that of other explorers, enables this to be done, and geography thus lies at the very basis of a true understanding of a very important episode in ancient history.

I need not tell you that there is a great deal of highly interesting and valuable work to be done not only in Palestine or in Egypt, but in every part of the world. Royal Engineer officers have unusual opportunities for such work. They learn many languages, and they live among many primitive peoples. The study of such regions as they may be sent to manage or to explore will not only wile away many tedious hours of up-country life, but it will, in time, infallibly bring its reward, because their superiors will naturally rely most on those who have the most reliable local knowledge; and in time of war such experience is invaluable. In India there is an immense amount of work to be done. The weak point of the "Aryan brother" theory of professors lies in the fact that, for the most part, the Hindus are not Aryans at all; and this fact, which has only been recognized of late years, has been brought to light mainly by the practical knowledge of soldiers and political officers. Some of the most distinguished living Orientalists (as, for instance, Sir Henry Rawlinson) are soldiers who have attained their learning during the exercise of their profession. In our own Corps Col. Yule and many others may be cited; and their studies have led not only to the increase of historical knowledge, but also to their own advancement to positions of trust and of influence.

It has always seemed to me that, for the credit of the Corps, it is necessary that the work of a R.E. officer should be carried out, not only in such a manner that criticism and investigation should prove that no holes could be picked in it, because it was done faithfully and with care, but also that it should be such that no one who comes after should be able to add thereto; in a word, that it should be exhaustive. But this can only be attained by following out all the lines which the work indicates, and by learning not merely that which is immediately required, but that which surrounds the subject. It would have been considered enough by our employers in Palestine that a good survey should be made. They did not demand of us linguistic or antiquarian knowledge; but if we had not set ourselves to the study of these departments, and to observation of the populations, the fauna, the flora, the geology, the inscriptions, the architecture, and the statistics of the country, a great opportunity would have been lost, and an opportunity which cannot now recur, because of the great changes which have now come over a country which was still very primitive in 1872, but which is now fast being absorbed within the area of so-called "civilisation."

There are few professions in which a man receives an education so specially fitted for the work of exploration in rough countries as is afforded by the years spent at Woolwich and at Chatham, where he may, if he will, learn languages and drawing, photography and survey, chemistry, geology, and, above all other things, discipline. There are few also in which he has afterwards such opportunities of acquiring knowledge of distant lands, and of turning it to uses which may serve his country as well as himself. It is with the R.E. officer to choose whether he will avail himself of such advantages.

When Sir Charles Warren came back from his wonderful excavations in Jerusalem, which made his name known as a thorough and scientific explorer not only at home, but in many other European countries, I went down as a *tyro* to ask his advice when starting on the survey work in Palestine. He told me that, being now division officer at Shoeburyness, he took a very great interest in drains. Perhaps it was the interest in drains, as well as his expedition to Sinai, that led him to the command of the Bechuanaland expedition.

Of all the distinguished men to whom it has been my privilege to listen at Chatham or elsewhere, the advice of none remains more in my mind than does a speech made by Lord Napier at our mess-table, after the Abyssinian War. I do not remember that he said much about keeping one's name in the papers, or having one's portrait in the *Graphic*. What he said was that an officer, wherever he was placed, or whatever he was directed to do, must do his duty to the utmost of his powers and understanding. In the words of the wise man, uttered so long ago, "Whatsoever"—be it drains or the exploration of Thibet, be it the command of a squad or the command of an army—"Whatsoever thy hand findeth to do, thou shalt do it with thy might."

PAPER III.

THE CONTEST FOR NORTH AMERICA, 1750—1760.

Compiled by MAJOR H. D'ARCH BRETON.

THE following has been extracted from Parkman's *Montcalm and Wolfe*. A short abstract was commenced for another purpose, but it became evident that a second operation would be necessary, and it seemed worth while to continue the work and so present an instructive chapter of history in a concentrated form. With the exception of a few amplifications of detail, and the re-arrangement of certain parts, it may be taken as condensed Parkman. Of the plates, Louisbourg is from Parkman, with some additions from Jefferys and the chart; Fort William Henry is from Parkman, with the addition of the figured ranges from Dr. Kingsford, affording some clue to scale; Ticonderoga, 1759, is from Dr. Kingsford; Quebec is from an engraving used by Campbell as well as by other writers. This Quebec engraving was originally re-drawn from a larger one, published apparently at the end of 1759, and several mistakes in spelling were then introduced. The operations and field works of the large plate were roughly plotted on a pre-existing plan, the lines of Quebec being those of 1690, and not those of 1759 shown afterwards in the survey made by the engineers of the army—a plan, unfortunately, too large for these papers. The intrenchments and redoubts on the the plate herein figured are only indicated by symbols and their position is inexact. Fort du Quesne has been reduced from the plan given by R. Strobo; Fort St. Frederick has been taken from Barber's *History of New England;* Louisburg, King's Bastion, and Ticonderoga, town and fort, from Jefferys' atlas, published in 1768. The information given by Parkman has been utilized in the preparation of the other maps. All have been drawn by the writer.

In the middle of the 18th century France claimed all America west of the Alleghanies, from Mexico and Florida to the North Pole, except the ill-defined English possessions on the borders of Hudson's Bay. The British colonies had a population of about 1,160,000 whites, Canada some 60,000 whites, and Louisiana and Acadia together rather more than 20,000 whites. The province of New York consisted of a line of settlements up the Hudson* and Mohawk, and was little exposed to attack save at the northern end, which was guarded by the fortified town of Albany, the base of the coming war. The British colonies were weak, and their weakness resulted from their jealousy of each other and of the Crown, while the strength of the numerically feeble Canada lay in the unquestioning obedience rendered to an absolute government. Against attack Canada was strong, owing to the natural boundary of the great lakes and the St. Lawrence. This line was defended by Quebec, Montreal, Fort Frontenac (now Kingston), Fort Niagara, Fort Le Bœuf, Fort Detroit, Fort Michillimachinac (now Mackinaw), and Fort St. Marie. The one sore point was the British post of Oswego. In the central portion of the continent France only possessed a slender chain of posts between the lakes and New Orleans, and of this chain Fort Chartres, on the Mississippi, in Illinois, was the chief link.

The advance of British traders from Pennsylvania across the Alleghanies into the valley of the Ohio necessitated counter action, for the establishment of British settlements would have cut French America in twain. In 1749 a small expedition was sent there from Canada, returning to Montreal after sovereignty had been formally declared, and endeavours made to secure the allegiance of the Indians. The Virginians then prepared a settlement in the Ohio country, and procured a grant of half a million acres from the Crown. The building of a British Fort Duquesne was, indeed, only prevented by the jealousy of Pennsylvania, both provinces claiming that part of the valley. In 1753 the Marquis Duquesne sent 1,500 Canadians

* So-called after the explorer of that name, who sailed up it, thinking he had found the north-west passage. In old histories it is frequently called the North River.

by way of Erie, French Creek, and the Alleghany to clear out the British, but the force was decimated by disease, and accomplished nothing beyond the construction of a post at Erie and another on French Creek. A British advance was now prepared, and in February, 1754, a party was sent to build a fort at the fork between the Alleghany and Monongahela, the two rivers that, when united, form the Ohio. In April a body of 500 French descended the Alleghany, took the unfinished work, and commenced a large fort on the same site named Fort Duquesne, now Pittsburg.* In June there were 1,400 men in garrison. After this Dinwiddie, Governor of Virginia and Washington, acted much as though war had been declared. In July a French force attacked a log fort held by Washington, and compelled him to capitulate and re-cross the Alleghanies. This defeat made nearly all the western tribes declare for France.

While Virginia now voted £20,000, Pennsylvania refused anything, and though in December the assembly voted £20,000, it was accompanied by impossible conditions. These they refused to yield, and told the governor they would rather be conquered by the French than lose their privileges. New York thought nothing of the French advance, but gave £5,000 to aid Virginia on learning the defeat of Washington. Maryland gave £6,000; New Jersey felt too safe to contribute; New England and Massachusetts were ready to fight. Discouraged by repulses, Dinwiddie applied for two regular regiments to England, who had but 18,000 men, while France had ten times that number, though unprepared for a naval war.

1755.

The application was granted, and in January Braddock sailed from Cork with two regiments. Though war was not declared, both England and France were taking effective measures, and both were guilty of duplicity. Boscawen watched the Brest fleet, with

* This was a square bastioned work with two ravelins. The ditch is described as having a breastwork, probably meaning a covert way. The parapets of the two exposed fronts were framed with heavy squared logs to a height of 12 feet, the bastions being filled with earth to within 4 feet of the crest. The remaining portions of the enceinte consisted of a stockade 12 feet high, the timbers mortised together, and loopholed for small arms. The magazine was almost entirely below natural ground level, and only 5 feet high; the heavy roof timbers were covered with potter's clay, 4 feet thick. The work was considerably strengthened by 1756.

1755. orders to attack should their destination prove to be the St. Lawrence. At the beginning of May they sailed, 25 sail of the line, other craft, and transports with 3,000 troops. In order to intercept them, Boscawen was cruising off the Banks; but nearly all eluded him, some getting into Louisbourg, and others making their way to Quebec. Three ships were met and attacked, one of them escaping under cover of a fog.

In the meantime a general plan of campaign was prepared, for which Shirley, Governor of Massachusetts, was mainly responsible. The French were to be attacked simultaneously at four points. Braddock was to advance on Fort Duquesne, Shirley, with two newly-raised colonial regiments, was to take Fort Niagara, and a colonial force from New England, New York, and New Jersey was to seize Crown Point, the key of Lake Champlain. The fourth point was Acadia, now Nova Scotia. Taking advantage of some ambiguous wording in the treaty of Utrecht, de la Galissoniere had laid claim to the greater part of Acadia, and French missionaries had succeeded in stirring up the people. In 1749 de la Galissoniere fortified the isthmus by the construction of Fort Beauséjour and Gaspereau, by this means appropriating the whole fur trade of that region* The British now proposed to take these works and to effectually reduce Acadia.

Braddock was much hampered by the unwillingness of the southern provinces to furnish supplies, and the transport was at last provided by the Pennsylvania farmers at the personal solicitation of Franklin. The interest exercised by a member of the Ohio company forced him to take a route costing £40,000 extra in money, six weeks in time, and probably the wreck of the expedition. Instead of landing in Virginia and moving by the Potomac and Will's Creek, the better and easier way would have been to start from Philadelphia. The route from Alexandria through the forest of the trackless Alleghanies was one of exceptional difficulty; Braddock, however, pushed on, as he heard the French were expecting a reinforcement of 500 men. With 1,400 men and 10 guns, exclusive of the transport convoy of 800 men, he had reached within 10 miles of Fort Duquesne, when he was surrounded in the forest by 900 Indians and French.†

* In 1750 an international commission had sat at Paris to define the boundaries of Nova Scotia, and separated in 1753 without coming to any decision.

† The place is now the site of great steel works, and still retains the name of "Braddock's."

Strangers to bush fighting, the troops crowded together, and finally broke, the Virginians suffering from the fire of the panic-struck mass of regulars. Braddock had four horses killed under him and was mortally wounded. Of 86 officers, 63 were killed or wounded, and out of 1,373 rank and file only 459 came off unharmed. Another account gives the number who escaped of all ranks as 583 out of 1,460. All the baggage and guns were taken. Braddock's letters and instructions were used by the French to throw upon England the onus of breaking the peace. The fugitives were not pursued; indeed, the French were not in a condition to do so, for the Indians always decamped after an action, and there were but few Canadians who had not departed at the first fire. Colonel Dunbar retired with the survivors to Philadelphia, and then moved north to join the Niagara expedition; but he went slowly and did not arrive in time. By his abandonment of Fort Cumberland, Maryland was subjected to terrible reprisals. 1755.

The second blow was to be the capture of Niagara. In importance this was the first, for its possession would have carried with it the control of the Ohio valley and made Braddock's expedition superfluous. In July, Shirley started from Albany with three new-raised provincial regiments, moving by the Mohawk, Wood Creek, Lake Oneida, and the Onondago to Lake Ontario. Oswego was the first place of assembly. Across the lake was Fort Frontenac, garrisoned by 1,400 regulars and Canadians, who were only awaiting Shirley's departure to attack Oswego, for Braddock's papers had informed them of the whole design. At Niagara, by the end of August, the French had 1,200 French and Indians from Fort Duquesne and the upper lakes. Shirley had 1,376 effectives and insufficient provisions for any immediate advance. The weather was bad, boats insufficient and unseaworthy, and the men had become discontented and unwilling. At the end of September it was decided to strengthen Oswego and to do no more. Leaving 700 men at the fort, Shirley returned to Albany at the end of October.

The third stroke was to be the capture of Crown Point, called by the French Fort St. Frederick, the fort at the south end of the broad portion of Lake Champlain. For this Massachusetts provided 4,500 men, or one in eight of her adult males. William Johnson, the Indian superintendent, was placed in command by Shirley, and on this Connecticut voted 1,200 men, New Hampshire 500 men, and Rhode Island 400 men. New York promised 800 more. But with all Johnson's influence only 300 Indians would take

1755. the war path. The French knew of the proposed attempt from Braddock's papers, and reinforced the garrison by the troops that had sailed from Brest in the spring. It had been intended to use them for the attack on Oswego, but this was now changed, and they moved to Crown Point by way of the Richelieu and Lake Champlain. In July Johnson was at Albany with 3,000 men, and experienced the troubles and delays consequent on the expedition being under five separate state governments. On the 25th August scouts brought word that 8,000 men were on the road to defend Crown Point, and a council of war applied for reinforcements. Meanwhile the main body had moved to Fort Edward, south of Lake Saint Sacrement, now named Lake George by Johnson, and on the 27th 2,000 men reached the lake. While Johnson was there in camp, Dieskau reached Crown Point with 3,573 men all told, regulars, Canadians, and Indians, and he moved on to Ticonderoga with nearly all his force. An English prisoner patriotically informed him that Johnson had fallen back to Albany, and Dieskau started to attack Fort Edward. Landing in south bay, at the end of Lake Champlain, Dieskau advanced with 216 regulars, 684 Canadians, and about 600 Indians. The capture of some wagons changed the plan. Dieskau now knew of Johnson's presence, and he proceeded to attack his camp. From his force of 2,200 effectives and 300 Indians, Johnson detached 500 to Fort Edward, and 500 to annoy the French. Dieskau ambushed his force and doubled up the column, the broken remnant escaping to the camp, following up his success by an attack on the camp, in which the French were totally defeated, and he himself was wounded and made prisoner. Johnson did not advance. He had insufficient stores and transport, his men were deficient in food and clothing, and were undisciplined, discontented and sickly. Raw recruits continued to straggle in, till in October there were 3,600 men there, most with only summer clothing. At the end of November they dispersed to their homes, small garrisons being left at the camp, now named by Johnson Fort William Henry, and at Fort Edward. Johnson was made a baronet, and voted £5,000 by the Imperial Parliament.

The fourth stroke was the reduction of Acadia. The British settlers in Nova Scotia had been in no condition to withstand encroachment. The troops were few and scattered, the militia of Halifax could alone be trusted, and the defences were weak. The fort at Annapolis was dilapidated and the other posts were mere stockades. On the other hand, the French had some 2,000 militia and Indians on the isthmus, while the Acadians within the peninsula had about the same number of available men. Reinforcement from Louisbourg and Quebec was, further, always possible. Fort Beauséjour was a pentagonal earthwork mounting 25 guns, and was strong. French plans for the ousting of the British required to be met, and to anticipate them was the aim of the present expedition. Massachusetts raised 2,000 men, despatched them in 40 sloops, and on the 1st June they anchored within five miles of the hill of Beauséjour. Colonel Monckton landed without opposition, and encamped at Fort St. Lawrence, a British post on the Nova Scotia side of Beauséjour, and separated from it by a creek. He was joined by the regulars in garrison, carried a blockhouse and breastwork on the far side of the creek, and invested Beauséjour. The garrison consisted of 160 regulars and between 1,200 and 1,500 militia. On the 14th the mortar battery opened fire, and two days after a shell broke into a casemate, killing six officers and an English officer, a prisoner. On this the work capitulated, and the French commandant gave a supper to the officers sent to take over the fort. A French priest named Le Loutre, a fanatic fireband and a ferocious beast, escaped, but was captured on his way to France, and immured for eight years in Elizabeth Castle, Jersey. Fort Beauséjour was re-named Fort Cumberland, its satellites surrendered, and all Acadia was made British. 1755.

The nett gain of the year's campaign was, therefore, the strengthening of Oswego, the construction of a barrier fort at Lake George, and the reduction of Acadia. But there remained a serious liability. The retreat of Braddock's expedition had opened a new route for invasion, and the French at Fort Duquesne were quick to seize the opportunity. The new commander, Dumas, was skilful at raising an Indian war, and soon boasted that by this means he had devastated a strip 90 miles wide in Pennsylvania, Maryland, and Virginia. The only defensive force was a turbulent body of 1,000 Virginians, afterwards raised to 1,500, commanded by Washington. To guard 700 miles of forest frontier was impossible, and the border settlers suffered the more desperately owing to the want of arms, the Indians having previously been too friendly for arms to be required. Meanwhile, the assemblies would do nothing. The Quakers and Presbyterians of Pennsylvania preferred their mutual squabbles to such matters as frontier defence, and only united in resistance to the governor. When the cries of the unhappy settlers grew to a pitch too high to be ignored, the Quakers preached in the streets on the

1755. iniquity of war. Nevertheless, a few years later they armed to resist an irruption of incensed Presbyterian borderers. Time went on, and the Indians were ravaging the country within 60 miles of Philadelphia. Under the pressure of some 2,000 men from Chester county and Berks, the assembly met and passed a useless law. This so-called militia law exempted Quakers from service, and constrained no one. Its sole effect was to legalize the voluntary formation of companies, and the election of officers by ballot. So passed the year, and winter settled down.

1756.

In May England declared war. On the 3rd April Montcalm embarked at Brest with two battalions, and reached the St. Lawrence in May. Vaudreuil, the governor, looked on him as a rival, and retained command of the local troops in his own hand. Montcalm had nearly 3,000 regulars, besides 1,100 in garrison at Louisbourg. Vaudreuil had about 2,000 local regulars, *troupes de la marine*, called "Colony troops," and about 14,000 militia, being the effective male population between the ages of 15 and 60. The numbers actually employed were, however, few. Even in 1758 only some 1,100 men were called out, save for two or three weeks in summer, though about 4,000 were employed on transport service.

In March Vaudreuil sent 360 picked men, who took a palisaded depôt on the route to Oswego, though Fort Williams, on the Mohawk, four miles off, was not attempted. A great quantity of stores and ammunition had been collected there, and the loss ensured sufficient delay for the strengthening of the French forts on Ontario. One battalion was now at Fort Niagara; two battalions with a body of Canadians at Fort Frontenac, now Kingston; and two battalions at Ticonderoga, while Montcalm and the governor awaited the development of events at Montreal. News came that 10,000 British were going to attack Ticonderoga, and a third battalion with a reinforcement of local regulars was sent there, while the militia was called out and ordered to follow. At the end of June Montcalm arrived, to find the fort approaching completion. It was a square bastioned work, with a parapet 10 feet thick of earth and gravel, faced with heavy timbers bonded with through logs. Barrack and bombproofs existed, and the outworks had been commenced. In parts the ditch was cut in solid rock.

On his return to New York from Oswego, at the end of the preceding year, Shirley laid his scheme for the next campaign before a council of war. It was at once bold and comprehensive. The plan was to master Lake Ontario by a naval force, and simultaneously to attack the French at Fort Duquesne, and along the line of Lake Champlain. A diversion was to be effected by an inroad on the settlements about Quebec by the River Chaudière. It need hardly be said that rivers formed practically the only means of penetrating the as yet untouched forests. The chief advantage of Oswego consisted in there being only one considerable portage between it and New York. The importance of Lake Champlain consisted in its being the natural road to Montreal, and, indeed, Quebec, though the capital could also be reached by way of the Connecticut and the Chaudière. 1756.

The council approved of Shirley's scheme, but required 16,000 men to carry it out, and these the provinces would not supply. Pennsylvania and Virginia, indeed, would do nothing, so that the attack on Fort Duquesne and the diversion towards Quebec had to be abandoned. The New England States were discouraged and embarrassed by debt; but on England giving them £115,000 they embraced the scheme with alacrity, though limiting action to Ticonderoga and Crown Point. For the Ontario expedition, therefore, Shirley had the remains of four British battalions, four provincial companies from North Carolina, the "Jersey Blues," and the four regular companies from New York. When raised to their full complements, he would thus have some 4,400 men. Although he knew he was to be superseded, he energetically prepared the way for the expedition by strengthening the route to Oswego and by collecting stores. By the end of May, 5,000 recruits, furnished by the New England colonies, were gathered together at the posts along the upper waters of the Hudson. To instil in them a spirit of discipline was, however, almost impossible, owing to the election of officers by men. At Fort William Henry three sloops and several hundred whale-boats were being built. Johnson, now Sir William, an independent Indian superintendent, was busily engaged in attaching the Indians to the British cause, though hampered by the action of the Governor of Pennsylvania in declaring war against them. Meanwhile Shirley was completing his preparations. Having no troops to spare, he armed his 2,000 boatmen, and passed a convoy safe into Oswego. In May Vaudreuil had sent a force of 1,100 men across the lake to cut the communica-

1756. tions with Oswego, and on the return of Shirley's convoy early in July, the first division of boats was surprised by the French. Reinforcements arrived, and the French were driven off.

During the preceding winter the garrison of Oswego had undergone terrible privations, and suffered heavily from disease. All necessaries had been lacking, and when relief came the survivors were found to be totally unfit for any service, while the so-called fort was itself in no state of defence. Through the spring and early summer Shirley continued to push up squads of recruits, for the safety of Oswego was vital, not only to the success of the Ontario expedition, but also to the attack on Ticonderoga and Crown Point. Towards the end of June Abercromby and Webb arrived at Albany with 900 regulars, and Shirley was sent to New York, to await Lord Loudon, who arrived on the 23rd July. The change in command caused a delay in forwarding reinforcements to Oswego that proved of fatal consequence.

On reaching Albany, Loudon decided to abandon the attempt on Ontario, and sent an officer to report on the state of the local forces. Like all untrained men, they had no idea of discipline nor of sanitation, and the camps at Forts Edward and William Henry were in a bad state. Out of 2,500 men at Fort William Henry, 500 were sick, and from 5 to 8 were buried daily. On the 12th August, Loudon sent a British regiment under Webb, and a party of armed boatmen, to reinforce Oswego. At the divide he heard that that post had been taken, and that the French were advancing, 6,000 strong. The posts at the divide were, therefore, burned, and Webb retreated down the Mohawk to German Flats, where Loudon ordered him to remain.

When Montcalm was at Ticonderoga, and a British advance seemed imminent, it had appeared to Montcalm and the governor that a feint against Oswego would divide the enemy, and might be converted into a real attack. Leaving Lévis with 3,000 men at Ticonderoga, Montcalm embarked for Montreal, and leaving on the 21st July, he reached Fort Frontenac in eight days. A Canadian force, about 1,000 strong, at Niaouré Bay, now Sackett's Harbour, had previously reconnoitred the position, and reported that success was certain. Deserters told them that 1,200 men had died at Oswego within a year. For the attack 3,000 men were now detailed, consisting of three battalions of regulars, local troops, and 250 Indians. Montcalm embarked on the 4th August with the first division, and crossed to Sackett's Harbour. He moved only at night, hiding in the day on Wolf Island. The other divisions followed, and all were united by the 8th. On the following day the Canadian force, previously at Niaouré Bay, marched to protect the landing, covered by the universal forest. Montcalm followed, coasting the shore, and landed within half a league of Fort Ontario at midnight on the 10th. Here they landed and bivouacked, not being discovered till the morning. Two armed vessels were then sent to cannonade them, but were driven off by the heavier artillery of the French. 1756.

Old Oswego stood close to the lake and on the left bank of the river. It consisted of the old trading house, surrounded by a wall, both of rough stone laid in clay. On the south and west an outer line of earthworks had been thrown up, and provided with guns. A quarter of a mile further west was an unfinished stockade, held by 150 Jersey men. Unfortunately, nothing had been done to strengthen the east side of Old Oswego, as labour had been hard to get, and on the opposite bank of the river, and within 500 yards, was Fort Ontario. This was a timber fort, mounting eight small guns and a mortar, and garrisoned by 370 men. It was now attacked by 26 guns, and as defence was hopeless, the garrison was ordered by signal to withdraw across the river into Old Oswego. By daybreak Montcalm had 9 guns mounted on the high ground on the east bank, and 11 more on the spot. On the east side the work was defenceless, but a shelter of pork barrels was improvised, and some light guns mounted behind them. Early in the morning the Canadians and Indians were sent across the river to surround the place. Their wild yells and firing, added to the fall of the British commander, and the fright of the women—more than a hundred in number—produced a panic, and the white flag was hoisted. Vaudreuil put it down to the hideous howlings of his men. The Reverend Father Claude Godfrey Cocquard was reminded of the fall of Jericho before the shouts of the Israelites. Vaudreuil took about 1,600 prisoners, including sailors, labourers and women. The British lost 50 killed, the French not so many. The victors carried off 100 light guns and swivels, burned vessels and forts, and so departed, leaving the place a desert. Two monuments were, however, erected. The priest Piquet planted a tall cross, with the inscription "In hoc signa vincunt," and the military authorities placed a pole hard by, bearing the arms of France, and the motto, "Manibus date lilia plenis." The force returned to Montreal, hung the colours in the churches, and sang the "Te Deum" in honour of their success.

1756. Some British scouts arrived to find the place still burning, and the news filled New England with despondency and alarm. Montcalm had decisively checked the whole scheme of campaign. Amid the confused wranglings of the nine states one thing was clear, Canada must be conquered. But though agreed on this essential point, the four New England states alone were bent upon earnest war, and even one of these solely in order to extort concessions from the governor. Loudon had now about 10,000 men cantoned between Albany and Lake George, he himself being at Fort Edward. Montcalm was at Ticonderoga with 5,300 men in a secure position. At Fort William Henry were 3,000 under Winslow, who employed them in forming an enormous abatis. Meanwhile, New York, New Jersey, Pennsylvania, Maryland, and Virginia were in the throes of an Indian war. Their borders were dotted with posts manned by bands of disorderly partisans, and their main dependence was placed upon monetary rewards for Indian scalps. Vaudreuil for his part had no regret for the cruelties of such a war, as his policy was to drive the British into making peace. Round Ticonderoga as a centre circled a partisan warfare of the most virulent type. On the 1st November the French began to move towards Canada, leaving five or six companies at Ticonderoga. Their example was followed by Winslow's men, and 400 regulars were left at Fort William Henry. Philadelphia, New York, and Boston all raised difficulties regarding the provision of quarters for the troops, and during the long dispute the sufferings of the men were severe; but Loudon at last used threats and the difficulties then disappeared.

1757.

Hostilities did not this year cease with winter. An expedition was sent from Fort William Henry in January, down the ice. It was attacked, and the discovery was made that there were at Ticonderoga some 350 regulars and 200 Canadians, besides Indians. It was further ascertained that the French intended to cut the British communications. In March Fort William Henry, with its garrison of 346 men, was attacked by 1,600 French, who came down the frozen lakes. Repeated assaults resulted in the burning of frozen-in sloops and boats, as well as the outbuildings of the fort—the storehouses, hospital, saw mill, and the rangers' huts. No more, however, was effected, and the French had to retreat.

In this same month a reinforcement of 2,400 men for Canada was detailed in France; and the announcement was followed by news of a great English expedition. If directed against Louisbourg there was nothing to be done, for Canada could not pretend to help. If against Quebec, all troops in the colony would be required, and all offensive action must be abandoned. France sent three separate squadrons across the Atlantic to Louisbourg, the conjectured point of attack. Political affairs in England caused delay, and the expedition of 15 line and 3 frigates, under Holbourne, with 5,000 troops, did not start till the 5th May. It then sailed for Halifax, where it was to be reinforced from America. Loudon had drawn the best part of the troops from the northern frontier, and was at New York awaiting embarkation. Though delay was annoying, he was unwilling to start without news of Holbourne, for a superior French fleet had been seen off the coast. But the season grew late, and Sir Thomas Hardy agreed with him that the risk must be run. Accordingly they sailed on the 20th June, and arrived at Halifax on the 30th. Holbourne had not yet appeared, but his ships began to straggle in, and by the 10th July all had arrived. The troops were landed, now 12,000 all told, but delays still continued. Louisbourg was partially reconnoitred, and an attack was decided. On the 4th August the troops were embarked. Letters from a captured French vessel were, however, brought by a sloop, showing that there were at Louisbourg 22 line, and several frigates, the greater number having arrived a month before Holbourne reached Halifax. The garrison had also been increased to 7,000 men. On this the enterprise was at once abandoned, and Loudon returned to New York. Being reinforced by 4 ships, Holbourne steered for Louisbourg, in the hope that de la Motte would come out and fight; but the French admiral was too wise. A gale rose suddenly while Holbourne was off a lee shore. One ship was wrecked, and the others were only saved by a sudden shift of wind. Nine were dismasted, and not one remained fit for action. 1757.

The scheme was Loudon's, and had it been energetically carried out it would have succeeded; but it was none the less wrong. Nothing could have excused the weakening of the frontier force in the face of an active enemy. The opportunity was seized by Montcalm, and he prepared for a decisive attack on Fort William Henry. In May he had 2 battalions at Ticonderoga; and on the outlet river from Lake George 4 battalions, besides colonial troops, Canadians, and 2,000 Indians; in all, 8,000 men. At the end of July they

1757. took 200 men out of a reconnoitring party of 300 provincials sent from Fort William Henry, and some of them were eaten by the Ottawa Indians, allies of the French. Here it may be remarked that Montcalm was not proud of his allies, that he detested the necessity for their use, and that he personally made every effort to restrain them, particularly after a success. A French dash at Fort Edward by 150 Indians resulted in the pickets being driven in. Leaving a detachment at Ticonderoga, Montcalm moved against Fort William Henry. Early in the afternoon on the 1st August he advanced with 6,000 men and 1,600 Indians, and reached the head of Lake George on the night of the 2nd. Near the west end of the head, and close to the lake, stood the fort—a square bastioned work mounting 17 guns besides mortars. It was constructed of a framework of logs filled with earth; the ditch was palisaded; and in the interior, lining the curtains, were four two-storey barracks having bombproof cellars. To the east of the fort was a marshy valley with a stream; then a rocky promontory with the intrenched camp; and then another marshy valley, with its stream entering the lake at the eastern corner of the head. The garrison of the fort numbered 2,200 men under Colonel Monro, including sailors and mechanics; at Fort Edward there were 1,600 under General Webb; and some 800 were in the rear at Albany and the intervening posts. Webb now applied for the New England militia to be called out, but did not move himself. This he refused to do till reinforced, despite the entreaties that came from Fort William Henry, for he probably realized that his force alone remained between Montcalm and New York. On the night of the 4th August the trenches were opened. La Corne and Lévis invested the place on the south, while Montcalm encamped on the west side of the lake, in rear of the siege works. By the 7th the besieged had 300 casualties, and smallpox was raging in the fort, while 7 light guns alone remained fit for service. The attack had 31 guns, and 15 mortars and howitzers. The fort capitulated on the 8th, and the sick were butchered by the Indians, notwithstanding Montcalm's precautions. The British column was also attacked on the evacuation and retirement, the war-whoop being started by Christian Indians. Order was at length restored, and Montcalm rescued more than 400 men from his allies. The refugees were then strongly guarded till the 15th, when they were sent to Fort Edward. On the day after the massacre the Indians decamped, and set out for Montreal with some 200 British in their hands. In the town of Montreal they cooked one, forced his comrades to eat of him, and made mothers to eat of their children. After destroying the fort and barracks, Montcalm retraced his steps. 1757.

For his apparent remissness in following up the success, he was blamed by Vaudreuil, but without cause. His Canadians were bound to be on their farms in September for the harvest, and even had this not been the case he could have done nothing against Fort Edward without artillery, while of transport he had none. On the last day of August Loudon arrived at New York and learned that Montcalm had withdrawn. Throughout this period Webb had remained at Fort Edward, the militia had been called out, and after the fall of Fort William Henry they began to arrive. Thousands congregated round Fort Edward, disgusted and mutinous. There was no camping equipment for them, and no prospect of a fight, and they were disbanded on the 17th August. The only satisfaction the British had in this disaster was that the Indians suffered much from small-pox, owing to their having dug up and scalped the corpses in the graveyard of Fort William Henry. These beasts were loaded with favours by Vaudreuil in the very midst of the horrors they perpetrated in Montreal. However, he bought the surviving prisoners from them for two kegs of brandy each, and took great credit to himself for so doing.

1758.

Petty warfare continued round Ticonderoga in winter, and out of a British scouting party of 180 men only 20 escaped; but more important operations were at hand. In the preceding year Pitt had joined the government, and the one War Minister of the epoch was quick to seize the reins of power with a firm hand. His scheme was first to take Louisbourg as a step towards Quebec, then Ticonderoga, lastly Fort Duquesne. Loudon was re-called, but Abercromby was allowed to remain and attack Ticonderoga with the aid of Brigadier Lord Howe. The Duquesne expedition was given to Brigadier John Forbes, and Louisbourg to Amherst. Under Amherst were three brigadiers, Whitmore, Lawrence, and Wolfe. The last had distinguished himself in the Rochefort expedition. Boscawen sailed for Louisbourg with 41 ships, and transports with about 12,000 men, besides officers; and effective naval measures were taken to prevent the reinforcement of that fortress. The French squadron detailed

1758. for this service was divided between Toulon, Cartagena, and Brest, and of these the Brest detachment alone succeeded in reaching Louisbourg, where, however, they did not remain. Transports and storeships had also been collected at Rochefort, Bordeaux, and other ports; but their escort was defeated by Hawke, and although the Bordeaux contingent got to sea, three out of twelve, besides the escort, were taken in the Bay of Biscay. Sailing on the 18th of February, Boscawen reached Halifax on the 9th May. On the 28th the expedition started for Louisbourg, 157 sail, the number of effectives being reckoned at 9,900 men. On the 2nd June he reached Gabarus Bay, and found the question of landing to be a serious matter. The only accessible places were Kennington Cove, Flat Point, and White Point; while there was one inlet on the east side also available for landing. The troops were formed into three divisions, two advancing on Flat Point and White Point, while a detached regiment made a feint on the east side. The third division, under Wolfe, was to make the real attack, and force a landing at Kennington Cove, the place most strongly defended of all, as afterwards appeared. The weather prevented any attempt till the 8th, when the troops landed at daybreak under cover of seven frigates. When close to the beach Wolfe received a sharp fire from some 1,000 French hidden by an intrenchment, and also from eight guns. He signalled to sheer off, but three boats of light infantry under young officers pushed on, and he supported the movement. The surf was heavy and some boats were stove, but the landing was effected and the nearest battery stormed, with a loss of 109 killed, wounded, and drowned. The advance of the other divisions forced the French to abandon their guns and intrenchments, and some 70 were taken and 50 killed. The rest circled round to the fortress.*

After having been a stone quarry for a century, Louisbourg is now a deserted ruin. At this time it was the strongest place in America, but the works were incomplete, and the masonry of the ramparts so bad in places that it had been replaced with fascines. The circuit of the works was more than $1\frac{1}{2}$ miles, and there were about 4,000 inhabitants. The garrison consisted of 3 regular battalions, a battalion of Volontaires Étrangers, 2 companies artillery, and 24 companies of colonial troops; in all, 3,080 rank and file. Of

* In the attack of 1745, the fleet anchored off Flat Point. A landing there was prevented by the fortress troops; but the division landing in Kennington, or Freshwater Cove, effected their purpose before the French had time to oppose them.

these 2,900 were effective at the commencement of the siege, and there were also some armed inhabitants and Indians. The works mounted 219 guns and 17 mortars, the most important being the Grand battery on the inner shore of the harbour, and the Island battery at the entrance. The land front was about 1,200 yards in length. In the harbour were 5 line and 7 frigates, carrying 544 guns and 3,000 men, and having more than a year's supply of provisions for the place. Their crews were landed, but do not appear to have taken part in the defence. **1758.**

Amherst camped out of range, and the guns and stores were landed at Flat Point Cove. The surf did not admit of any of the guns being got ashore till the 18th. The French abandoned Grand battery, and the battery at Lighthouse Point. It would be interesting to know why they made no effort to retain the Point, for its possession was all important to the attack. As it was, Wolfe moved round with 1,200 men, and mounted guns there against the Island battery, silencing that work on the 25th, when he strengthened his posts and returned to the main attack on the land front. Now that the Island battery was silenced, the harbour could be easily forced, so Drucour sank four large ships at the entrance, and subsequently sank two more.

In the meantime Amherst had been organizing the land attack. The limits of the siege field were practically determined by the marsh, and though this was avoided as far as possible, the communications to the left attack had to be carried through it. This attack was taken in flank by the small frigate *Aréthuse* from a station close to the bar of the Barachois. On the 25th Amherst made a lodgment on the hillock within half a mile of the works, and commenced the approaches. On his return from the other side of the harbour, Wolfe started the right attack on the hillocks close to the sea, and was attacked on the night of the 9th July by 600 men. Though driven back to the second line, the English finally repulsed the French, with severe loss on both sides. Some days before there had been an unsuccessful sortie against the left attack. The *Aréthuse* was now withdrawn, her shot-holes plugged up, and in the night of the 14th she was towed through the obstructions, and set sail for France.

On the 16th July the troops of the left attack seized a hillock called the Gallows' Hill, and intrenched themselves within 300 yards of the Dauphin's bastion. Five days after they opened another parallel within 200 yards. This day, the 21st, one of the French

1758. ships was set on fire by a shell, and blew up, firing two others. Three of the five now remaining were thus destroyed. The two left were taken by boat attack on the night of the 24th; one got aground and was burned, the other being towed safely out. The land front had now but four serviceable guns, while the attack mustered forty. On the 26th the last gun was silenced, and there was a practicable breach. The governor, Drucour, the military and the naval commanders, proposed a capitulation; but this was refused, and a surrender insisted on. To this they would not consent, but the governor was induced to do so by the Intendant, as representing the 4,000 civil inhabitants. Including officers and sailors, the garrison numbered 5,637 men, who were sent to England in August as prisoners of war; 221 guns, 18 mortars, and a quantity of arms and stores were found in the town. Whitmore was left in command with four regiments. Dalling was sent to occupy Fort Espagnol, now Sidney; Monckton was sent to reduce the French settlements on the St. John and the Bay of Fundy; and Lord Rollo with 3 battalions received the submission of Isle St. Jean, now Prince Edward's Island, and tried to remove the inhabitants, though he only managed to catch 700 out of 4,000.

Wolfe was anxious to follow up the success by a dash at Quebec, but Boscawen was against the idea, and Amherst thought the first step should be the reinforcement of Abercromby. Wolfe, with three battalions, was therefore, sent to destroy the settlements at Gaspé and other places on the Gulf of St. Lawrence, after which he returned to England, while Amherst sailed with six regiments for Boston.

In 1757 Loudon had called on the colonies for 4,000 men; this year Pitt asked for 20,000, on the condition that they would have only to provide for clothing and pay, and that Parliament would be asked to vote some compensation for this. In June, the British force was assembled at the head of Lake George—6,367 regulars and 9,034 provincials, including officers. Abercromby was in command, assisted by Lord Howe, the virtual chief. On the 4th July they started to the attack of Ticonderoga in 900 bateaux, 135 whale-boats, and with a number of heavy flatboats for the artillery. They reached the north end of the lake, about 40 miles, in a day and a half, and then landed for the march. In the thick forest the columns got confused, and the guides lost their way.

Montcalm had been left at Ticonderoga with a force less than one-fourth of the British strength, and Vaudreuil had intended to create a diversion by a raid into the Mohawk valley by Lévis with 1,600 men, when joined by as many Indians. Some captive rangers, however, stated that Ticonderoga was to be attacked by 25,000 or 30,000 men, and Vaudreuil abandoned his plan, ordering Lévis, who was still at Montreal, to reinforce Montcalm. There ensued a long delay, during which Montcalm was left to himself. What was best to do was doubtful, and he found it a difficult matter to decide whether to remain at Ticonderoga or fall back to Crown Point. On the 5th July he heard of the embarkation, and ordered a battalion to throw up a breastwork and abatis on the high ground in front of the fort. **1758.**

The landing and advance of the British had cut off the retreat of a party of 350 French who had been observing their movements, and the party took to the woods. On their way back, they fell in with the British main body, headed by 200 rangers, accompanied by Lord Howe. The advanced guard of two regiments and a party of rangers were at no great distance in front, and the French were taken between two fires. Some 50 escaped, and 148 were made prisoners. In numbers, the British lost few, but Lord Howe was killed, and in him they lost the whole expedition. The general was incapable, and there seemed no one of the requisite calibre to succeed Howe in acquiring the art of forest warfare, in ensuring discipline, or in securing the affection and admiration of the men.

Abercromby kept the army under arms all night, and after a cautious delay reached the falls on the outlet river of Lake George, about two miles from Lake Champlain. On the point between the river and the lake stood Ticonderoga. Inland from the fort the ground falls a little, and then slowly rises for about half a mile, when it begins still more gradually to fall again. On this ridge was the breastwork and abatis already mentioned, and here, at last, Montcalm decided to make his stand. At dawn on the 7th July, when Abercromby was afraid to advance till advised the way was open, the whole French force was set to work on a timber parapet, between eight and nine feet high, following the contour of the ridge. To the distance of a musket shot, trees had been felled and left lying, and the stockade itself was surrounded by a formidable abatis.* The French had provisions for only eight days.

Abercromby had been told by prisoners that Montcalm had 6,000

* These lines are shown in the plan of Ticonderoga inserted in the account of the proceedings in 1759.

1758. men, and that 3,000 more were hourly expected, so that he was in haste to attack. General and army were infatuated with an idea that that sort of obstacle could be carried with a rush. Without trying to take the breastwork in rear, without waiting for his guns, Abercromby ordered an assault. Notwithstanding his anxiety to attack, due to false information, it is difficult to understand how he could have expected an assault to succeed over such ground, to say nothing of the parapet itself. The first assault was repulsed after an hour's attempt, some men managing to reach the foot of the log wall. A second similarly failed. Early in the action Abercromby tried to turn the French left by sending 20 bateaux down the outlet river. They were met by the fire of the Canadians stationed on the low ground on that side, and so unfortunately moved on. This brought them under fire of the fort, and two were sunk, while the rest were driven back. Later on a third assault was delivered, and Captain John Campbell and some men of the 42nd climbed the log wall, and were bayoneted inside. In an hour another vain attempt was made, and then followed a lingering fire till twilight came on, with the object of covering the parties bringing off the wounded, and of protecting the retreat of the troops to the falls. Abercromby lost 1,944 officers and men. On the night of the 7th, Montcalm had been reinforced by Lévis with 400 regulars, raising his force to 3,600 effectives, and his loss was 377. The British retired in disorder to the head of Lake George, leaving behind them several hundred barrels of provisions, and a quantity of baggage. Abercromby even sent orders to the commander at Fort William Henry to send the sick and the heavy artillery to New York, though he himself arrived too soon for the order to take effect. Here a great intrenchment was constructed, and many of the troops sent to the Mohawk, others to the Hudson. The time was passed in levelling the French siege works, and in jealousies between the regular and provincial troops. The supercilious superiority of the English officer, and the prejudiced pride of the provincial, had their effect in hastening the struggle for independence.

While at one end of the lake Abercromby's force was being weakened by detachments and disease, at the other end Montcalm was receiving reinforcements, and was at length in a position to assume the offensive. He was content, however, with strengthening the fort at Ticonderoga—Fort Carillon as the French called it—and with re-constructing the lines he had defended so well; at the same time sending out raiding parties who were generally more or less successful. One of them took a convoy, and Abercromby sent the celebrated ranger Rogers to cut off the enemy ; but the French had retired quickly, and Rogers was too late. When camping, on his way back, he indulged in a rifle match, and the sound brought down a party of 450 French and Indians. About 7 p.m. Rogers and his 700 men continued their march through the forest, necessarily in single file, first the Connecticut men, then a "small" force of light infantry (probably one, or at most two, companies), and then Rogers with his 80 rangers. They marched into an ambush and lost 49 killed, continuing their march after the French had given way. A party sent from the fort buried more than 100 French and Indians. 1758.

A more important expedition had meanwhile been accomplished. At the instance of a council of war, Abercromby had approved of an attack on Fort Frontenac, and had given Bradstreet for the purpose 3,000 men, nearly all provincials. Bradstreet moved to Oswego, and was joined by a few Indians. On the 22nd of August the expedition started in whale-boats, and three days after landed near the fort. On the night of the 26th, Bradstreet made a lodgment within 200 yards, and early in the morning the garrison surrendered; in all 110 soldiers and labourers. The whole naval force of nine armed vessels was also taken, as well as a great quantity of stores. Sixty guns and 16 mortars were taken in the fort, the fort was dismantled, the buildings burnt, and Bradstreet then returnéd. Had he been able to hold the place, the command of Lake Ontario might have passed to the British ; nevertheless, the advantage was great ; many of the Indians henceforward stood neutral or declared for England, and Fort Duquesne was deprived of supplies.

Early in October Amherst came with five regiments from Louisbourg to join Abercromby, and the two commanders decided it was then too late for Ticonderoga. In a fortnight news was brought that Montcalm was breaking up his camp, and Abercromby followed his example.

In April Brigadier John Forbes was at Philadelphia organizing the expedition against Fort Duquesne. The men had not yet been enlisted, and an expected battalion of Highlanders had not arrived. It was the end of June before they were all on the march, and meanwhile the General had been seized by an internal inflammation that prostrated him during the advance and return, and killed him three months after his arrival at Philadelphia. To reach Fort Duquesne, two routes were possible. One was to march direct, cutting a new road through the forest, the other was to march 34

1758. miles to Fort Cumberland, and thence to follow Braddock's road. Pennsylvania and Virginia had rival interests in the matter, and dispute was keen. Washington foretold disaster unless Braddock's road was taken, but Forbes pronounced against it. His plan was to make a sure but slow advance, fortifying supply depôts on the way. The delay caused by this mode of progress was calculated to weaken the Canadian and Indian forces through desertion, and to give time for a persuasive policy to act on the various Indian nations now allied to the French. But this very delay barred a movement by Braddock's road, as the autumnal floods would have rendered the rivers impassable. The force consisted of 1,200 Highlanders, a detachment of the Royal Americans (a four-battalion regiment), and provincials from Pennsylvania, Virginia, Maryland, and North Carolina, amounting with transport and camp followers to between 6,000 and 7,000 men. The advance guard was commanded by Colonel Bouquet, of the Royal Americans, a Swiss ; and early in July he was at Raystown, while Forbes was leaving Philadelphia for the frontier. Road-making over the main range of the Alleghanies proved heavy work, and the parallel ridge of Laurel Hill turned out to be worse. Not only was the ground exceptionally difficult, but the whole was covered by a forest in which "nowhere could one see 20 yards." Having secured his magazines at Raystown, and built a fort there called Fort Edward, Bouquet, in September, moved on 40 miles across the Alleghanies, and commenced another post within 50 miles of Fort Duquesne. Forbes had been in total ignorance of the French strength ; but a party reconnoitred the French fort in August, and reported that the estimates of their force were much exaggerated. Vaudreuil wrote home at first full of confidence. He had ordered troops from Niagara, Detroit, and Illinois, and also the western Indians. When peace came he would build a stronger fort. Later on he grew nervous, and feared the English would not attack till the Indians had tired and gone home.

Meanwhile the Indians were being converted by a Moravian, by name Christian Frederic Post, who had gone to them as envoy. The task was full of danger, but it succeeded, and in October a convention was held, resulting in a joint message of peace being sent to all the tribes of the Ohio. The Delawares, Shawanoes, and Mingoes declared for the English, and this was the more disheartening to the French, seeing they had scored a success some weeks before. A Major Grant, of the Highlanders, had induced Bouquet to give him 800 men for a reconnoitring raid on Fort Duquesne. On the 14th September, at

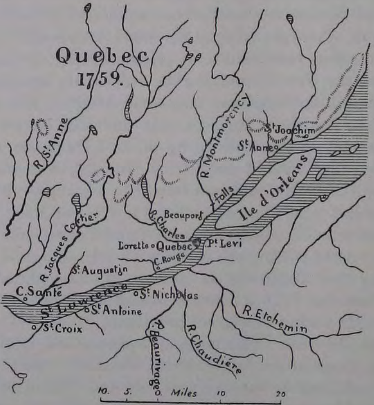
2 a.m., he reached a hill thenceforth called Grant's Hill, and divided his force into four parties. Thinking his position secure, and that the French were too weak to attack, he beat his drums ; the French came out, routed one detachment, and rolled back upon Grant the remains of this one and of another. Grant in his turn was defeated, and the baggage guard retreated. He himself was taken prisoner, and his force lost 273 men killed, wounded, and prisoners. Although the French pushed their advantage well, raiding up to Bouquet's camp, their position was getting desperate. The militia of Louisiana and Illinois, the Indians of Detroit and the Wabash, left for home in November. The supplies for Fort Duquesne had been destroyed at Fort Frontenac, compelling Ligueris to dismiss the greater part of his force. **1758.**

The road across the Alleghanies, constructed with so much toil, was rendered impassable by exceptional rains, and it was not till the beginning of November that Forbes was carried to the second camp, Loyalhannon, where the troops then were. A council decided to do nothing more that year ; but some prisoners reported the defenceless condition of the French, and Forbes ordered an advance. On the 18th November 2,500 picked men started with a few of the light guns only, and without baggage. At midnight on the 24th they heard the sound of the blowing up of Fort Duquesne, and arrived the next evening to find only a few Indians, who said that the garrison of 400 or 500 men had retired to Venango. Barracks and storehouses had been burned, and the fort blown up, so a stockade was planted round a cluster of cabins, and Forbes called the place Pittsburg. After putting the work into a tolerable state of defence, and leaving 200 Virginians as garrison, Forbes started for home early in December. To follow the French, or even to remain there, was impossible, owing to want of provisions.

So ended the year. Frontenac, Duquesne, and Louisbourg had been taken, Ticonderoga, in the centre, remained secure. In Canada the power of France was failing. For the patient endurance of hardships incident to war, the inhabitants required success, and this was not forthcoming. Maladministration was general, the peculation had been vast. Moreover, the St. Lawrence was blockaded, and, owing to the poor harvest, flour had risen to 200 francs per barrel, and most of the cattle, with many of the horses, had been killed for food. In November, as a forlorn hope, two envoys were sent home to plead the cause of the colony to a France unfortunate at once by land and sea, and further crippled in finance.

1759.

With all their assiduous appeals, the envoys were unable to gain anything very substantial. The Colonial Minister, indeed, only replied that when the house was on fire one could not occupy oneself with the stable. However, various promotions and decorations were granted, and they obtained between 300 and 400 recruits for the regulars, 60 engineers, sappers, and gunners, and a sufficient addition of arms and stores to carry the colony through the next campaign. They arrived in the St. Lawrence in spring, and with them Montcalm received warning of an expedition fitting out against Quebec. He was also informed by the War Minister why the colony was abandoned to its fate. If a large reinforcement were despatched it might be intercepted on the way, and France



could never send forces equal to those the English were prepared to provide. Montcalm's whole energies were to be directed to secure a single foothold in North America. More he could not do; but were that footing lost, to recover the country would be almost impossible. Montcalm's reply was, "We will save this unhappy colony, or perish," and French rule in America was eventually buried in his grave. His scheme of retreat, as a last resort, was to descend the

Mississippi and make a final stand in the swamps of Louisiana. The available forces for the coming struggle comprised some 13,000 effective men in the governments of Montreal, Three Rivers, and Quebec; 3,500 troops of the line; 1,500 colonial troops; a body of irregulars in Acadia; and the militia and *coureurs-de-bois* of Detroit and the other upper posts, with from 1,000 to 2,000 Indians. **1759.**

Pitt's scheme of attack provided for an advance by way of Lake Champlain concurrently with the attack of Quebec. The two armies might thus unite, or at least a diversion be effected on behalf of Wolfe. At the same time Oswego was to be re-established, and Amherst was further directed to pursue any other enterprise that would not be detrimental to the main purpose of the campaign. Accordingly, he proposed the capture of Niagara. These expeditions may be separately considered.

Wolfe had been selected by Pitt for the command of the Quebec expedition, with Monckton, Townshend, and Murray as brigadiers. The Duke of Newcastle had told George II. that Pitt's new general was mad, and the old king had replied that if so he hoped he would bite some of the others. On the 17th February, the fleet set sail—19 line, with frigates and transports. When Saunders arrived off Louisbourg he found the entrance blocked with ice, and had to go on to Halifax. Holmes, with his squadron, had sailed a few days earlier, and proceeded to New York to ship troops. Durell, who wintered at Halifax, had steered for the St. Lawrence to intercept the ships expected from France. In May, the whole fleet was united in the harbour of Louisbourg. For the expedition, 12,000 troops were to have been employed, but the move of some regiments from the West Indies was countermanded, while the force supplied by New York and the Nova Scotia garrisons was less than had been expected. The actual number employed was somewhat less than 9,000 men. On the 6th June, the last ship left Louisbourg harbour for the St. Lawrence.*

Durell's blockade had not proved effectual. In May, 18 ships of

* In 1690 Sir W. Phipps was sent against Quebec with 34 sail, and an army of colonists. The scheme being undertaken too late in the year, the superior officers being inexperienced, and great sickness happening among the men, the fleet returned without effecting anything, and with a loss of 1,000 men and many transports.

In 1711 Sir H. Walker sailed from Boston with 68 sail and 6,463 men against Quebec. Against the advice of the pilots they entered the St. Lawrence at night, and some went ashore in a fog. Having lost eight transports and 884 men, it was determined to abandon the attempt owing to the ignorance of the pilots.

1759. the Point—armed burghers, Canadians, Seminarists, Indians, and about 100 volunteers from the regulars. In the darkness they fired on each other, were seized by panic, and fled to their canoes.

Having secured his posts at Levi and the Point of Orléans, Wolfe set about crossing to the north shore. On the 8th July several frigates and a bomb bombarded the camp of the Chevalier de Lévis, though with little effect, owing to its elevated position. Before daybreak Townshend and Murray landed a little below the falls with 3,000 men—grenadiers, light infantry, rangers, and five battalions. On this Lévis occupied a ford higher up the Montmorenci, and posted Repentigny not far off with 1,100 Canadians. The ford was passed by 400 Indians, who sent word to Repentigny that there was a body of English in the forest, who might all be destroyed if he would come at once. Repentigny sent to Lévis for orders, and Lévis referred to Vaudreuil, three or four miles off. Vaudreuil replied that no risk should be incurred, and that he would come himself. Two hours elapsed before his arrival, the Indians grew impatient, and they attacked the rangers, driving them back on the regulars, who stood their ground. The Indians re-crossed the river with 36 scalps. Had Repentigny advanced, followed by Lévis, the consequences might have been serious, for, in the woods, one Canadian was counted as equal to three regulars. Montcalm and Vaudreuil agreed, however, that it was inexpedient to attack a force of unknown numbers and position, and Wolfe was left to intrench his position.* His three detachments were far apart, there being six miles between Levi and the falls; but the French remained on the defensive, and Vaudreuil would not hear of another attempt on Point Levi. One effect of the occupation of the falls was the commencement of desertion on the part of the Canadians.

The artillery duel continued. Quebec was abandoned and deserted, save by robbers and a few of the more courageous inhabitants. A part of the fleet had worked up into the basin, above the Isle of Orléans, and here they watched the blaze of the burning town. News of the attack on Niagara and the movement on Ticonderoga quickened desertion, and on the 19th July a deserter reported that nothing but fear of the Indians kept the Canadians in camp. On the 18th the *Sutherland*, with a frigate and some small craft, ran past the Quebec batteries at night, favoured by the wind, and covered by a heavy fire from Point Levi. They went up to the Cap Rouge river, 12 miles above

* The plate shows two French encampments. Of these, the one next the Montmorenci was Montcalm's, Vaudreuil's being next to Quebec.

Quebec, where they destroyed a fireship and some small craft. It now became necessary for Montcalm to occupy the accessible points in the line of precipices between Quebec and Cap Rouge, and he sent there 600 men under Dumas. On the next day he sent 400 more, hearing that the English had portaged boats over Point Levi, and were embarking troops above the town. Although this weakened Montcalm at Beauport, it effected Wolfe yet more, for his force was now split into four, with intervals too wide for any mutual support. On the night of the 20th, 600 men of the force above the town rowed 18 miles up the river and raided Pointe-aux-Trembles. **1759.**

As Montcalm would not come out and fight, Wolfe decided to attack him. After providing for his camp and Point Levi, Wolfe would have at his disposal less than 5,000 men, while Montcalm could collect twice that number in an hour; but Wolfe had a poor opinion of the Canadian militia. He had discovered the ford three miles above the falls, but found the opposite bank too steep, wooded, and strongly intrenched for a passage there to be attempted. Towards the Montmorenci the banks of the St. Lawrence are extremely high and steep, the falls themselves being 250 feet in height.* At a mile from the falls there is at high tide, a strand about 200 yards wide, and low tide leaves bare a strip of mud nearly half-a-mile wide. At the edge of the dry ground the French had built an armed redoubt, and there were others on the strand nearer the falls. They were under fire of the intrenchments on the brow of the heights above, but this was unknown to Wolfe. He hoped that the attack of one of the redoubts would bring on a general action, or at any rate that he would gain an opportunity for reconnoitring the heights, and determining the places most favourable for an ascent. In front of the gorge of the Montmorenci there was a ford during several hours of low tide, so that the troops landing from Point Levi and the Isle of Orléans could be reinforced. On the 31st July, the *Centurion*, 64, with two armed transports, each of 14 guns, anchored and engaged the redoubts. The two transports stood in as close as possible, and were left high and dry at low tide in the afternoon. At the same time a battery of 40 guns on the bluff east of the Montmorenci opened fire on the flank of the upper intrenchments, though without much effect owing to the number of traverses. The contingent from Point Levi appeared about 11 a.m. and moved about for some hours west of Beauport. Montcalm was at first perplexed, but soon

* They now provide power for the electric light installation of Quebec.

1759. grasped the situation and proceeded at 2 p.m. to the camp of Lévis. Towards the end of the afternoon some 12,000 men were concentrated between the Montmorenci and the river of Beauport.

At 5.30 p.m. the tide was out, and the Levi troops landed, covered by a heavy gun fire, while a mile away, a column of 2,000 men from Wolfe's camp was seen crossing the ford. The first on shore were 13 companies of grenadiers, and a detachment of Royal Americans. At some distance behind was Monckton's brigade of two regiments; but without waiting for the brigade, or even for orders, the grenadiers pushed on for the redoubt. The French abandoned it, but it proved untenable under the fire from above, and the grenadiers began to struggle up the ascent, dead and wounded rolling down the slope. A heavy rain storm came on, wetting the ammunition, and stopping the attempt, while each side claimed that the other was saved by this accident. A retreat was ordered, French and English waving their hats, and daring each other to fight, and the two transports were burned. The English lost 433 of all ranks. Vaudreuil was jubilant, Wolfe was downcast, and the grenadiers were reprimanded in general orders.

Wolfe's original intention before he had seen Quebec was to have occupied the plains of Abraham and besiege the town, but he soon found this was impracticable. To attack Montcalm seemed hopeless, and he steadily refused to be drawn out to a general action in the open. Partly in revenge for the barbarities committed by the Canadians and Indians upon sentries and outposts, partly to provoke Montcalm to attack, Wolfe raided the country round in the middle of August. St. Paul was sacked and burned, and the villages on the north shore to St. Joachim, 25 miles below Quebec, were partially destroyed. At St. Joachim there was a severe skirmish. Still Montcalm stood fast, and Wolfe now changed his plan and renewed upon a larger scale the movement started in July. With every fair wind ships and transports passed the batteries of Quebec, under cover of a heavy fire from Point Levi, and generally succeeded with more or less damage in gaining the upper river. A fleet of flatboats was also sent there, and 1,200 troops marched to embark in them under Murray. Admiral Holmes took command of the fleet now collected above the town, and operations in that quarter were systematically renewed. To oppose them Bougainville was sent from Beauport with some 1,500 men, and had to guard 15 or 20 miles of shore by means of vigilance and constant marching. Murray made a descent at Pointe-aux-Trembles and was repulsed. He tried again at another place and was again repulsed. A third time he succeeded, landed at Deschambault and burned a large building filled with stores, including all the spare baggage of the French officers. Montcalm hastened to the spot, but found the English gone. Vaudreuil now wished he had not laid up the frigates, and sent the crews to again man them; but it was too late, for Holmes was now too strong, and they were re-called. **1759.**

Both parties were now in difficult plight. Dysentery and fever were rife in the English camps, and it was evident that if the work were to be done at all it must be done at once. The French were on short rations, and feared that the British operations above the town would result in their supplies being cut off, for these came from Three Rivers and Montreal. Discipline had become relaxed, and desertion constant. Early in August news came of the loss of Ticonderoga, Crown Point, and Niagara, and also of the advance of Amherst on Montreal. Lévis was sent to the rescue, and the garrison in consequence further weakened. Quebec was again fired by the batteries on Point Levi, 167 houses being burned in one night, and nearly every house in the front of the upper town was ruined. Towards the end of August it became known that Amherst was not moving on Montreal, and Bourlamaque wrote that Isle-aux-Noix was safe. On the 27th a deserter reported that the English were tiring and would soon raise the siege, thus restoring the confidence of the French.

On the 20th Wolfe fell sick, and was so far recovered by the 29th as to send a memorandum to his brigadiers, Monckton, Townshend, and Murray, in which he proposed three schemes for consideration. The first was to send a part of the force across the Montmorenci eight or nine miles above its mouth, and to fall on the rear of the French at Beauport, while the rest landed and attacked them in the front. The second was to cross the ford at the mouth, and move along the strand till an accessible place was found. The third was to make a general attack from boats at the Beauport flats. He had previously entertained two other plans, one being to scale the heights at St. Michel, about three miles above Quebec, but he had abandoned this on learning that the French were there in force. The other was to storm the lower town, but he had abandoned this because the upper town commanded it and was inaccessible. The brigadiers rejected all three, and advised that an attempt should be made to gain a footing on the north shore above the town, and force Montcalm to fight or surrender by interposing the force between him and his base

1759. of supply. The scheme was at once accepted by Wolfe, and he requested Saunders to run small craft above the town with six weeks' provisions for 5,000 men. Since June he had lost 850 killed and wounded, to say nothing of the sick, and after providing for Levi and Orléans this was the utmost force he could command.

On the 3rd September, Wolfe evacuated his camp at the Montmorenci, a threatened attack on the rear-guard being averted by Monckton, who embarked two battalions at Levi in the boats of the fleet, and feinted a landing at Beauport. On the night of the 4th a fleet of flatboats passed above the town with the baggage and stores. On the 5th, Murray, with four battalions, forded the Etchemin under fire of the batteries at Sillery on the north shore. Monckton and Townshend followed with three battalions, and the united force of 3,600 men embarked on board the ships with Holmes, who now had 22 vessels. Bougainville was reinforced, his strength being raised to 3,000 men, and he was ordered to watch the shore as far as the Jacques Cartier, his headquarters being at Cap Rouge, six miles above Sillery. Wolfe personally examined the shore as far as Pointe-aux-Trembles, and afterwards saw from the south shore a path running up the wooded precipice, and a cluster of tents at the top. This was Anse du Foulon, now called Wolfe's Cove, 1½ miles from Quebec, and the tents belonged to a post of 100 men under a Capt. Vergor, who was supported by a battalion that should have been encamped on the plains of Abraham. A little beyond his post was another at Samos of 70 men and four guns, and beyond this there was a third of 130 men on the heights of Sillery.

On the 7th the expedition was off Cap Rouge, and for five days Bougainville was harassed and wearied by the incessant movement of vessels and boats, necessitating his keeping up a ceaseless forced march. It is related that on the 10th September the naval commanders decided that the fleet must leave without delay, and that Wolfe gained a respite on the ground that he had found a place where the heights could be scaled. He proposed, therefore, to send up 150 or 200 men; if they gained a lodgment the rest would follow, if not he would abandon further attempt. On the 12th the attempt was made, 1,200 men being drawn from Levi and Orléans, and his force consequently raised to 4,800 men. In the evening Admiral Saunders co-operated by bombarding the Beauport camp, and Wolfe sent off 1,700 men to effect a landing and secure the heights. Success hung upon the following chances:—Deserters had brought news that provision boats were going down to Quebec at night, and Wolfe had intended they should be preceded by his boats, but the provision boats were countermanded; the sentries were not, however, told of the countermand. Vergor had given most of his men leave to go home for harvest work, he kept careless watch, and went himself to bed. The battalion ordered to encamp on the plains of Abraham remained by the St. Charles. Bougainville did not follow the boats with his weary troops, thinking they would return as usual by the flood tide. Two sentries in succession were deceived by French replies. **1759.**

At 2 a.m. the boats started, and reached their destination in about two hours. The 24 volunteers climbed the cliff and surprised the post, the sound of firing and cheers signalled success, and the remainder followed. The path had been obstructed, but was cleared. Troops now followed from the ships, and Wolfe sent a party to take the batteries at Samos and Sillery, as they were firing on the boats. At daybreak he formed up his force of 3,500 men on the plains of Abraham, here less than a mile wide. Quebec was not a mile off, though hidden by a ridge of broken ground about 600 paces distant. At 6 a.m. this ridge was occupied by the missing French battalion from the St. Charles. Some time after there came a sound of firing from the rear, where a detachment of Bougainville's command had attacked a house, but were repulsed. The firing at Samos aroused Montcalm, and failing to get word from Vaudreuil, he rode up at 6 a.m. When at Vaudreuil's quarters he saw the English some two miles away, and ordered up the troops. Vaudreuil did not come, nor did the troops from the French left at Beauport, nor the garrison of Quebec. Had these joined, his force would have been strengthened by 2,000 or 3,000 additional men. Bougainville was but a few miles distant, and some of his troops were much nearer; a message could have reached him in an hour and a-half, and a combined attack in front and rear concerted. But Montcalm and his officers were for no delay, a fight was inevitable and the sooner it came the better, before the English were reinforced, or the Canadians further discouraged.

Out of 25 field guns demanded, the commandant of Quebec supplied three, saying he required the others for his own defence. Montcalm sent out 1,500 Canadians and Indians to skirmish on the front and flanks of the English line, and opened fire with his three guns. Towards 10 a.m. the French were formed in three columns for attack, and their advance was stopped by volleys at 40 yards, rank by rank. The English then charged and the French broke.

1759. The sharpshooters, however, kept up their fire from the bushes, corn-fields, and broken ground, till driven out with much loss. Wolfe received three shots, the third proving mortal. Montcalm was carried by the ebb of fugitives towards the town, and was shot. Wolfe's body was embalmed and sent home, Montcalm was buried in a shell crater in the chapel of the Ursulines. While it is almost unique for both commanders in a battle to be killed, it is certainly without parallel for two such noble natures to be pitted against each other, and for both to be simultaneously slain.

The rout had just begun when Vaudreuil crossed the bridge from Beauport, four hours since he first heard the alarm two miles from the battlefield. He re-crossed the bridge and joined the militia and crowd of fugitives at the bridge-head. A cry was raised to cut the bridge, but the sacrifice of half the force was prevented by a few officers who had not lost their heads. Montcalm sent word that there were three courses open: to fight again, retreat to the Jacques Cartier, or surrender the colony. Bougainville had 3,000 men; 1,500 were in garrison in Quebec; between 500 and 1000 men of the Beauport camp had not been engaged; and the defeated force would raise the total to some 10,000 men. Policy seemed to dictate a junction with Bougainville and a resumption of the offensive; but at 9 p.m. Vaudreuil commenced a retreat to the hill of Jacques Cartier, on the St. Lawrence, 30 miles off. He left orders for the commandant of Quebec not to await an assault, but to surrender when provisions failed.

The English under Townshend, for Monckton was wounded, intrenched themselves on the battlefield. At noon Bougainville appeared with 2,000 men, but withdrew on seeing the force. By midnight Townshend had made the position strong, and brought up his guns. The victory had cost them 664 all told. According to Vaudreuil the French loss was 640, or 1,500 according to the English official report.

Vaudreuil had sent a messenger to Montreal to bring up Lévis, who induced him to march the army back to relieve Quebec. Bougainville had remained fast at Cap Rouge, and sent 100 mounted Canadians with biscuit round to Beauport, whence they could reach the town by canoes; he himself followed with a large supply. Vaudreuil sent to the commandant revoking his order to surrender, and it was hoped that all would be well. On the 18th the French marched to St. Augustin and there learned that the city had surrendered. The party sent to Bougainville had arrived just as the signed articles had been despatched, the terms of which provided for the garrison being sent to France. 1759.

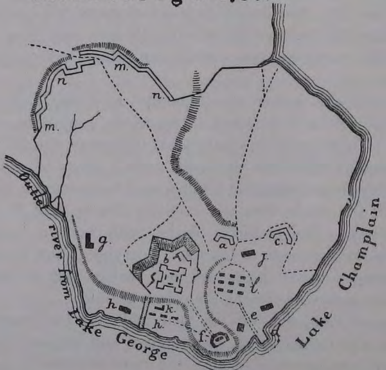
Townshend at once set to work to strengthen the defences, and Saunders deferred his departure longer than he had once judged possible. It was past the middle of October when he started down the river with the marines, Louisbourg grenadiers, and some of the rangers. To defend Quebec there remained 10 battalions, with the artillery, and one company of rangers. Monckton and Townshend returned home, and Murray took over the command. He at once proceeded to repair the ruins, built eight advanced timber redoubts, and formed a magazine of fascines. The French returned to Jacques Cartier under Lévis, and Vaudreuil went to Montreal, where he occupied himself in vilifying the memory of Montcalm. On a dark night late in November, the French ships attempted to escape down the river past Quebec. Seven or eight succeeded, four ran ashore and were fired by their crews, and one was stranded and abandoned. She was boarded by two officers with 40 men, and blew up, killing most of the party at once, while the others suffered a lingering death.

In England the despairing despatches of Wolfe had produced a prevalent dejection that found utterance in grumbling against the Ministry. Then came the unexpected tidings of the fall of Quebec, and the sudden revulsion produced such a mass of addresses that Horace Walpole declared the King would have enough to paper his palace. Of the whole dramatic situation the death of Wolfe was the fitting climax. The country blazed with bonfires, and he was elevated to the pantheon of heroes. Everyone knew he had practically reduced Canada; they did not realize that he had secured potential independence to the American colonies.

The plan of campaign for the year included, besides the capture of Quebec, the reduction of Ticonderoga and Crown Point, and a subsequent invasion of Canada; the re-establishment of Oswego; the strengthening of Fort Duquesne, now Pittsburg; and other contingent operations. Amherst decided to send Brigadier Prideaux against Niagara, Brigadier Stanwix to Pittsburg, and to march himself against Ticonderoga, Crown Point, and Montreal. Towards the end of June he reached the head of Lake George, where 11,000 men had been concentrated, half regulars and half provincials. Fortified posts had been built along the road to Fort Edward at intervals of three or four miles, and on the site of the intrenched camp by Fort William Henry he commenced Fort George, of which one

1759. bastion alone was ever finished. The force embarked on the 21st July, landed at daylight, drove back a French detachment, and marched by the portage to the falls. There was little resistance and they occupied the heights. The intrenchments that had repulsed Abercromby were found to have been re-constructed; they were, however, not defended, though Amherst had fewer men than his predecessor, while Bourlamaque had a force nearly equal to that of Montcalm. Amherst brought up his guns and began his approaches, when on the night of the 23rd it was found that Bourlamaque had retired, leaving 400 men. Vaudreuil had ordered him to retreat to Isle-aux-Noix and there defend himself to the last. The siege continued to the evening of the 26th, when deserters reported the garrison was escaping and a match laid to the magazine. At 11 p.m. it blew up, destroying one bastion, and the fort was then occupied.*

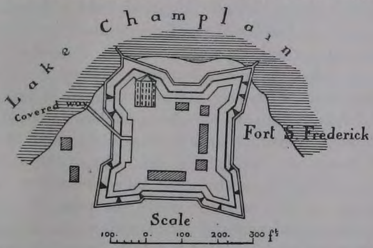
Ticonderoga 1759.



a. Stone battery. b. The Fort. c. Earth battery d. Wharf. e. Stone houses for naval stores. f. Redoubt. g. battery. h. stonehouses for prisoners. j. Limekilns. k. nine Ovens. l. gardens. m. French lines. n. batteries.

* Defensive works were first erected at Ticonderoga by Captain Glen in 1690. Dieskau occupied it in 1754, and Montcalm built Fort Carillon in the following year. Abercromby's defeat here in 1758 has been described, as also the abandonment of the position by the French in 1759.

In 1775 it was surprised and taken by 85 New England men under Arnold, Amherst was preparing for an advance on Crown Point when, on the 1st August, he learned it was abandoned, and accordingly occupied it. Here he commenced a new fort a few hundred yards off, with three small detached works, sent out exploring parties, cut a road to Charlestown, on the Connecticut, and improved the road to Ticonderoga. The delay was fatal to the idea of effecting a diversion in favour of Wolfe, but it appears to have been due to the French naval force on Lake Champlain. This consisted of four armed vessels, and owing to the want of ship carpenters, autumn was well advanced before the English were ready with a brigantine, a floating battery, and a sloop. On the 11th October they sailed, and the French vessels made off. One reached Isle-aux-Noix, one was run aground, and two were sunk by their crews. Leaving the provincial troops at work on the fort, Amherst embarked the regulars in bateaux and proceeded north, but on the evening of the 12th a head-wind rose to a gale, and he was driven to take shelter. On the 17th it blew as hard as ever and frost had come, so he came to the conclusion that it was too late, and returned to Crown Point.* Bourla- 1759.



when 48 soldiers surrendered and 174 guns were taken. In 1777 St. Clair held it with 3,446 men and 47 guns; but Burgoyne forced an evacuation by a bombardment from Mount Defiance, on the opposite side of the outlet river from St. George, and St. Clair's rear-guard was defeated. Ten weeks after the Americans recovered it with 1,000 men, 293 prisoners being taken, and 100 American prisoners released. With the place were taken 200 bateaux, an armed vessel, and 5 guns. The fort was dismantled a few weeks later, and in 1780 the position was re-occupied by Haldimand with troops from Montreal. Since that time Fort Ticonderoga has been deserted, but the name is generally retained in the American navy.

* Samuel de Champlain, with two Frenchmen and 60 Hurons, landed here and defeated a party of Iroquois in 1609. In 1631 the French occupied the opposite point, Point à la Chevelure, and built a stone fort mounting 5 guns. A century later they built Fort St. Frederick upon the steep bank of the lake, a square stone bastioned work mounting 62 light guns, and enclosing barracks, a church, and a bombproof tower. The place is now deserted, but there was

1759. maque was still at Isle-aux-Noix with 3,500 men and 100 guns, securely intrenched in a position of great natural strength, too strong in his opinion for attack.

Before Amherst started from Crown Point he had received news of the Niagara expedition. Prideaux had been ordered to ascend the Mohawk with 5,000 regulars and provincials, leave a strong garrison at Fort Stanwix at the portage, establish posts at both ends of Lake Oneida, descend the Onondaga to Oswego, leave there nearly half his force, and with the remainder attack Niagara. These orders were carried out. In July the re-established post of Oswego was attacked by 1,000 French and Canadians, a body of Indians, and the priest Piquet, who solemnly blessed the force and told them to give the English no quarter. The place was surprised, and a reverse might have occurred had not some of the Canadians been seized by panic. As it was, the French were repulsed with the loss of 30 men. Prideaux reached Niagara and commenced the siege. The fort was garrisoned by 600 men, reinforced before the siege by the garrison of another work, a mile and a-half above the falls. The commandant, Captain Pouchot, had also hopes of further relief. In obedience to orders from Vaudreuil, the French inhabitants of the Illinois, Detroit, and other distant posts, with the Western Indians, had come down the lakes to recover Pittsburg, and restore French ascendency on the Ohio. Pittsburg had been in great danger, and it was not yet safe, though Stanwix was doing his best. These bands were now at Le Bœuf, Venango, and a large proportion at Presquisle. To these Pouchot now applied for aid. When the siege batteries opened fire, a premature mortar shell killed Prideaux, and Johnson took command. In two or three weeks the rampart was breached, more than 100 of the garrison killed and wounded, and the rest exhausted for want of sleep. On the 24th July Pouchot heard the firing of his anxiously-awaited relief.

then near the fort a village of 1,500 inhabitants. In 1759 the fort was abandoned by the French when on their retreat to Isle-aux-Noix, after their evacuation of Ticonderoga, and Amherst built a pentagonal bastioned work some 200 yards to the south-west. Including the bastions, the perimeter of the English fort was 853 yards. The ramparts were 25 feet high, and 25 feet thick, faced with masonry. The curtains varied in length from 156 feet to 300 feet. The ditch was cut in solid limestone, and furnished material for ramparts and also for the barrack blocks. Two of these still partially remain, one being 192 feet, and the other 216 feet in length. In 1773 the barracks took fire, and the magazine blew up, demolishing a portion of the enceinte. In 1775 it was taken by the Americans, and in the next year was occupied by the Americans in their retreat from the abortive attempt on Canada. In 1777 Burgoyne made it his main supply depôt for the advance on Albany.

The relieving force had left Presquisle a few days before. Vaudreuil reported their strength as 1,100 French and 200 Indians; Portneuf, commanding at Presquisle, at 1,600 French and 1,200 Indians; Aubry to Pouchot at 2,500, half being Indians; Johnson at 1,200 men, with a number of Indians. The Indians were, of course, a variable quantity, as it by no means followed that the number who started actually arrived. It may be taken that 1,200 French did arrive. Pouchot watched the action from the bastion next the lake, whence he could see $1\frac{1}{2}$ miles, as the forest had been cut away. The deserted appearance of the siege trenches invited a sortie, but on the French showing themselves along the covered-way the trenches were lined at once, and the idea was abandoned. After half an hour the fire ceased, and Pouchot remained in suspense till 2 p.m., when an Indian brought word that the French had been cut up. Pouchot would not believe him. **1759.**

Johnson had about 2,300 men and 900 Indians to guard the trenches and the bateaux, and to fight the relieving force. For the last, he detached Colonel Massey with 150 of the 46th, two companies of grenadiers, the provincial light infantry and the pickets. Parkman does not quote their strength. They took post behind an abatis with the Indians on their flanks. After a while the French broke, and nearly all their officers were killed or taken. The fugitives fled to their canoes above the falls, hastened back to Lake Erie, burned Presquisle, Le Bœuf, and Venango, and retreated with the garrisons to Detroit, leaving the English in command of the whole region of the Upper Ohio.

At 4 p.m. on the same day Pouchot was summoned to surrender, and sent an officer to ascertain the truth. This being done he capitulated, and the garrison were sent prisoners to New York. They specially feared revenge for the massacre after the fall of Fort William Henry; but Johnson effectually restrained his allies and no blood was shed. The capture of Niagara severed Canada in two, cutting off Detroit, Mackinaw, the Illinois, and the other interior French posts.* Amherst sent Gage to supersede Johnson, and directed him to descend the St. Lawrence, take the posts at the head of the rapids, and hold them through the winter; but Gage found this impracticable, if only on account of French superiority in force.

* Fort Niagara is on Lake Ontario at the entrance to Niagara River. The site was first occupied and palisaded by La Salle. In 1687 De Nonville built a square bastioned fort, and this was deserted for some time previous to 1725. The largest building in the fort was the mess-house, a defensible structure of strength, and erected by stratagem in the following way :—The

1760.

The sufferings of the garrison of Quebec during the winter were severe, and they were intensified by the want of proper clothing and the difficulty of obtaining fuel. Parties of axemen, strongly guarded, had to be constantly maintained in the forest of St. Foy, four or five miles from Quebec, and the logs were brought to town through the snow-drifts on sledges drawn by eight soldiers. Rumours of a French attack in force were continually in the air, and in January the outposts at St. Foy and Old Lorette began to suffer annoyance. In February the outpost affairs became more serious, and troops had to be sent across the ice to Point Levi to repulse attacks upon that post. The garrison retaliated by sending 500 men against the French post at Le Calvaire, near St. Augustin, two days' march from Quebec. The French were driven from their breastwork and lost 80 prisoners, the English had six wounded, and nearly a hundred frostbitten. Late in February Murray was informed by a British officer, prisoner at Montreal, that he was about to be attacked by 11,000 men; but the rehearsals of an escalade proved so unfortunate that the scheme was postponed, and nothing further occurred till after the middle of April, when the garrison was informed that all Canada would be upon them when the ice broke up. Murray accordingly ordered the French inhabitants to leave the town within three days. Of the 7,000 men left at Quebec in the autumn, only 3,000 were fit for duty on the 24th April, so great had been the ravages of scurvy, aided by dysentery and fever, while some 700 dead had been temporarily buried in the snow-drifts.

Vaudreuil was at Montreal, well informed of the condition of the garrison, but compelled by want of transport to wait till the river

French obtained leave from the Indians to build a wigwam, and induced them to go out on a long hunt, to find on their return that a strong post had been practically completed. The fortifications subsequently built covered 8 acres. Johnson found in the fort 2 14-prs., 19 12-prs., 1 11-pr., 7 8-prs., 7 6-prs, 2 4-prs, and 5 2-prs., as well as 1,500 12lb. shot, 40,000lbs. musket ball, etc., etc. It appears from this that in 1759 the disadvantage of mixing calibres in a work was not considered to be of vital consequence. The work is described in an old history in terms that are worth repeating:—"In time it became a place of considerable strength. It had its ravines (*sic*); its ditches and pickets; its curtains and counterscarp; its covered way, drawbridge, and raking batteries; its stone towers, laboratory, and magazine; its mess-house, barracks, and bakery, and blacksmith's shop; and a chapel with a large ancient dial over the door." The Niagara Falls are about 9 miles from the fort, and about 1¼ miles above them on the American side stood Fort Joncaire, while Fort Schlosser is 1½ miles above Joncaire and on the same bank.

became navigable. Preparations were, however, made, and Lévis was the soul of the enterprise. Provisions, stores, and arms were gathered from all parts, and some articles were even smuggled out of Quebec itself. Early in the spring the militia were ordered out. Two frigates, two sloops, and a number of small craft were still available, bateaux were collected, and on the 20th April the force embarked, including 8 battalions of the line, 2 of colonial troops, colonial artillery, 5,000 Canadians and 400 Indians. The total strength was between 8,000 and 9,000 men. On the 26th they landed at St. Augustin, bridged the Cap Rouge, and advanced on Old Lorette, the English falling back to St. Foy. Lévis followed, and after marching through a terrible night arrived before St. Foy at break of day. On debouching from the wood he was compelled by the English guns to fall back, and being ignorant of the weakness of the port, Lévis decided to wait till night and then outflank the enemy. **1760.**

Some time after midnight the watch on an English frigate that had wintered in the dock at the lower town heard a faint cry from the river, and a boat found a man lying on an ice-floe. In the landing above Cap Rouge his boat had been upset, his comrades drowned, and he had escaped by climbing on the ice. The ebb tide had taken him down to Isle d'Orléans, and the flood had now carried him up to Quebec. His news was that Lévis was marching on the town with 12,000 men. At 3 a.m. Murray was informed, and soon after daybreak he marched out with 10 man-harnessed guns and more than half the garrison, to withdraw the outposts from St. Foy, Cap Rouge, Sillery, and Anse du Foulon. On reaching St. Foy they cannonaded the woods covering Lévis, and returned to Quebec when the outposts had joined, whereupon the French occupied St. Foy and Sillery. Murray was well aware that the walls of Quebec were no defence against artillery, and had long intended to intrench his force on the Buttes-à-Neveu; but the frozen ground made this impossible. So he chose his third alternative, and with a rash fearlessness marched out at 6.30 a.m. on the 28th with 3,000 men, the absolute whole of his strength, save 300 or 400 left in Quebec. His two howitzers and 20 field guns, spoils of French Quebec, were drawn by 500 soldiers. Murray formed up his force on the farther slopes of the Buttes, the same ground occupied by Montcalm on the morning of his death, and then went forward to reconnoitre. The flanks and centre of the plateau in front of Sillery wood were occupied by the French vanguard, and the right of the line was in

1760. position, while the other troops were rapidly moving up. Judging the moment favourable, Murray ordered an advance. The English line consisted of eight battalions, rather more than 2,000 men, with two battalions in reserve; in the intervals were the guns; the right flank was covered by some light infantry, and the left by a company of rangers and 100 volunteers. Murray advanced till his troops were on nearly the same ground that Wolfe had occupied previous to his attack, and then brought his guns into action, with the result that Lévis sent orders to the corps on the left to fall back to the cover of the woods. Murray mistook the movement for retreat, and advanced his whole line. Having thus abandoned their favourable position, the battalions of the right soon found themselves on low ground in deep mud and half-melted snow.

On the extreme French left was a house and windmill, held by five companies of grenadiers. These were attacked, driven out, and pursued by the light infantry; but the troops advancing from the woods repulsed the pursuit, and pushed back the light infantry on the main line. Eventually they fell to the rear, where they remained, having lost nearly all their officers. The French were again driven out from the mill, and it was left unoccupied by either party; but the fight continued for an hour, when the ammunition of the English failed, and the deep slush prevented the wagons getting up with a fresh supply. While this was passing on the English right, the advance had proved no less disastrous to the left, for it had brought the troops close to the woods occupied by the French. Two blockhouses on the extreme French right were taken, but superior numbers told, and though the reserves were brought up, Murray was forced to retreat after an action of two hours. Lévis followed close, only desisting when he found that the retreat was not without order. The English lost more than 1,000 men killed, wounded, and missing, more than a third of the whole; the French lost between 800 and 900 men.

With the detachment left in Quebec, Murray had now some 2,400 men fit for duty, although in miserable condition. Within three days order was restored, and all were hard at work strengthening the works with such means as were at their disposal. Guns were hauled up from the lower town with officers in man-harness, and officers did labourers' work at the batteries equally with the men. All this time Lévis was busied in digging trenches along the stony back of the Buttes-à-Neveu. Every day the English fire strengthened, till at last nearly 150 guns were mounted on the ramparts, while May was well advanced before Lévis could bring a single gun to bear. Although some guns had been landed at the Anse du Foulon, his hopes chiefly rested on help from France, for in the autumn he had requested the despatch of a storeship in time to meet him in April at Quebec, and there was further hope of the arrival of ships that had wintered at Gaspé as soon as navigation opened. Murray's hope on his side lay in the arrival of an English squadron, and so the interest of both sides was riveted on the river. **1760.**

On the 9th May the garrison watched a frigate beating up to the town, eager to see which flag she would display, and when the English colours slowly opened the excitement was supreme. Officers and men mounted the parapets and hurrah'd for near an hour, while the gunners "did nothing but load and fire for a considerable time." The frigate brought news that a squadron from Halifax was at the mouth of the St. Lawrence, and would be at Quebec in a few days, while Lévis, in ignorance of this, was still hoping that the French squadron would arrive in time. The siege batteries were now overpowered, and the attack harassed by repeated sorties, so that it became clear that success could only be secured by assault. To this end ladders had been prepared; but no attempt was made, and on the 15th there arrived a line of battleship and a frigate. On the next morning the two frigates passed the town to engage the French vessels, two frigates, two small armed ships, and two schooners. The commander fought well, refused to strike even after his ammunition was spent, and was made prisoner. The others resisted little; one threw her guns overboard and escaped; the rest ran ashore and were burned. As they contained his stores and provisions, Lévis was now forced to raise the siege, and in the evening he retreated, followed at dawn by Murray, who was unable to overtake him. The camp was abandoned, with the sick, wounded, and stores, as well as 34 guns and 6 mortars.*

To subdue Canada effectually and with speed, a decisive action was required, one, moreover, that would preclude any possibility of retreat. The place was evidently Montreal, and Amherst proposed a simultaneous movement on it from three points, Murray from Quebec, Haviland from Lake Champlain, and he himself from Lake Ontario. The available French force did not now exceed 8,000 or

* A French reinforcement of 3 frigates, and 20 ships with troops and stores, had been sent from France; but as the English squadron was in the St. Lawrence, they landed in the bay of Chaleurs. Here they were attacked and defeated by three men-of-war.

1760. 10,000 men, as most of the Canadians below Three Rivers had sworn allegiance to King George. The defensive arrangements made by Vaudreuil and Lévis were to post detachments on the St. Lawrence below Montreal, 300 men at Pointe-aux-Trembles, 200 at Jacques Cartier, 1,200 at Deschambault under Dumas, and 2,000 or 3,000 at Sorel under Bourlamaque. On the Richelieu, Bougainville was stationed at Isle-aux-Noix with 1,700 men; and Roquemaure with 1,200 or 1,500 men, besides all the Indians, at St. John, a few miles distant. A force of Canadians under La Corne watched the rapids above Montreal, and a small island near the head of the rapids was strongly held.

When spring had fairly commenced Murray removed the Quebec garrison to the Isle d'Orléans, where scorbutic symptoms soon disappeared under the influence of fresh provisions and other advantages of the place. On the 2nd July he received orders to advance on Montreal, and started with 2,450 officers and men on the 15th, in 32 vessels and a number of boats and bateaux. They were followed some time after by Lord Rollo with 1,300 men from Louisbourg, that fortress having been dismantled.* The movement was carried out with deliberation, landings being made from time to time to skirmish with detachments, to disarm the inhabitants, to administer the oath of neutrality to them, and to procure supplies. The guns on the hill of Jacques Cartier fired on them, but the place was passed, as also Three Rivers, where they arrived on the 4th August. The French kept abreast of the flotilla, Dumas on the north and Bourlamaque on the south bank. Murray was now in a critical position, for although within a few leagues of Montreal, and in the presence of a greatly superior force, he had as yet no news of the other columns. He accordingly camped on Isle Ste. Thérèse, just below Montreal, sent five rangers towards Lake Champlain to get news of Haviland, and proceeded to detach the Canadians from the French service. Security was promised to those who remained at home, while those houses from which the men were absent were to be burned. That Murray was in earnest, though much against his will, was shown by the destruction of a settlement at Sorel. The effect was immediate success, and before the end of August half

* It would be more correct to say "reduced from a first-class to a fourth-class station." The Island battery was retained, as also the King's bastion where were the barracks, and which bastion could readily be converted into a work capable of being well held by a few companies. The reduction was due to British possession of Halifax and Quebec, and to the port being liable to be closed by ice.

Bourlamaque's force had disappeared. But the colonists were in a measure between the devil and the deep sea, for Vaudreuil promised the same penalty, with the addition of summary execution, to all who deserted or gave up their arms. Still desertion continued, for the Canadians knew that France had completed their ruin by refusing to redeem the paper currency, and they preferred to propitiate the foe rather than exasperate him by a vain defence. 1760.

Haviland embarked at Crown Point with 3,400 regulars, provincials, and Indians, and reached Isle-aux-Noix in four days. Here he landed, mounted guns in the swamp, and opened fire. The light infantry and rangers dragged three field guns through the forest to the river bank in rear of the French position, and opened fire on the three armed vessels and several gunboats constituting the naval force. A shot cut the cable of the largest and she drifted ashore, being then taken by the party. The others made all sail for St. John, but stranded in a bend of the river, where the rangers, swimming out with their tomahawks, boarded and took one, and the rest soon surrendered. This was fatal to the defence, and on the 27th August Bougainville, with his 1,700 men, abandoned the island at night. Followed by Haviland, he made his way with infinite difficulty through the forest and joined Roquemaure at St. John, twelve miles below. Roquemaure had with him 1,200 or 1,500 men, besides all the Indians, and the two leaders continuing the retreat, they joined Bourlamaque on the St. Lawrence.* The united force at first outnumbered that of Haviland, but fast melted away. Haviland opened communications with Murray, and both looked daily for the arrival of Amherst.

Amherst had collected his force at Oswego in July, and on the 10th August he embarked with 10,142 men, besides 700 Indians, under Sir William Johnson. Before the 15th the whole had reached La Présentation, otherwise called La Galette, and now Ogdensburg. Near this was a French 10-gun brig, which was attacked and taken by five gunboats. Near the head of the rapids, a little below La Présentation, stood Fort Lévis, built the year before on Isle Royale, an islet in mid-channel. Lévis had hoped Amherst would amuse himself with capturing it, as valuable time would thus be gained; and Amherst proceeded to do so, partly, perhaps, because he did not care to leave a fortified post in his rear, partly because he expected

* The junction of the Richelieu with the St. Lawrence is 46 miles below Montreal.

1760. to find there pilots for the rapids. On the 23rd he bombarded the work from his vessels, the mainland, and the neighbouring islands. There was no earth on the island, and the logwork structure formed but a poor defence against artillery. The defence, under Pouchot, the late commandant of Fort Niagara, was, however, well sustained; and he did not surrender till a bombardment lasting three whole days had reduced his works to ruins. On this, Johnson's Indians prepared to kill the prisoners; and as this was not allowed, three-fourths of them deserted. The expedition now descended the rapids* with a loss of 46 boats wrecked, 18 damaged, and 84 men drowned, passed through lake St. Louis, and landed on 5th September at Isle Perrot, a few leagues from Montreal. The rapids had been watched by La Corne, but for some unknown reason he attempted nothing. After a night's rest the troops re-embarked, landed at La Chine—nine miles from the city—marched without delay, and encamped before the walls.

Montreal was at this time long and narrow, and boasted a single armed redoubt on a high mound at the lower end of the town. The whole was surrounded by a shallow moat and a bastioned wall, efficient against an Indian attack, but not against artillery. On the 7th September Murray landed to encamp below the town, and Haviland occupied the southern shore. Abandoned by all their militia, Bourlamaque, Bougainville and Roquemaure had crossed to Montreal with the few remaining regulars. There were now in Montreal but 2,200 troops of the line, and some 200 "colony" troops, to represent the power of France in Canada, and the discipline of these was broken. Around the city were 17,000 men, and Amherst was getting up his guns. On the night he arrived Vaudreuil called a council of war and a capitulation was proposed. Negotiations went on, but Amherst steadily refused to grant the provision that the garrison should march out with the honours of war. He insisted that they must surrender and not serve again during the war, on the grounds of French incitement of Indian barbarities, of open treacheries, and of flagrant breaches of faith. Intolerable as was the demand, it had perforce to be accepted, and the capitulation of Canada was signed on the 8th September. Half a continent was merged in the British Empire, and the American colonists had learned their power. The principal members of the *noblesse*, and many of the merchants, were conveyed at their own request to France, in

* The rate of the current is 18 miles an hour.

company with the troops, the peasants and poorer colonists remaining to commence a new life under a new flag. On arriving in France 21 persons were brought to trial in connection with the frauds and peculations that had helped to ruin Canada, 10 being condemned, 6 acquitted, and 3 admonished. Thirty-four failed to appear, of whom 7 were sentenced in default, judgment being reserved in the case of the others. Vaudreuil was acquitted. Bigot was banished, fined $1\frac{1}{2}$ million francs, and his property confiscated. Cadet was banished for 9 years from Paris, and condemned to refund 6 millions; while other heavy fines were enforced. **1760.**

From his review of the war, Parkman appears to be of the opinion, and rightly so, that success would have been sooner obtained but for the miserable depletion of the English army at the commencement of the war. He might have added, with equal justice, that it would have been delayed but for the European war that was exhausting France. Frederick the Great wrote of the French: "These fools will lose their Canada and Pondicherry to please the Queen of Hungary and the Czarina."

Regarding the future, Parkman does not speculate. There is, however, no reason for supposing that an attack from the southward would follow other than the old lines. Albany remains the primary base, Montreal the first objective to an invader not in command of the sea. Lake Champlain and the Richelieu remain the line of communications, and Isle-aux-Noix the outpost of the defence; while the main defensive position would be at St. John, now an important centre, as was purposed in 1760. That the defence did not then succeed was due immediately to the preponderating numbers of the advancing troops, and the same will hold good in the future. While success may be assisted, or defeat deferred, by the action of a strong naval force, the issue must be decided upon land. Victory will rest with the big battalions.

H. BRETON.

23rd November, 1893.

PAPER IV.

TWENTY YEARS OF TACTICAL EVOLUTION IN GERMANY

By Captain Maude, late R.E.

Anyone who conscientiously follows the course of a German soldier's training throughout the whole year, and not merely for the period of the autumn manœuvres, cannot fail to be struck by the almost diametrical contrast their methods present to our own.

If he extends his comparison to the current military literature, and still more to the opinions held by the average German officer, which, in due course, will, doubtless, become literature too (for the active officer has usually little time for writing, and the military papers are mostly maintained by the retired list), he will, I think, find it difficult to believe that both methods—the English and the German—are intended to be the solution of the same problem, *ostensibly* based on the same data.

Both start from the events of 1870 primarily, and yet, after 20 years, whereas in Germany we see steadiness on parade and faith in the offensive raised to the first place in the soldier's training, in England the advantages of the defensive and the uselessness of smartness under arms are accepted almost unanimously as the cardinal points in our military faith. Whilst in Germany everything centres on the destruction of the enemy first and the rest afterwards, in England the avoidance of loss by the employment of suitable formations is elevated to the dignity of a dogma.

The object of my lecture is to trace out the gradual steps by which this divergence has arisen, as far as my contact with German officers has allowed me, and to endeavour to indicate the ultimate goal to which they are now tending.

In the nature of things, I cannot give chapter and verse for each of my statements, for, as above mentioned, some of the books are not yet written. I can only ask you to believe that the men from whom I have derived them are representative types, whose signatures to a book or pamphlet would everywhere ensure attention.

The conventional attitude of mind in which the study of the 1870 campaign is approached is a belief that everything happened by design, that both strategy and tactics employed had been thought out long in advance, and accepted throughout the army as the best possible means of attacking the solution of the problems, propounded to the leaders by changes in organization and in armament combined. As regards strategy, this attitude is defensible, but as to tactics almost the exact opposite was the case, and most particularly with the infantry, with which I intend chiefly to deal.

Though the *foundations* of the existing organization had been laid as far back as 1808–13 by Scharnhorst, the *above-ground* work had not really been commenced until the accession of the old Emperor, and the appointment of Moltke as chief of the staff, about 1856.

Scharnhorst's principles were sound, but much of his detail was adapted only to the conditions of armament of his period; and it happened that, in the lassitude which followed the great wars, some of the principles were allowed to lapse, and others of the details crystallized by tradition into "drill" prescriptions.

Thus, when the old army was swept away at Jena, and its place taken by what was little better than a *levée en masse*, precise details as to the formation of advance guards, outposts, etc., had to be laid down. Matters, which in a war-trained army such as our own at the time, or the Napoleonic one, could be safely left to the experience of the regimental officers required to be precisely formulated in measurable terms; whilst more important matters, to which Scharnhorst and his pupils attended themselves whilst they lived, and which required rather more than average qualifications to detect by inspection, were scarcely adverted to.

Of these were the responsibilities of the company commanders, and the individual training of the soldier.

In an army constantly engaged in active operations these things work themselves. The work is too heavy for the battalion commander to master single-handed, and he is compelled to delegate power to his subordinates. But in peace time the command of a battalion can be easily directed by one man. Things always have a tendency to settle into the routine of least resistance, and ultimately the colonel and sergeant-major, or the adjutant and sergeant-major, monopolize the power. The captains take as much leave as they can get, and do as little as possible meanwhile; their subalterns follow their example, and in course of a generation, when promotion takes the senior captain, he assumes his new position without ever having mastered the rudiments of his profession, which can only be done by the pressure of *direct responsibility* exercised under *compulsion.*

This state of things is most graphically described in a reprimand addressed by Frederic the Great to one of his crack cavalry regiments, the Gensd'armes, during the latter years of his life, after 25 years of peace:—

"Gentlemen,—I am entirely dissatisfied with the cavalry, the regiments are completely out of hand, there is no accuracy in their movements, no solidity and no order. The men ride like tailors, I beg that this may not occur again, and that each of you will pay more attention to his duty, more particularly to the horsemanship.

"But I know how things go on. The captains think only of making money out of the squadron, and the lieutenants how to get the most leave. You think I am not up to your dodges, but I know them all, and will recapitulate them. To-morrow, when you start on your march back to your garrison, before you are 10 miles on the way the squadron commander will ask the sergeant-major whether any of the men live in the vicinity, and the sergeant-major will reply: 'Yes, sir, there is so-and-so and so-and-so live quite close to here, and would be glad to go on furlough.' 'Very well, then,' the captain will say, 'we can save their pay. Send the names in to me to-night, and they shall all have it,' and so it goes on every march. The lieutenants get leave to visit their friends, and the captain arrives at his garrison with half his squadron, leading the horses of the other half, like a band of disreputable Cossacks.

"Then, when the season for riding drills comes on, the captain sends for the sergeant-major, and says: 'I have an appointment this morning at so-and-so, and must get away early, tell the 1st lieutenant to take the ride. So the sergeant-major goes to the 1st lieutenant and gives him the message, and the latter says: 'What, the captain is away? then I am off hunting, tell the 2nd lieutenant to take the men,' and the 2nd lieutenant, who is probably still in his bed, says: 'What, both of them gone? then I will stay where I am, I was up till three this morning at a dance, tell the cornet I am ill, and he must take the ride,' and the cornet says: 'Look here, sergeant-major, what is the good of my standing out there in the cold, you know all about it much better than I do, you go and take the ride,' and so it goes on; and what must be the end of it all? What can I do with such cavalry before the enemy?"

He himself never seems to have realized that it was his own system of *supercentralization* that had alone rendered the state of things he so accurately described *possible*, and that, thus, he unconsciously became the author of his country's downfall.

But so it was, for the usual consequences followed. *Staff officers* were selected who knew nothing of the requirements of the men, and from them and regimental officers, equally ignorant, *generals* were chosen who could only inspect on the lines laid down by their predecessors, excellent for the conditions under which they had been introduced, viz., chronic warfare, but totally insufficient for a peace-time service.

For during the era of winter quarters, the utmost that could be done with the recruits on the parade-ground was to impart as much steadiness as *possible* to them. Steadiness *could* not be overdone in the time available, and any excess corrected itself the first day under fire in the spring. The actual education of the young soldiers was carried out in the guard-houses and barrack-rooms by the old soldiers, who had a very real and direct personal interest in the matter—for their lives might at any time depend on the knowledge their comrades had acquired—the men lived together and fought together in squads as they do now under our new regulations, and as long as the war-period lasted nothing could have answered better; but when peace set in, and the veterans gradually disappeared, all the old soldiers did was to teach the young hands how to get on the blind side of the officers, and in proportion as they were more or less successful, the battalions worked with a minimum of friction and punishment, and presented an imposing appearance of fictitious smartness.

Bullets were no longer there to check the tendency towards over-rigidity on the parade ground, and thus every year generals, officers and privates worked away contently digging the grave of their own reputation.

The campaign of Jena proved the sufficiency of their exertions;

the result could hardly have been more complete. The difficulty was to find some explanation of it.

They could not attribute it to the want of passive discipline in the men, nor could they, even by the most rigid courts of inquiry, bring home neglect of duty to the officers. (Some few, nine in all, were indeed sentenced to death, and about 50 to confinement in fortresses, but owing to the terrible state of confusion throughout the administration and the disorganization of the communications due to the presence of the French, none of the sentences were executed, and ultimately all were amnested in 1814). Nearly all were able to shelter themselves under the plea of literal obedience to the regulations, which, being the rule of the service, nothing could be said.

There remained, therefore, nothing to fall foul of but the system of tactics employed, and that having neither soul to be saved nor body to be kicked, they trampled on *con amore*.

Memo. after memo. was sent in to the War Office pointing out the superiority of the French methods and urging their imitation, and they read precisely like the similar papers which appeared in our current literature, and were read before the R.U.S. Institution a few years ago, advocating the grafting of German forms on English institutions; but like them they were based on the same ignorance of the origin of the French methods, as prevailed and still prevails in England on the origin of the German ones. The French system was one of small columns and skirmishers, and had evolved itself on active service from the line as a consequence of the deficient discipline in the early revolutionary armies.

Nominally, these armies were trained on the drill-book of 1780, a translation of the Prussian regulations, published in Brunswick a few years previously, and, I believe, the same one from which Dundas's celebrated eighteen manœuvres had been adapted, the parent of all our subsequent red-books.

But the rabble of the early days of the revolution proved quite incapable of advancing in line up to decisive range of the opposing forces, and as soon as the bullets began to fly they disintegrated into layers according to the specific courage of individuals, the bravest rushed to the front, and the remainder balled together into clumps, and were led as best they might be in support of the skirmishers. By degrees the skirmishers developed a very high degree of skill and the clumps were drilled into small columns.

The fire of the skirmishers diminished the losses of the columns, and the columns gave a moral support to the skirmishers.

If the resistance in front was in any degree obstinate the columns were absorbed in the fighting-line, and their place taken by fresh troops from the reserve.

The attainment of a sufficient fire superiority to risk an assault with the reserves became thus a matter of *time*, and *numerical* superiority fed up from the rear, and the character of the battle was completely changed from what it had been in Frederic's day, when reliance had been placed in the discipline of the troops, as measured by their capacity for enduring losses, to bring up to decisive ranges a sufficient number of muskets to achieve a crushing superiority by means of a few well delivered volleys. For it must be noticed, though Frederic, in his instructions to his men, always laid the chief stress on the bayonet-charge, he was himself perfectly aware that against a respectable enemy the charge was only the consequence of *fire superiority* already required; but experience had taught him that if he limited his demands to the delivery of a few volleys at decisive ranges, decisive ranges were apt to receive so liberal an interpretation that the fire superiority might never be acquired at all.

Had Frederic with his war-seasoned army survived in his full youth to encounter Napoleon and the French troops at the best they ever attained, I think there would have been little doubt of the result. Frederic's line was by no means *wooden* during the seven years' war, as a look at the ground they traversed at Prague and Torgan, for instance, will prove; and in those days the Prussians had excellent light troops for the express purpose of protecting the line during its formation and preliminary movements. But the light troops had been abolished on the conclusion of peace, and though many committees had advocated the expediency of re-constituting them, their reports had been retained in the War Office pigeon-holes, and nothing practical had been undertaken; and, meanwhile, under the system of peace-time inspections, alluded to above, the line had become hopelessly rigid and more in want of the light troops than ever.

The essential difference between the Frederician and the Napoleonic system (evolved from the Revolutionary one) was therefore this.

The line was formed deliberately under cover of light troops, or the ground if available, and then launched at the enemy, relying on discipline and skill in the use of arms to overpower him at one blow; whereas the French went for the enemy wherever they found him, and sought to wear him out by a long continued fire fight, relying on skill in the use of cover to minimize losses, and ultimately on sheer weight of numbers to break down his resistance.

The line was the perfected weapon forged by years of experience, and calculated to do most work in the shortest time, and with the fewest numbers, but requiring above all things *time* for the training of its ultimate units and a racial tendency towards subordination. Skirmishers and small columns were the expedient of a nation deficient in subordination, with limited time for preparation, but almost unlimited numbers. When, as a consequence of Jena, re-organization, in fact, *re-creation*, was thrust upon Prussia it became evident that under the terms of the treaty with Napoleon a revival of the line was impossible, the necessary time was wanting, and hence, perforce, the skirmisher and small column plan had to be adopted. Popular opinion was also entirely in its favour, and for a time the War Office was bombarded with proposals to abolish all rigid discipline, and substitute the *go as you* please style. Men were to be trained to skulk behind every hedge, ditch and furrow, quite in the approved modern style; but Scharnhorst would not be misled by any of these cries, and his pencilled remarks on the margin of one of these effusions form the keynote of all modern Prussian tactical progress. "We should teach the soldier to know how to die and not to fear dying," and "too much of this cover taking nourishes the natural cowardice which dwells at the bottom of all our hearts," yet he clearly saw that, in the absence of the old veterans in the ranks, provision must be made for educating the recruit in light duties, whilst at the same time, as far as possible, precision of drill and movement must be retained.

In 1813, 1814, and 1815 the skirmishers and small columns did remarkably well, for the intense hatred of the French and real patriotism of all ranks compensated for the want of discipline; but when peace was finally concluded a tremendous reaction set in.

Scharnhorst was dead, and the country high and low were sick of war. Centralization ensued, inspections took a stereotyped form, the individual education of the soldier, being the most difficult to inspect, gradually lapsed and only the literal wording of the regulations was followed, their spirit being entirely neglected.

Twenty years afterwards the Prussian army had become about the most inefficient in Europe, its cavalry could neither charge, gallop, or march, its artillery was wanting in mobility, and its infantry had gone back to the old automaton machine made stage.

Yet the principles on which it was based remained, and these principles ultimately worked out its regeneration.

And in this way.

As long as the generation of old war-experienced officers lasted (and they mostly outlived their usefulness), the younger officers had been content to look up to their superiors and also to allow the responsibility, which was theirs by right of their commission, to slip out of their hands; but as the old men passed away, the inherent virtue of short service (for a peace-trained army) began to assert itself.

There being no old soldiers to teach the young soldiers how to hoodwink their subaltern officers, the latter could not be led astray by fictitious smartness; besides, having but few non-commissioned officers to assist them they were compelled to master their work for themselves, and finding little assistance from their seniors, as soon as they felt secure in their knowledge they began to cry out for more independence, in fact, only what was their due by the terms of their commissions, but which their seniors had allowed to slip from them.

The change began first in the cavalry, partly because the old officers were retired at an earlier age, and partly because the work demands far higher intellectual activity than the training of infantry; hence about the fifties, the subalterns and captains were beginning to teach themselves the elements of their service, and it was from these men that the von Schmidt's, Rosenberg's, Krosight's, etc., in fact, the men who made their mark as regimental and brigade commanders in 1870, were derived; and they owed their opportunities to the fact that rapid promotion, the advantage which pertains of right to royal birth in a monarchical country, had placed Prince Frederic Charles, a man of about their own age, at the head of the cavalry. In the infantry the process was very much slower, and how little progress had been made in decentralization up to 1868 may be seen from Capt. May's two pamphlets published about that date, *The Tactical Retrospect* and *The Prussian Infantry*.

These two pamphlets and the mass of literature which accreted around them deserve special attention, though not for the reasons usually assigned in current British military literature. May certainly spoke for the regimental officer and affords invaluable evidence not only of the comparatively slight connection between the staff and the troops (*vide* Bronsart von Schellendorf's reply), but also of the degree of efficiency reached by the infantry, and the very superficial knowledge of military history amongst its officers.

His reading and that of most of his colleagues seems to have been limited to the Napoleonic wars, and of the fundamental principles of Frederic's time he seems absolutely ignorant; he starts from false premises and naturally reaches untenable conclusions.

To him the problem of attack presents itself as an assault against a certain constant quantity of bullets whose effect can only be minimized by certain formations, whereas in practice the quantity of fire, or rather its intensity, is a variable factor which it is in the power of the leader of the attack to reduce by artillery fire to almost any degree he desires.

I have said that the tactical system introduced after Jena was one of skirmishers and small columns, but neither escaped the influence of centralization and the barrack square for long. Skirmishing is of all things the most difficult to inspect, and the manual and march past the easiest (the latter only apparently so). Hence all conditions appeared to have been fulfilled when the skirmishers kept their intervals from one another properly, and the distances between them and the supports were correctly observed; and by degrees, as a consequence of the impossibility of adequately reproducing the picture of the hour-long fire fight (the essential feature of the Napoleonic infantry engagement), and the consumption of troops it entailed, the skirmishers began to be looked on as a mere *screen* to the following columns and the bayonet charge of the columns attracted chief attention.

An endeavour was made to check this tendency by von Wrangel in 1848, who tried to revive the original idea of the semi-independent company column, a moment of great importance in the subsequent development of the 1870 type of fighting, for it formed the starting point from which the company leaders derived their idea of independence. The breechloader introduced about the same year also tended in the same direction, but the tactical literature of the next twenty years, including Moltke's and Bronsart von Schellendorf's reply to May, show how little the *full consequences of the change were appreciated.*

Moltke's influence began to be felt first in organization and particularly in the training and selection of staff officers and corps commanders. When he assumed his office as chief of the staff the wheels of the mobilization machinery had become thoroughly rusty. The partial mobilizations of 1848 and 1849 dragged painfully, and even in 1859 worked very stiffly. It required ceaseless labour on his part to effect the re-organization which 1866 and 1870 disclosed, and what time was left over, after satisfying the demands of this permanent necessity, was only sufficient to imbue the staff with broad and general conceptions of the leading of armies; for the minor details of drill and training nothing was left.

The conditions, therefore, under which the Prussians took the field in 1866 were briefly these: a drill-book which was felt to be superannuated, a general tendency amongst the captains to escape from control, a misconception as to the true *rôle* of skirmishing in any *skirmisher and small column* system, and a discipline based on the training in *mass* and not the *individual* which proved insufficient to stand the strain put upon it by the misconception of the *skirmishers'* part alluded to above; and it must be remembered that there was no revolutionary fanaticism or patriotic fervour to compensate for the absence of the true discipline.

On the other hand, there was everywhere a high sense of duty and supreme confidence in the superiority of the new weapon. Fortunately the Austrians were in even worse case as regards over-centralization and armament, and were handled in absolute defiance of all common sense tactical requirement. With their excellent cavalry and artillery, trained to manœuvre in large bodies, they might, in spite of their strategical blunders, have easily compensated for the want of the breechloader (for the actual inequality in infantry armament was hardly as great in 1866 as in 1870, when the Germans managed to extricate themselves from the difficulties the French chassepôt prepared for them), but ignoring the fact that the fighting efficiency of an army is the "product," not the "sum," of the efficiency of the three arms, each fought independently of the other, and without any attempt at fire preparation by the artillery, the infantry flung themselves in masses against the unshaken power of the breechloader and were mowed down in sheaves. But relatively slight though the fire power of the Austrians was, it proved sufficient to disintegrate the particular kind of discipline the Prussians brought against it.

Captains took the first opportunity of escaping from their majors (battalion commanders) and throwing out their skirmishing sections, followed with the remainder in company column at the *prescribed distance.*

The company columns, *finding the prescribed distances* calculated for the old musket insufficient to protect them from the "overs" of the Austrian rifles, scattered into "individuals" who, having confidence in their breechloaders but none in their commander, and taking the common sense view of the matter that the more rifles in the fighting line the sooner the work would be completed, dashed forward to join the fighting line.

In fact, almost the same thing happened that had occurred when the early levies of the French Revolution attempted line tactics without adequate discipline.

It is difficult to say whether the war experience thus gained did as much good as it did harm.

It was a case of a little knowledge is a dangerous thing. On the one hand it gave increased zeal to the officers in their work, on the other it did not give experience enough to distinguish between what was fundamentally sound in the old regulations and what was merely barrack square tradition.

The fundamental conception which underlay all the old drill-books had been, and indeed is still, forgotten. Drill-books were meant to form finished tools to be employed by skilled men, who used their own judgment in deciding when and where to employ the formations laid down. In the choice of formation the regimental officer had no voice ; he had but to obey.

The young officers, with their total experience under fire of two, or at the most three, days, set themselves to criticize the views of the framers of the regulations, who had spent more years in the field than they had put in weeks at the manœuvres, and the consequences were in many respects exceedingly detrimental.

They judged the matter almost entirely from the infantry officer's standpoint, forgetting, that in a well-handled artillery, a leader possesses the power of so modifying the intensity of the fire to be encountered that *any formation* may become feasible (even the densest of columns, though that would be a very extreme case). Moreover, being entirely unseasoned to scenes of slaughter and suffering, they had been greatly impressed with the results of their own fire, which they believed to be abnormal and entirely due to the breechloader, neither of which was exactly the case.

Moreover, as accounts of the new French weapon and its performances at Mentana—greatly magnified by French reporters—reached them, an uncomfortable feeling began to spread that though the breechloader was an admirable weapon when one had the monopoly of it, it would be a very different thing when the other side had it too, and a far better one into the bargain.

The question began to be raised how best to meet it, and opinions were very much divided.

The idea which found most favour was a further extension of the skirmisher system. The chance of the individual standing for himself alone of being hit by an aimed bullet was obviously less than the chance of a column or line being struck, but on the other hand it was overlooked that the best plan to avoid being killed at all is to kill the other man first. The safest way to attain that end is to employ from the outset as many rifles as the space available will contain, and, further, the more you extend your men the less your power of control becomes.

It was also proposed to increase the distance between the supports and skirmishers, so that the former need no longer serve as stop butts for the latter; but against that it was pointed out that the greater intensity of the fire would crush the skirmishers faster, and, therefore, the supports must be nearer.

Things were in this confusion, and no light had as yet been shed on the matter from on high, when the war cloud of 1870 burst on them, and when they actually moved off to the field the only point on which all were agreed was that, in view of the enormous superiority in range of the French rifle, the first thing to do when coming under fire was to push in to the effective range of their own weapons as quickly as possible. And this they conscientiously endeavoured to do. In proportion as they succeeded they lessened the time for artillery preparation. Skirmishers, supports and reserves, all alike, came under the sweep of the French fire. The close bodies broke through to the front, being deficient in the quality of the discipline necessary to retain their ranks, and to quote the words of Meckel—admittedly their most able writer—"villages, woods and hollows filled with stragglers, and only the open fields lay tenanted by the dead and dying victims of our premature violence."

For further details as to the characteristics of the fighting I must refer you to Meckel's *Midsummer Night's Dream*, Hoenig's *Twenty-four Hours of Moltke's Strategy*, and *The Tactics of the Future*, by the same author, in which, by the way, he speaks of the methods at St. Hubert and the quarries of Rozerieulles as the "bankruptcy declaration of our tactical school."

There are a few points here to which I particularly desire to call your attention, as they are vital to the study of the tactical literature of the period available in our language:—

1st. The great inequality in efficiency between the old Prussian army and the contingents of the minor states—a fact which, in order to intensify the conception of German unity, had to be considerably slurred over in official and popular histories.

2nd. The fact that the artillery were still in a transitional period, and were only beginning to learn to shoot, not more than one battery in four in the Prussian army had been systematically trained in "ranging," the others working mostly by rule of thumb, *outside* of the Prussian artillery proper, the proportion cannot have exceeded one in ten.

At the lowest computation I cannot place the gain in power of the artillery since 1870 at less than 15-fold, and it is probably even more, for the gun alone, as a man-killing implement, is 10-fold better than then. (The Prussians in 1870 had neither shrapnel, double-wall shell, or high explosive bursters).

3rd. The backward state of the cavalry. This arm had improved much since 1866, thanks to the appointment of Prince Frederic Charles as Inspector-General, and the exertions of regimental and squadron commanders, for whose selection he was mainly responsible, but it was still untrained to move in masses, deficient of a true standard of *condition*, backward in its riding, and completely under the influence of the "cavalry cannot charge unshaken infantry" fallacy—the legacy of the Napoleonic wars.

Further, though it readily assimilated the idea of strategical reconnaissance, it almost invariably failed to report what tactical information it obtained directly to the troops most interested, viz., the infantry immediately at hand, and must, therefore, bear in great part the blame for many of the premature attacks, the cause of the heavy losses which gave rise to the *fiction* of the overwhelming nature of the breechloading fire. Unfortunately for the cavalry, mechanical invention can do nothing to effect a *per saltum* improvement, as it may do in artillery, for instance; but as far as care in the breeding and management of horses, intelligent breaking-in and training of re-mounts, and in the instruction of men and officers in a sound appreciation of true horsemanship, drill, and their duties in the field generally, the improvement in the German cavalry has been far the greatest of all the three arms.

I spoke above of the "fiction" of the overwhelming nature of breechloading fire. It may seem a large order, but "fiction" it really is, and nothing more.

Whether fire is overwhelming, exterminating, or whatever epithet one may choose to employ, is entirely dependent on the number of bullets to be faced in a given time, and their distribution in space at a particular moment. Which end of the weapon they were originally inserted at is entirely immaterial.

The truth is that, ever since the musket was introduced, troops have been formed for action in such a manner as to ensure a fire power far in excess of all possible requirements as long as they remained unshaken. Victory or defeat has always depended on the judgment of the leader in not committing his troops to the assault until one way or another the desired degree of demoralization has been achieved.

The dilemma for the leader on the defensive has always been how to cover a sufficient front and yet retain sufficient fire power, and the advantage to the attack has lain in the choice of the point to strike at, and it will be evident, therefore, that the greater the means of delivering a sudden and overpowering blow the smaller the numbers required to successfully administer it; but this was precisely the object aimed at by the old line tactics and the "push" tactics adopted by the French, though, no doubt, a practical expedient under the conditions of the moment was, nevertheless, a tactical retrogression.

Now in all times since the introduction of effective projectile weapons of war, when a leader blundered up against the unshaken fire power of his foe his troops were sent reeling back in disorder. Is there, then, any cause for surprise that the same mistake entailed the same penalty in 1870?

This is where the difference in the premises, from which the British and German schools respectively start, begin to tell.

We assume that the Germans made no special blunder. The Germans assume nothing, *they* know very well that they did.

We assume that because the Germans were ultimately invariably victorious, they must always have behaved like heroes, and what heroes failed to perform it would be presumptuous for ordinary men to attempt.

But the Germans know there was very little question of heroism involved in the matter, their men simply behaving as an ordinary body of men trained to discipline, without any clear conviction of the purpose of that discipline, and insufficiently trained at that, would behave.

Evidence on these points is not wanting; my only difficulty is to deal with it adequately in my time. The first place, in point of notoriety, must undoubtedly be yielded to the celebrated attack of the guards on St. Privat.

No other incident in the war has been more extensively exaggerated or been made the basis of so many false tactical theories.

It was not 6,000 (I have heard it put at 8,000) out of 18,000 who "fell beneath the leaden hail of the breechloader in 10 minutes," but 4,000 out of 12,000 who succumbed in a fight which lasted from 5 p.m. till far into the night, and during those hours the leaders committed one startling blunder, due to a misapprehension of the effective range of the chassepôt, which, if deplorable, was at least excusable, and which, under any conditions of armament, was bound to entail condign punishment.

The legend arose in England out of a confusion of personalities, easily comprehensible. The original statement was made in a pamphlet by the Duke of Würtemburg, an Austrian general who joined the Prussian headquarters some days after the event, and picked up the idea from camp gossip. Now Prince August of Würtemberg commanded the Guard, and on this point should have been a credible witness, but it is difficult even for a German court official to keep the run of the German Princelets, and hence it can be readily seen how the mistake arose in our own country, to which I believe it is at present confined. For full details I must refer you to the regimental histories. Briefly summarized it comes to this: the two Guard brigades came under fire about 3.30, and began to lose men; about 5 they were ordered to attack, though it was pointed out that the Saxons were not up, and the gunners had not done their work, but the orders once given were adhered to. One brigade endeavoured to change front in rendezvous formation, *i.e.*, a dense column practically of 6,000 men, and were overwhelmed with fire in the act. The movement was not carried out with the precision of the drill-ground, but they attained their new direction and everyone went forward with a blind rush; it was the desperation of brave men, not the ordered advance of disciplined troops; companies disbanded and went astray, only a few clinging together under their officers, and at length, utterly winded by the ascent, they flung themselves down just outside the effective range of their weapons. Then in the midst of this hopeless scene of confusion was witnessed by the men on the right flank of the assaulting body a sight which should have attracted the admiration of the civilized world. The 3rd Foot Guards, which had stood in second line, swept forward, its three battalions in three deep line, colours flying, bands playing, the men in "paradeschritt." They passed over the *débris* of their comrades without faltering, and ultimately carried the wreck of the fighting line in a few paces nearer to the enemy; then, seeing themselves unsupported, and realizing the impossibility of storming the village alone, they too flung themselves down to wait for the general advance which took place some two hours later. The village was carried shortly before eight o'clock, and then ensued a scene of confusion which baffles all analysis. Into the masses thus densely crowded together the French shells crashed for a couple of hours, then a further advance took place and the infantry fire did not die out till long after midnight.

Turn the thing every way you will, and it is impossible to believe that more than one-quarter of the total loss was incurred in the first rush forward, or 1,000 in 30 minutes, the time given in the Prussian official, a very different story to the 6,000 out of 18,000 in ten minutes.

Am I not right, therefore, in maintaining that the incident to which we mainly owe the abolition of what was best and most characteristically British in our old system is a pure myth and nothing more?

Why did we not turn our attention to the 3rd Foot Guards, with, to quote Napier, "its proud and beautiful line" instead, which line, be it noted, in the whole day's fighting lost fractionally less than its fellows? And if the "extended order" was all our fancy paints it, why did the surviving officers on the hill, after the first rush was spent, use all their efforts to re-form their men into the line we reject? Yet, their regimental histories prove that they did so.

The slaughter of St. Privat was by no means the worst "blood-bath" of the war; the fate of the 38th Brigade at Mars la Tour was decidedly worse.

Time fails me to go into the details, but, in brief, the 38th Brigade, numbering 4,500 bayonets, arriving at Mars la Tour after a most exhausting march, received orders to attack, in co-operation with the 39th Brigade, which was advancing from the direction of Tronville, against the copses of that name. The order arrived too late, and at the moment of moving off—"direction N.W. corner of the Tronville copses"—the other brigade was already beaten and in retreat, but this they did not learn till afterwards.

The two batteries attached to the brigade trotted off, and as the infantry crossed the high road they heard the first shots fall. At that moment a storm of lead burst on them from the north, and the mounted officers saw for the first time—the men on foot could not—the whole of the ridge of Bruville lined by continuous lines of infantry and guns, in fact, the whole of L'Admirault's corps.

Instinctively, and without orders they brought up their right shoulders and endeavoured to change front. The 16th, on the left, naturally completed the wheel first, and some of their companies actually got into the ravine, where they were met by a counter stroke of the French and lost 300 prisoners; but the 57th (two battalions) and two pioneer companies on the right had further to go; they simply raced forward, never stopping to fire, in skirmishers, small columns, and line, and ultimately reached the southern edge of the ravine, where they opened a rapid fire which soon shrouded their front in smoke.

Hoenig, to whose writings I have above referred, and who is my authority for the above, was adjutant of the fusiliers (57th), and rode with his colonel, von Ruell, in the centre of the line; they reached the edge of the ravine and there Ruell fell mortally wounded, and the next moment Hoenig was hard hit too; he took a last look round him, and the scene, as he says, is burnt in on his brain; to his left a long ragged line of skirmishers, to his right two companies in "line" who had just fired a volley, and the surviving captain was calling on them to advance, when through the smoke, and not ten paces distant, burst forth the bayonets of the French infantry, who, some six battalions strong, had been laying for them in the ravine. That was enough; the whole turned and bolted, and the French swept forward in pursuit.

They had followed some 500 yards, the rout of the brigade was complete, and there seemed no reason in the nature of things why a single German should ever have re-gained his fatherland, when from the S.E. the "1st Garde Dragoner" appeared on the scene. They had trotted up through burning Mars la Tour, negotiated the enclosures and wire fences in the hollow, then increased the pace and galloped out in column to the flank, changing direction as they went, then wheeled into line and charged down on the French, who were advancing, if in some disorder, still flushed with success; they swept right over and through them, circled round and broke up the rallying squares, and in five minutes the remnant of the brigade was delivered and the German army saved. They then re-formed, out of the three squadrons about 200 sabres. Horses came in riddled with bullets and spurting blood, then fell dead. The commanding officer, von Auerswald, mortally wounded but still erect on his horse, formally handed over command to the next senior, then called on his men for a cheer for the King, and leading it, fell dead out of the saddle.

The truth about the fighting on the Gravelotte wing (18th August) has only recently been given to the world by Capt. Hoenig, who, though not present owing to his wound received two days before, has collected and collated the evidence of a vast number of survivors, and I noticed in Germany that none had ventured to question his accuracy; a *précis* of his work will be found in the *Journal of the R.U.S. Institution* for December, 1892, and I can conscientiously recommend it to everyone who wishes to know something of the shadow side of the German tactical system in the last war.

He has recently supplemented it by a special pamphlet dealing in detail with the events around Point du Jour and the quarries of Rozereuilles. Briefly stated it comes to this: from first to last, certainly 9,000 men were poured into the wood, which clothes the north-eastern slopes of the Manse ravine, the leading troops, though in great disorder on reaching its further border, which was well under the French fire, though the latter were far outside the limits of their own, made one gallant dash forward and succeeded in reaching the gravel pit and the quarries, to which they hung on; by degrees the remainder in the open dribbled back to cover in the wood, where indescribable confusion reigned, and in the gravel pit, the men, seeing themselves deserted on either flank, were seized by panic and bolted; and the men in the wood seeing them racing back and imagining the whole French army to be after them made a desperate rush to the rear, those nearest the western edge breaking back across the valley, up the slopes and through the guns. The garrison of the quarries still hung on, and after a pause a Captain Wobesser—a singularly appropriate name—succeeded in collecting a group of some 88 men with which he again occupied the gravel pits. A few men too reached the quarries as reinforcements, but the two groups together cannot at any moment have exceeded 200 men of different companies and regiments.

From time to time the French made counter-attacks which were beaten back by these two little handfuls of heroes, aided by the artillery fire from across the ravine; but each attack, though unseen from the wood, managed somehow to communicate its proximity to its occupants, and back they all bolted again. On this flank nothing whatever decisive was done, but as a consequence of inherent faults of training, 200 brave men did all the fighting whilst several thousands wandered about in the woods communicating the infection of panic to one another.

After Gravelotte the Germans had learnt a little common sense, got their second wind so to speak, and they now understood the value of waiting for the artillery fire to take effect, and the consequence was that at Sedan some of the assaults across the open were successful (to the surprise of everyone) with almost an infinitesimal amount of loss.

After Sedan the *morale* of the French had been so entirely crushed and the individual self-confidence of the Germans so enormously raised that extended order formations proved amply good enough for their purposes; but it would be most dangerous to use the experiences of this part of the war as a foundation for the tactics of the next, without first applying corrections whose nature is hardly indicated by the conventional histories of the events.

This error has, however, largely crept into the works of a certain class of German tacticians who are more honoured in this country than their own. They have assumed the intensity of the breech-loader fire as a constant quantity, and deduced the reduction of their losses which marked this period as due to the open character of the formations used, forgetting that the accuracy of the fire to which they were exposed had fallen off enormously and the self-confidence of the individual on which the cohesion of these open formations depend had correspondingly increased.

The degree of variation possible in the intensity of infantry fire is indicated by a comparison between the losses of the Guards and 38th Brigade above quoted, and the losses of the Leib Hussars (Posen) in the action at Artenay (5th October), on the Orleans road. Two squadrons of the hussars fought 12 battalions of infantry for about 3 hours as skirmishers at ranges from 100 to 400 paces and lost 2 men and 3 horses slightly wounded—say 600,000 rounds for no one killed. Many other instances might be quoted almost equally bad.

The result of the war was simple chaos in tactical thought, an aggravated condition of things to what 1866 had created. Every tactical dogma had been upset, the seniors had lost all confidence in their own pre-conceived ideas, and the juniors felt that May had been justified in his protests. Mindful of the notoriety he had achieved and anxious to share it, many of the latter rushed into print.

This is the starting point of our difficulties. Intense interest had been excited in the war in military and volunteer circles, and the early publications were jumped at. Publishers were found ready to issue translations and the market was flooded with them, but the interest soon flagged, the books remained on the publishers' hands, and the latter having incurred considerable losses, declined, and still decline, to risk their money on works subsequently printed in Germany, which might considerably have modified our original impressions.

We overlooked the fact that in a well-organized army the leading men who have the ear of the authorities do not require to publish books in order to obtain a hearing, and jumped at the conclusion that the early pamphleteers represented a true and complete picture of the collective tendency of the German army, and hence all our difficulties arose.

To justify their existence in a certain sense and to escape the fatal "blue letter" of dismissal, which many of them no doubt felt they had richly deserved, the brigadiers and colonels, the survivors of the years from 1830 to 1850, developed phenomenal activity in the invention of new and improved methods of winning victories without bloodshed, and in the prevailing chaotic condition of opinion were allowed considerable latitude.

Every kind of absurdity was exhibited on inspection parades, troops attacking in files of 20 men and more 20 paces apart, moving end on to the fire, Col. Sir James Macdonald's 4-deep system, etc., etc., but by degrees the common sense of the army began to revive, and all those faddists were laughed out of court.

The trouble which lay like a dust-cloud over all was simply this. Every man who had fought in the fighting line was aware of a condition of confusion which exceeded his wildest ideas and all pre-conceived impressions, yet in spite of everything they had conquered, and *were, therefore, heroes.*

No factor previously known to them could account for the phenomena, but there was a new one, viz., the breechloader of which much had been predicted by the experimentalists in peace time. The conclusion, therefore, lay near to hand and was eagerly swallowed, viz., that the confusion was inevitable and the direct consequences of the breechloader fire.

Meanwhile work had to go on, and the consequence of the independence of the company leaders, which they had fairly conquered, began to disclose themselves. The dust began to settle.

One thing had become perfectly evident to all the company officers, viz., that the system of training previously in vogue did not suffice for the skirmishing line, more attention required to be paid to the education of the individual, and this was a step in the right direction bound to justify itself, whatever might be the form ultimately adopted.

About this time some first-rate men were appointed instructors to the different tactical schools, and they had to bring out text-books up to date. Foremost amongst these was Meckel, who dropped a shell into the camp by questioning whether after all the losses in 1870 had really been so unprecedented. He instanced Leuthen, Torgan, Zorndorf, and the battles of the Napoleonic wars, " but," he says, " we do not hear that Frederic's officers spent their evenings in winter quarters discussing changes in formations for the purpose of reducing the losses in the coming campaign." I may add that they subsequently did take to something like it, but that was 40 years later, on the eve of the catastrophy of Jena.

Meckel's remark, however, lost much of its sting, because, owing to his semi-official position and the recent date of the events to which he alluded, he could not criticize the blunders which had been the cause of the few isolated cases of incontestably heavy losses, as Hoenig and others are now doing, but it set some minds at work nevertheless. This was about 1876.

About the same year, General von Quistorp, whose name is little known outside the staff, but who by clear thinking has done much to further the cause of sound tactical evolution, pointed out in a paper in the *Preussiche Jahrbücher* that, as a matter of fact, though the desire had always been to get in to decisive distances, the actual fighting and decision had always been fought out at a range outside the point blank, *i.e.*, decisive ranges, of the opposing weapons. The point thus raised was of extreme importance, for it touched on the pivot of all the old tactical systems, based on equal armament on both sides, but as yet it has borne but little fruit.

Scherff, who, I may mention, was staff officer to the 38th Brigade on the day of their defeat at Mars la Tour, now stepped into the field; his first book, which was translated into English, under the title of *The New Tactics of Infantry*, in 1873, stamped him as an original thinker of exceptional power, and his chief work, which followed about 1880, *Uber Kriegführung*, is simply a masterpiece of logical composition. Unfortunately it is still inaccessible to all of us who read German with difficulty and a dictionary. It is a model of logical inquiry. When one has mastered that book, one knows *why* one knows a thing, which is different from remembering merely to have heard or read a thing somewhere.

Whether one accepts his premises or not, the study of the book brings positive knowledge, and the habit of thought acquired is an absolute gain. I do not accept the premises, for it appears to me that throughout Scherff ignores Quistorp's point above cited; he fails to appreciate the power of artillery; and finally seems entirely to overlook the extraordinary disparity between the infantry weapons on either side.

Von der Goltz soon followed, about 1881 or 1882, with his two admirable books, *The Nation in Arms* and *Roszbach ŭ Jena*, the latter as yet not Englished, another severe loss to our standard works. He was the first to open out the archives of the Frederician period, to expose the shallowness of the condemnation passed on his system after Jena, and to point out the distinction between deciding the battle at a blow, and the Napoleonic method of "Attrition," wearing out by a prolonged fire fight, as described by Clausewitz in his campaign of 1815 (criticism on Ligny). But he too fails to bring out adequately the points above referred to. Meanwhile work was progressing on the drill grounds and it was noticeable that it was precisely the Guards on their historic drill grounds, the "Tempelhofer," at Berlin, who were keenest to revive the smartness and precision of Frederic's time.

Everybody had accepted extended order for the fighting line as inevitable and *decisive* range as the goal, but the reinforcements and supports had still to be brought up to the fighting line, and experience entirely condemned extended order in these. In popular language the fighting line said "we cannot object to the enemy's bullets from the front, that is all in the legitimate game, but we can and do most emphatically object to another firing line in rear of us; but that is what it will come to if you relax the stringency of control and discipline behind us."

At the same time very thorough experiments on the ranges showed that the vulnerability of line to company column was as one to two, and hence it was decided that in open ground, line must be the formation for all troops in rear of the fighting line, that is to say, of at least three-quarters of the force engaged. At a very early stage it had dawned on the average common sense man that if you wanted to avoid being killed yourself the best plan was to kill the other man first, and what was true of the individual was true of the mass also.

This led to a very dense extension of skirmishers from the outset, with supports following close behind, and reinforcing till the attacking line became a dense unwieldly mob five or six ranks deep. The confusion even in peace-time became appalling, and to check it, serious inroads had to be made on the individuality of the skirmisher.

People now began to ask where does the skirmisher cease and the line begin? and Meckel's *Midsummer Night's Dream* was the answer—advocating sections in single rank—practically line; but the point was not immediately grasped, and to my mind Meckel missed his opportunity by still insisting—perhaps hankering after—decisive point-blank range as the final goal.

Besides, as with many English authorities, the word "line" is as a red rag to a bull, recalling the worst traditions of the barrack square. They have reasons perhaps for their aversion, but I fail to see any justification for this aversion on our part.

In 1892 a new writer, Colonel Malachowski, appeared on the scene with a most excellent work entitled *Scharfe ŭ Revue Taktik* (Ball *versus* Blank Tactics), unfortunately not yet translated. He goes in wholesale for the "principles" of Frederic the Great, and says that just as the cavalry have found salvation in reverting to the tactics of Seylitz, the bulk of the force in first line and the idea of a blow developed to its utmost possibilities, so also must the infantry return on their path to the old Frederician ideal. But he too stops short of "line" in the fighting line, but would make higher demands on the individual in the fighting line, and to reduce loss would keep the supports further away; and again, he too misses the point that, though you may strive for decisive. *i.e.*, point-blank ranges, the decision, as a fact, must take place, *with equal weapons*, outside of decisive ranges.

The point round which all tactical discussion in Germany and elsewhere appears to me to centre is briefly this. What do we really mean by line, and what by extended order? Let me suggest two definitions and see how the attack problem then shapes itself.

"Line" is that formation which permits of the development of the greatest intensity of fire under efficient control.

"Extended order" (I prefer the word "skirmishing") is that formation which enables you to inflict the maximum of injury on the enemy with the minimum risk to your own side.

Now assume infantry attacking infantry, both in large masses, brigades or divisions, in open ground, and without artillery, as that is obviously the most unfavourable condition possible.

Assume two brigades advancing side by side, and coming under fire at say 1,500 yards.

(*a*). One brigade extends a dense line of skirmishers, two paces between the files, followed by supports at 200 yards, and main body at 400.

(*b*). The other moves forward in ordinary line two deep with second line 500 yards behind.

Both begin to lose men, but neither stops for the first, second, or third casualty.

Ultimately, as the intensity of the fire increases, a point is reached beyond which neither can advance without reply. Which will reach the limit of its endurance first?

The experience of the Franco-German war proves abundantly that troops in close order will bear more than double the loss without losing the power of control that extended formations can stand, and the vulnerability of a dense skirmishing line, backed by supports, is in itself greater than a single ordinary line.

If then (*a*) finds its limit at say 900 yards, and lies down to fire, (*b*) has still a good deal in hand, and will get into say 700 before it is compelled to halt; and when it does open fire it will be with all the greater effect due to the diminished range, and to the fact that the men, being under close order discipline, are more habituated to obey.

I am assuming the vulnerability of ordinary line and dense skirmishing line practically equal, as to all intents and purposes they actually are; but let us substitute in (*a*) a more extended line, the consequences will only be more men in the supports who must follow at a closer distance, and when firing does commence the thinner line will not take the edge off the enemy's fire as rapidly as the denser one, but in both confusion must result as soon as supports and fighting line intermix.

The fight now resolves itself into a struggle for the fire superiority, at whatever the range, and *this is the crucial point, the really decisive* moment of the action; for if the assailant fails to attain it the fight either comes to a deadlock or the *rôles* change sides—the defender becomes the assailant. And I would ask all practical men with which brigade they would prefer to be, with (*b*) at 700 yards, with men trained by habit and tradition to look to their officers and obey, without reference to their own lives; or with (*a*) at 900, companies intermixed, and men in that order in which they have been taught sometimes to obey and sometimes to think for themselves, but always to take care of their own skins first. The mechanism of the attack goes on the same in either case. As the bullets begin to sing about the ears of the defenders, the accuracy of their aim becomes impaired, and the following troops reach the fighting line with less loss than the first one. Their fire intensifies the pressure, and a third line reaches the first with less still. Ultimately, if the staff have judged the situation rightly and massed a sufficient body of troops against the required point, the fire superiority is assured to the assailant. As they feel the fire pressure diminish in front they rise and dash forward as far as the enemy's fire, which blazes out afresh, allows them, then the same process repeats itself *da capo.*

Ultimately, if the resistance is obstinate, extreme confusion is inevitable in every case, and troops must be trained to meet this eventuality; but in which is it likely to arise first?

The German system of training is exactly adapted to meet the case I have described in (*b*), and, indeed, their regulations leave the leader free to adopt my plan, but custom and habit, not the letter of the law, are against it.

Their plan is to drill men to the extreme of close order, accuracy, and in the spare time, which cannot usefully be devoted to drilling to educate them to fight each for his own hand when the occasion arises.

They recognize that the complete concentration of mind and body required in drill, as they still understand it, and we used to do, cannot be kept up indefinitely, but relaxation of effort is indispensable, and this they give them by teaching them pure light infantry work, and allowing them every reasonable indulgence on the march; but the moment they come under close order conditions again, whether on fatigue duties, or whatever they may be, the most rigid and instantaneous execution of the command is exacted, and on service, when coming under fire in close order, they look on this habit of concentrated effort of obedience as the chief guarantee of victory.

Colours are uncased, the bands strike up the regimental march, and the men move forward in "paradeschritt" with the same absolute precision and steadiness as on the parade ground. Men who have been through it tell me the effect is overpowering, and one can well believe it. Everyone knows what it is to have the *unexpressed but silent* feeling of a mob or meeting against you; everyone knows what it is to *have it in* your favour, and the Germans seek to ensure this silent *will power* acting with them. Bullets destroy it by degrees no doubt, but the greater the determination and the power of *will* in each individual, the longer it will be before dissolution sets in. Therefore they say, develop the intelligence of the man to the utmost by education, train him by drill as an individual to concentrate that intelligence, finally stimulate the intelligence to the utmost, and, by rigid close order drill, teach *all* to will together.

When men spent years of their life in active service their common sense led them to see identically the same ultimate conclusion, though they did not attempt to explain it to themselves psychologically, and the results were seen in such instances of heroism and endurance as the assault of the hill at Albuera, and the conduct of the 10th and 24th Foot at Chillianwala, the 22nd at Meannee.

The Germans may have equalled, though they never excelled us, trained on the same system, but under the hybrid system of extended order and over-centralization tested in 1870, it will be found on analysis that 15 per cent. of loss invariably stopped the advance of the skirmishers and small columns, of which only 5 per cent. is estimated to have fallen on the skirmishers.

One word more with regard to the intense conviction entertained in the German army as to the advantages of the offensive; it is *traditional*, but they find in recent development of their own army additional reasons for their faith.

The greater the numbers engaged, the longer the line to be held, and the greater the uncertainty as to the point of attack. This uncertainty necessitates the reserves at a greater distance and prevents the deployment of artillery masses.

Their ideal offensive battle is briefly this. The cavalry having driven in that of the enemy, reconnoitre and fix the limits of his position; this is a *sine qua non*. The artillery then deploy in overwhelming force against the point of attack chosen, and the defender is compelled to come into action under their fire, in itself an enormous gain. Infantry may have to cover the guns, but that depends on the nature of the ground and degree of cavalry superiority gained.

During the artillery duel and the preparatory fire on the defender's infantry, the attacking infantry form in rendezvous formation under cover, and not a man is seen till the moment has come. Then, and not tell then, the infantry break cover and march resolutely in till stopped by the defender's fire. Line follows line to ensure the fire superiority, which has to be asserted again and again, until the enemy's line is definitely pierced. Then the cavalry pours through the gap, and takes up the pursuit until the last breath of man and horse.

The calculation is that all reserves having been disposed for one eventuality only, which can be foreseen, they are each in turn more likely to reach the required point in time than those of the defender disposed to meet a variety of possibilities; *and* the heavier the initial blow the less work will there be for the reserves to complete.

A last point to notice is that, whilst a certain section of our reformers has been urging the imitation of the German strong companies, the Germans themselves have been moving in precisely the opposite direction. Their battalions are now brigades of four weak battalions, and their companies battalions of three weak companies; for the position of the English company officer is more nearly analogous to that of the German lieutenant than to that of the German company leader, and we, thanks to a relative plethora of officers, can afford the step of decentralization better.

In conclusion, I would point out that it is difficult to compress the teaching of the whole history of the past 150 years into a lecture of one hour, and my effort lacks, therefore, both the continuity and precision I should like to have been able to give it. Briefly, the line of argument I have held before me is this:—Frederic the Great, handling a war-trained army, saw clearly that victory was to be won by the "blow" of disciplined troops (their discipline being measured by their capacity for enduring heavy loss) more economically than by the "attrition" of masses. The French Revolution and Napoleon not having highly disciplined troops at at their command were compelled to employ the "attrition" of masses. This method employed against the over-centralized and peace-trained armies of Prussia and the rest of Europe was successful, but at an enormous collective cost of life. Against our, relatively, war-trained disciplined line it failed uniformly. Napoleon's successes against the rest of the continent induced changes of organization in his adversaries' forces; these changes gave them the command of unlimited numbers, and the great collective loss of life his methods entailed ensured victory more certainly than any attempt to emulate the Frederician system with short service (two to three years) men could possibly do.

These short service armies required formations relatively dense in depth, and now that all nations have adopted the same system, and armed themselves with long-ranging, flat-trajectoried weapons, the only way by which tactical advantage can be secured is by the aid of improved methods of inculcating discipline, to render possible the application of relatively *less* dense formations in point of depth, in other words, to revert to the principles of Frederic the Great's line tactics again.

The essential condition of victory is, and will always remain, the attainment of fire superiority at the decisive point. Whether this fire superiority is the collective work of guns and rifles or of rifles alone, but in proportion as the share of the work accomplished by the former is greater or less, the work of the infantry is diminished or increased.

The inequality in infantry armament between French and Germans was too glaring to allow of true principles being deduced from their experiences, but given equality of armament, then advancing troops must be stopped at some point outside what is termed the decisive zone of the weapons in use—whether the advance can be continued beyond that point depends, discipline being equal, on the regularity with which the feed of fresh troops works, in other words, on the proper distribution of the reserves, but by hypothesis, the attack knows where it means to strike, and will, therefore, presumably be better able to secure this regularity. Next, the higher the "discipline" of the attacking force, the closer it will get to its enemy before opening fire, and the greater the intensity of the fire when it does open, also the greater the distance between successive reinforcements, and hence the less the collective loss.

"Discipline" is, therefore, the point at which we have to aim in the preparation of our troops, and those formations will be the best which facilitate the maintenance of this discipline in the highest degree, without, however, exposing too vulnerable a target to the enemy. Of all known formations, line, either two deep or single rank, meets these conditions most nearly, and, therefore, the maintenance of discipline and the employment of line tactics affords us the best guarantee of victory in the future.

PAPER V.

FOUNDATIONS IN SAND.

BY JOHN NEWMAN, ASSOC. M. INST. C.E., F. IMPL. INST.

IN asking you to direct your attention to the subject of "Foundations in Sand," upon which I have been requested to deliver this lecture, first, it is advisable to consider what is sand. It is described in dictionaries as "any mass of fine particles of silicious stone, but not strictly reduced to powder or dust." We have to regard it in a much more definite manner. It is a word any old parliamentary hand would like to wrestle with. In what kinds of sand have foundations generally to be made? In the superficial beds at a maximum depth of from 130 to, perhaps, 150 feet below the surface. The latter, at present, may be considered as about the greatest depth at which any such foundation may have to be established. It would be of no advantage to speculate as to the absolute limiting depth of a foundation in sand below water-level. You have principally to erect structures upon foundations at ordinary depths; therefore, let us proceed to consider the nature of such sand. It may be any mass of fine particles of silicious rock, pure or impure, and consist of minute concretions or fossils indissoluble by water. Sand may be said to chiefly consist of silica, alumina, magnesia, lime, and some metallic oxides. When silica is in a high percentage, sand is in a purer condition, and cohesion, for practical purposes, ceases. When alumina and magnesia are present in considerable quantities, the mass becomes slightly cohesive, although the cohesive qualities of the cementing agents may soon become destroyed by water and other influences.

The almost universal presence of sand in the earth declares its variety. It may be derived from very hard rock, such as quartz, millstone grit, red sandstone, etc., or any rocky mass of indurated sand of large or small grain, pure or impure ; also from gravel conglomerate or very small shingle, or be mere "blown" sand, such as is contained in the low, sweeping hills by the sea or in the restless desert. Even in a small area its stability as a foundation may vary very greatly. For instance, frequently along a shore the sand is of different degrees of fineness. It is often caused to be somewhat coherent by silt or mud, but if unmixed it may be easily moved by the waves.

By knowing the nature of the rock from which it is derived, the character of any soil is ascertained to some extent ; thus, if the rock be sandstone, the soil is sandy ; if claystone, clayey ; if limestone, calcareous ; and if the rock is any mixture of the three kinds of matter, the soil is of the same variety. In fact, soils have generally been formed of the loose earth derived from the crumbling or decay of solid rocks, and from transported material being conveyed from the higher grounds by great floods which devastated a country, although afterwards they fertilized it, or by other agencies. Therefore, the soil may have no relation in its character to the rocks which cover the adjacent country, or that upon which it rests. By observation and analysis, the composition of such deposits, however, can be ascertained, and their probable origin.

Let us briefly consider what are sandstones or grits. They usually consist of grains of sand or small pebbles cemented together either by silica, their most durable cementing material, the salts of lime or magnesia, oxide of iron, clay, the least effective compacting agent, or an admixture of two or more of these, or some such cementing medium. Sandstone is but sand cemented together and indurated, and when it is considered that about 3,000lbs. to 4 tons upon a square inch and a much greater compressive strain is frequently required to crush sandstone from a renowned quarry, we can understand the value of the cementing material in bringing the rock strength of the grains into effective resistance. But even hard sandstone has been found unable to withstand tropical rains in damp situations.

All varieties of sand are included under the general definition of sand rocks, sandstone, flint, and quartz, whether hard or compact, or of the loosest texture. The shape, colour, purity, impurity, proportions of clay, fertile or barren nature, all vary, and the grains may be worn into different shapes and degrees of hardness. We see sands in the deserts of Africa and Arabia in one form; in another familiar case, as in the Lancaster sands, at the base of an almost mountainous country; at Nottingham Castle as soft rock; at Alum Bay, Isle of Wight, in various colours; at the Goodwin Sands as treacherous ground; in Devonshire as comparatively firm, clean soil; and instances could be given almost *ad infinitum* to demonstrate the varied character of sand.

When sand approaches its natural gray tinge, or even is slightly red, usually there has been too much attrition or friction by the action of wind and waves for a metallic oxide coating to be attached to it. Coloured sands, *i.e.*, other than the naturally gray to those of slightly red tinge, are generally impure, but large tracks of sand are usually tawny and uniform in colour. The caverns in Sandstone Rock, at Nottingham, and those adjacent to the Elbe, near Dresden, are generally considered to have been formed by water undermining a portion of a sandstone rock without eroding the whole mass. This is a proof that the compactness and hardness of sandstone rock varies, for water finds the line of least resistance. Even when sand is of similar character, it is modified by climate and causes connected with elevation. In the neighbourhood of rivers and watercourses, sand will usually be found more silty than when farther away, and beds of peat may be present. To show the variable character of sand, at the Betchworth Tunnel the green sand encountered was hard and only required face protection, but it gradually changed to sand mixed with boulders, and then to fine, dry sand having no cohesion, which moved until it assumed a slope of 2 to 1. The tunnel had, therefore, to be firmly lined through the latter sand.

Experiments have been made showing that gas, at the ordinary pressure from a gas works at which it issues, will be forced through ordinary sandstone, as the gas can be lighted on the other side. This is a proof of the porosity of such soil and its capability of receiving impurities. On the other hand, during the construction of the Herculaneum Dock, at Liverpool, it was separated from the river by a natural wall of red sandstone rock, about 500 feet in length and 60 feet in width at high water level, and at spring tides there was a head of 31 feet of sea-water upon it, and although very slight leakage occurred, for all practical purposes it was impervious. Still, a sandstone block is sometimes used as a filter. Many experiments have shown that the power of absorption of sand decreases with the fineness of the grain, and that sand, when thoroughly wet, will contain water equal to about one-third to two-fifths of its bulk, and that almost all this can be drained; hence its varying condition and instability.

That sandstones have a marine origin is considered to be established. Thus their very formation has taken place under conditions by no means likely to cause them to be pure pieces of rock, however minute they may be, for the grains gradually become covered with various kinds of material. In the dark red sandstone iron rust is the compacting agent, but in the case of the lighter sandstones it is lime and free silica. It is important to notice whether the diffusion of any chemical action or attaching substance is *uniform or not*, as the behaviour of the sand will vary accordingly. Thus we meet with the thick-bedded sandstone or comparatively equally massed sandstone rock. Then we come to the fissured sandstones of varying thickness like flagstones, in which the solidifying action has been intermittent or disturbed, and so on until no cementing agent is present in the sand sufficiently powerful to compact it. In some sandstones streaks and spots of different colours may be seen; these are impurities, and should be regarded as weak places, for they are considered to be produced by vegetable matter. Many sandstones of considerable strength and compact texture, which would stand firmly at a steep slope, are affected by moisture and frost, as they cause exfoliation and decay. Sand derived from them will also be similarly deleteriously affected. In the very red sandstones it is rare to find any organic remains or fossils, except a few vegetable impressions, for mollusca sought clear water, and not that impregnated with iron or mud, but they liked the sand which had lime on it. By fine mud and other sediments occasionally being brought by currents or floods, such limestone bands in sandstone were formed.

This necessarily very brief sketch will show how greatly the nature of sand, whether in the form of rock or blown sand, must vary, and the importance of a thorough examination of the soil before determining the safe load upon it or the method of constructing the foundations.

Sedimentary rocks, such as sandstone, seldom lie perfectly horizontal, but generally have some dip, *i.e.*, they are inclined to the horizon. If a foundation is on sandy soil, and near a cliff, river, or cutting of any kind, and the inclination of the strata is towards the open face, unless the bed is protected from deterioration or movement it may be disturbed and be always in a state of instability. It is the undulating nature of a country and the inclination of the strata which causes different kinds of rocks, stratified or unstratified, to appear on the surface and a necessary diversity of soil, and in such a movable material as sand it is dangerous to build upon it if it should be in an inclined bed that can be tapped or eroded by underground waters. When the sand is in horizontal layers, or in a basin or in table land held by two protruding rocky hills or mountains, it is generally safe from lateral movement, although the beds may subside ; however, it is seldom found in very deep beds, but generally with other diluvial and alluvial soils.

It is of importance to always bear in mind the constant relative position of the strata, so that the general features of the country may be known. It is recognized that where strata meet, although each may be an unfruitful soil, at about that level the earth will usually be an admixture of the decayed portions of the two adjacent rocks, and it will be fruitful ; hence it is, as a general rule, not so reliable for the purpose of a foundation as at a higher or lower level, where it is in a purer state and away from contact with other soils. Green sand may be more or less indurated, and also have beds of mud in it, which latter, although most valuable to it as a fertilizing agent, deteriorate it as a foundation. In brief, wherever organic remains are present, the earth is not so reliable as a foundation as when it is without them. A rough method sometimes adopted to ascertain the probable fertility of a soil may be used to indicate its bearing power as a foundation, and may thus be described :—Put a quantity of soil into a measure, wash it, separate the sandy deposit, run off the fluid portion and let that settle ; notice what the proportion is between them, and if any light particles are in suspension ; if so, it is likely to be decomposed matter. By a comparison of the quantity of impurities in the sand, the relative bearing-power may be inductively judged, for the more impurities the less the solidity and weathering and general resisting properties. In many respects, and taking a general view, apart from the inclinations of the beds, a fertile soil may be considered as not affording so permanent or as firm a foundation as one of a more barren nature.

Earth, when disturbed or broken, absorbs more water than when untouched ; light or porous soils about 6 per cent. more. A pulpy condition should be carefully guarded against in foundations ; hence it should be ascertained if there are any land springs, for they should be conducted away, and all percolating water, field and land drains, be carefully diverted from the site of a foundation. In excavating pervious earth in drained districts, the soil will sometimes be found sufficiently dry without pumping to about the level of the bottom of the contiguous drains. Below that level, water in considerable quantities may be expected.

Sand in a foundation for a building may be said to be very rarely pure sand, or even in a condition approaching it, it being in the top layers of the superficial beds. It is, therefore, well to remember the remarkable property of soils usually called the absorbing power, without which no fertilizing matter would be retained, for it would pass through, and in time land would become a comparative desert. This beneficently-bestowed property lessens the stability and weight-carrying power of a soil. Therefore, it is important to ascertain with what substances, which, for our purposes, may be called impurities and deteriorating agents, the sand has either absorbed or has attached to its grains, especially the latter, for it may be reduced from one that will easily bear five tons per square foot to such a condition as to be capable of supporting but a few pounds weight on the same area. In deep foundations, sand will almost invariably be found in a purer state than at or about the surface.

In foundations near the edge of water, it is necessary to ascertain the depth of any sand bed, and whether it rests upon an inclined solid stratum, because, if so, it may be forced away by the increased weight upon it, or be undermined or set in motion by the action of water. When rock is upheaved, or the bed not horizontal, it is unadvisable to build upon sandstone rock unless it is protected and supported from movement, for if sandstones are not placed on their natural beds, the stones when used in masonry often split at the joints, with the result that air and water are admitted between the laminæ, and disintegration and destruction follows. A similar result would happen in the case of a foundation. A thin deposit of sand upon rock should not be built upon, but the foundations be carried down to a solid stratum.

It is necessary to prevent the accumulation of subsoil water below the foundation level, and water rising by capillary attraction into a wall or floor of a basement, or gathering beneath. Due provision must be made to guide any waters either by simple earth, pile, box, stone drains, or other forms of conduits. If the sand is likely to be in a damp state in winter, and water can freely percolate to the foundation, the effects of frost must be considered and guarded against.

Dry sand, if the mean breadth of the foundation is equal to the depth of the stratum, is usually considered for such purpose as incompressible, but immediately water percolates to it its character changes, and it may become a quicksand if sufficiently impure. In any case, it will subside. The chief conditions of a safe foundation in sand are that it cannot escape laterally, be undermined, eroded, or too heavily loaded.

Enclosing the foundations by means of props and planks, or sheet piles, is useful in soft soil, as it not only protects them against erosion, but prevents any movement of the exterior soil. In movable earth, as sand, the foundations should be put in quickly, to lessen tendency to movement, and short trench-work may be necessary. Generally, in trench-work it is advisable to provide cross dams, so that it can be divided into lengths, as all runs of soil should be prevented. Fine sand especially has a tendency to flow into the foundations, and, therefore, should be disturbed as little as possible. On the Metropolitan District Railway the general practice was not to take out and timber the entire width of covered-way, but to excavate a couple of six feet in width trenches for the side walls, to build the latter to four feet above the springing of the arch, then to excavate to the full width to that level, fix the centreing, turn the arch, and finally to remove the central remaining earth. This is found to be an excellent way of constructing tunnels or covered-ways near buildings so as to prevent accidents, especially in sandy soil. It will generally be necessary to support any bared face of sand and to complete the work in short lengths.

It is important to remember in a building that the weight upon a foundation may vary considerably according to the height of the walls and the weight they have to sustain. The bearing area should be similarly increased. By evenly distributing the load as much as possible, unequal settlement can be avoided. A uniform reasonable settlement is not dangerous. As a bed of Portland cement concrete affords an even bearing upon the soil, more so than stone slabs or a timber platform, or piles, it may be generally considered as a preferable and economical means of providing an even and reliable distribution of the load on a foundation.

The foundations of the hospital at Berck, a building 55 feet in height, had to be made on an undulating sandy dune. They were artificially levelled by depositing sand from the hillocks in the hollows so as to make a mean formation. Experiments were made with the deposited sand in boxes 39 inches in depth, and it was found ramming reduced the sand from $2\frac{1}{2}$ to $3\frac{1}{2}$ inches, and when water was poured in it settled 2 inches more, or a total of about 12 per cent., and it seemed as firm as the natural dune. Trenches were dug and concrete deposited upon them, and the building erected thereon. These experiments agree with many others.

The foundations of a skew bridge near Rouen, the subsoil being bad, were supported by a bed of concrete on a wide layer of sand, thoroughly soaked, 39 inches in thickness, confined and boxed in around the site, and have answered well, and saved the considerable sum which would have been required for a pile or other deeper foundation.

The property of semi-fluidity possessed by sand has been utilized to restore buildings at Charleroi, where some piles became decayed. A trench was dug underneath and very fine wet sand spread, and concrete placed upon it, and the wall then erected. As sand does not transmit lateral pressure beyond a certain angle, usually that of its slope of repose, by the use of dry clean sand, which can be placed in an iron open-top cylinder or in a wooden box with the lid removed, the props or struts supporting centreing of arches can be very gently lowered. In an example, the centres rested on the sand in 1-foot cylinders one foot in height and $\frac{1}{32}$ of an inch in thickness. About two inches from the bottom they were pierced with holes about three-quarters of an inch in diameter drilled in the sand-box, which were stopped by common corks or plugs. The centreing was eased by removing the corks, and the fine dry sand escaped until it formed a cone at the base of the cylinder. This alone arrested any further descent. By clearing it away simultaneously the lowering of the centreing can be regulated to a thousandth of an inch. If the sand becomes wet it does not flow out of the holes freely.

With regard to the depth below the surface of the ground at which the foundation of an ordinary building should be placed, it should be such that it is beyond any deteriorating weather influences; it will, therefore, vary according to the climate, situation, and general circumstances. It has been ascertained by experiment that in sandy, gravelly loam as much as 30 per cent. of the rainfall may percolate three feet into the soil, hence the advisableness of some adequate drainage works about the site, or other protection. They can with safety be placed at little depths if they are protected from all deteriorating influences, and provided always that the strata are not inclined. As the joints of masonry or brickwork become impaired rather quickly, a good practice in loose soil, as sand, is to en-circle the outside of a wall placed upon a Portland cement concrete base with such concrete to the ground level. It is then firmly held and protected, and there is not so much filling in of loose earth. With the view to keep the earth in its normal condition, a deep puddle wall has been inserted around a building erected on treacherous ground. This system was adopted at the Capitol at Albany, U.S.A.

Respecting the depth, character, and protection, which alone is a wide subject, this lecture must be taken as a whole, as in those for structures about to be considered many remarks apply to any kind of foundation in sandy soil.

The absolutely reliable and immovable safe load upon a foundation is that required to be known. It is impossible to positively declare this until a reasonably sufficient test has been made. However, the probable safe load can be ascertained by the weight safely borne in soils of the same character, and the few values about to be mentioned are those which have been and are so supported.

The approximate safe maximum load in tons per square foot is :—

Upon quicksand, sandy morass, sandy peat, moss, and sandy silt	0 to 0·20
Upon sandy alluvial deposits of moderate depths in river beds, etc.	0·25 to 0·33
Upon loose sand in shifting river bed, the safe load increasing with the depth	2·5 to 3·00
Upon silty sand of uniform and firm character in a river bed secure from scour, and at depths below 25 feet	3·5 to 4
Upon ordinary superficial sand beds	2·5 to 4
Upon firm sand in estuaries, bays, etc.	4·5 to 5
(The Dutch engineers consider the safe load upon firm, clean sand as $5\frac{1}{2}$ tons per square foot).	
Upon very firm, compact sand, foundations at a considerable depth, not less than 20 feet, and compact sandy gravel	6 to 7

The sustaining power of sand increases as it approaches a homogeneous gravelly state.

In my book on *Earthwork Slips and Subsidences* (Spon) you will find full information as to the safe bearing power of various soils.

In determining the safe load, it should be remembered, by excavation a foundation is relieved of a certain load, namely, that due to the weight of the earth removed. If a foundation was at a depth of 50 feet in damp sand, the normal load would be about 2·75 tons per square foot at that depth, and it would be relieved of this weight by the soil being excavated, and any load in excess of this pressure is the only *extra* load placed upon it by the erection of a structure. In the case of screw or disc piles, or ordinary timber piles, there is no excavation, and, therefore, no normal pressure is removed. A severe test to ascertain the weight-sustaining power of sand was made at the Jumna Bridge, Allahabad. After a settlement of about half an inch, when the first load with light weights was imposed, no sinking occurred with a load of 10 tons per square foot, the sand having 42 feet head of water on it. Eight to nine tons per square foot is approximately the weight upon the close sand foundations of the Gorai Bridge, the sand being very firm and the depth considerable; so that if a 5-ton load per square foot upon a screw blade in sand is considered a safe weight, and it has been frequently adopted, the load on the sand at the Gorai Bridge is practically about the same, and, moreover, there is no certainty that a screw blade may not be fractured, whereas, in the other case, it is known the whole foundation receives the load. On the Ulverstone and Lancaster Railway Works numerous experiments were made to ascertain the safe sustaining power of the sand into which the piles had to be sunk, and it was found to be about five tons per square foot.

It has been proved that, in order to obtain equal settlement of a structure upon a yielding foundation, it is always desirable to so design it that as great symmetry of the mass as possible is obtained, particularly with the view to prevent any overturning tendency on the base, or fracture above it, and that wide bearing is essential to success. If time and circumstances permit, it is always advisable to allow the longest possible interval to elapse between any works done to consolidate a foundation and the permanent erection of a structure.

By way of illustrating the load marshy or slaky ground which has sand in it will sustain, two experiments may be mentioned. At the Tyne Docks, in building a quay wall opposite the Jarrow Chemical Works, the late Mr. T. E. Harrison, Past President, Inst. C.E., found that 7cwts. per square foot was the greatest load the soil would sustain without settlement, and 5cwts. per square foot was adopted as the maximum load, with very satisfactory results.

On the Madison extension of the Chicago and North-Western Railway, when a greater weight of earth than $3\frac{1}{2}$cwts. per square foot was tipped upon it, the soil deposited sunk into the marsh. There is, obviously, a wide range in the bearing capacity of sandy soil, when 10 tons, and only $3\frac{1}{2}$cwts., or $\frac{1}{57}$th of the former load, upon the same area, a square foot, can be supported.

A few methods of increasing the bearing area of a foundation are:—In cylinder foundations, by enlarging the diameter of the cylinder at, or about, the ground line or bed of river (*Fig.* 1). This not only increases the area of the base, but also that of the surface friction. Another method is by mining to a depth of about 4 feet under the cutting edge or bottom of the cylinder or well (*Fig.* 2), some 2 or 3 feet around the base, and extending the hearting for that distance. Thus, in the case of a 6 feet in diameter cylinder increased to a 10 feet bearing, the area would be $\frac{100}{36}$, = say, three times greater by this simple method; but care must be taken that the cylinder does not sink suddenly when unsupported. But such action can be controlled, see my book, *Notes on Cylinder Bridge Piers and the Well System of Foundations* (Spon). This system was adopted at the London, Chatham, & Dover Company's bridge at Blackfriars, and also at the Haarlem Bridge, U.S.A. It is one more suitable for compact than loose soils, but it can be adopted if the sand is scooped out in short lengths, and Portland cement concrete inserted and supported, boards and other means being used to prevent a flow of sand, which must not be allowed.

On the Boston and Providence Railway, at a bridge over the Sec Konk River, U.S.A., the cylinders, 6 feet in diameter, had 12 piles driven inside them to a depth of 40 feet, the cylinders being sunk 10 feet in the ground, and filled with concrete. Thus the pier is practically a concrete column resting upon piles, and the latter are protected from possible attacks of marine worms. At the Zegeden Bridge, in Hungary, piles were used in the interior of the cylinders to increase the bearing area, but the cylinders were sunk to a usual depth.

In clean sand, the system of injecting cement grout might be used around and in the earth at the base of a cylinder to consolidate the soil and increase the bearing.

At the Rio Tinto Railway Company's pier, Sir G. B. Bruce increased the bearing area of the iron screw piles by means of a pitch-pine platform upon the surface of the ground, bearing girders, connected by flanges with the iron piles, resting upon the platform.

It was found marine worms did not affect the timber. If they did, the longitudinal bearers might be protected by being covered with cement concrete or by random rubble; for at the New York Docks such stone, where it covers the heads of the piles to about the depth of two feet, protects them against the ravages of the *teredo navalis*, but if the stone protection was removed or impaired, the piles would there soon be impaired by marine worms.

In loose, sandy soils screw piles have had two complete screw blades cast on the shaft to gain increased bearing, a blade being fixed to the pile in the usual way at about its point, and on the shaft, about 10 to 12 feet from the point, another complete screw blade was cast on at such a depth as to be, when the pile was finally screwed, about 6 to 7 feet below the surface of the sandy bed of the estuary, which, instead of being subject to scour, was inclined to silt up at the site of the bridge.

With regard to the lateral or surface friction of sand or sandy soils on a cylinder pier, or well, it is most frequently not considered as a means of reliable support. The Dutch Engineers who have had much experience with sandy soils, do not consider it as giving support to cylinder piers in *permanent* works, but they do in *temporary* structures. Vibration, disturbance of the soil during sinking operations, which, it has been found, reduces the surface friction by 20 to 25 per cent., percolation of water and air, and the irregular character of such support, causes it to be unreliable. Still, timber piles are principally dependent upon it for supporting a load, and, therefore, surface friction can be trusted in some cases.

The nature of the material much affects its surface friction on the earth; thus, excepting in the case of mud and silt, the frictional resistance of unplaned cast iron has been ascertained to be about 25 per cent. less than the values for wood. As the outer cylindrical surface of brick wells, when used for bridge piers, quays, etc., is generally smoothly plastered or rendered, or has a coating of Portland cement, it should be considered as the same as an unplaned superficies of cast iron. In the same soil frictional resistance often greatly varies, consequent upon the amount of moisture in the earth; the roughness, evenness, and smoothness of the face in contact with the soil; the compactness, looseness, or degree of fineness of the strata; the manner in which the load is applied, whether suddenly or gradually; and the mode of sinking a cylinder or pile. The following are a few values of surface friction in sandy soils in the ordinary condition, and they are for depths not subject to weather influences or disturbance :—

	Approximate surface friction per square foot. lbs.
Silty, fine sand, liquid when disturbed by water, on unplaned cast iron	250 to 300
Ordinary sand, on unplaned cast iron	300 to 400
Clean river-bed sand and sandy gravel, on unplaned cast iron...	400 to 600
Sharp sand, on clean timber sawn piles	1,100 to 1,500
Fine soft, drift, sand, on clean timber sawn piles ...	1,500 to 1,700

The last two should be considered as high values, and not usual resistances.

In sand, the permanent friction may be said to depend upon the force with which the grains are pressed together, if not to such an extent as to make them compact and dense. When the sand is waterlogged, the resistance will increase with the head of water. As timber is liable to indentation, the surface friction will increase with time. Loose and incoherent soils, and those which are gritty and loamy, that is, of a sandy nature, possess considerably greater frictional resistance than oily, soft clays. Fine sand gives great frictional resistance because of the smallness of the particles of which it is composed, but it is easily converted into a fluid, and then the surface friction is almost wholly destroyed. The frictional resistance of earth increases with the smallness of the particles composing soil of the nature of sand or gravel. Before proceeding to consider the all-important question of the protection of sandy foundations, without which they cannot be regarded as of a permanent character, a few of the principal points relating to foundations in sand for certain structures will be mentioned.

With regard more especially to the foundations of tunnels, sewers, and pipes in sand, experience has proved that the value of an invert to the toe of a wall can hardly be over-estimated, as it effectually prevents sliding, and also that a semi-circular arch is a much better form to adopt than an elliptical. Mr. Shelford, member of the Council, Inst. C.E., has stated that whereas in a tunnel in the London clay an elliptical arch 10 rings in thickness was crushed, a semi-circular arch of 6 rings stood well. It would be the same in sandy soil with the same pressures.

It is always very important that sewers and pipes should be thoroughly well packed, and as solidly as possible, so that equal support is afforded to them laterally, and on their resting beds or foundations.

The cylindrical is the best form for resisting internal pressure, or collapsion, and it is the strongest for the amount of material used. Other advantages are—(1). There are no long, straight, side walls, which have to resist the pressure of the earth, and may, therefore, yield. (2). The bond can be made the same throughout. (3). There are no corners or angles.

With respect to a railway or road upon a beach or shore, in sandy soils, or even ordinary beach, it may often be preferable to have an open iron or timber trestle viaduct on piers placed at right angles to the greatest force of the sea, and allow the waves to expend their force on the natural beach, than to build a heavy retaining wall and oppose force by force. An example on the Kent coast may be mentioned, namely, the timber trestle viaduct on the South-Eastern Railway, near Dover. Of course, if the level of the railway or road is nearly that of the sea, it would prevent such a system being adopted, as, for instance, at Dawlish, on the old South Devon Railway. When the permanent-way or road will be above the level of the waves or spray it is by no means to be considered as a temporary system, or other than in the light of a very efficacious one, as it is easily repaired, and can be quickly erected at far less risk than a structure requiring excavated foundations and protective works.

Sand is a good material for ordinary embankments, because it can be easily tipped, it consolidates rapidly, and the particles are of comparatively uniform size.

In preparing the foundation for an embankment on sand, solid hillocks or firm mounds that in any way tend to arrest motion should not be levelled, but all trees, roots, vegetable or bush growth should be destroyed, as they will decay, and turf and all soft, soapy matter and *débris* should be removed, so that the deposited earth rests upon a sound stratum, and a thorough connection is made between the ground and the earth forming the embankment. The turf stripped can be put on the toe of the slopes of the bank. As the ground is bared, it should be covered by the embankment, and not left unexposed. It may be considered only necessary to bare the soil by stripping turf for, say, 20 feet or so from the toe of the slope on each side. In cases where slips are probable, the ground can be excavated a foot or so at the centre

(*Fig.* 3), and pared off to nothing at the toe of the slope, so as to cause a tendency for the sand to settle towards the centre.

There is a limiting height of an embankment in sand or any earth. It is that which is so great as to crush the base by superincumbent weight, but in a yielding soil, as sand, it has not sufficient cohesion to support its own weight to any great height. In gravel or sand, the usual limit of the height of a cutting is about 70 to 80 feet; in embankments, 50 to 60 feet. Spreading of the toe of the slope and foundations may be prevented by cutting steps in the subsoil, and making a revetment wall of some selected firmer soil. Also by flattening the slopes at about every 15 or 20 feet (*Fig* 4), as the height of the embankment increases, the flattest slope being at the bottom; but it should be remembered that an unnecessary flat slope is not only a monetary waste, but it may be a cause of instability, for it exposes a larger surface to deterioration by weather. The steepest slope at which bare, firm, coarse sand will stand is $1\frac{1}{4}$ to 1, and $1\frac{1}{2}$ to 1 ordinary fine sand. This is a usual slope. As the sand approaches a loamy condition, that is, clay and about 30 to 70 per cent. of sand, 2 to 1 to $1\frac{1}{2}$ to 1; but very fine dry sand may not stand at a less slope than 2 to 1. Firm sand in sea embankments, the surface being protected by fascine mattresses, as in Holland, and exposed to a moderate sea, at 2 to 1, the least slope, to 3 to 1. By preventing any lodgment of water upon the top or bottom of an embankment or cutting, and proper provision being made for conducting field waters, and due regard being given to the other points mentioned, the foundations of an embankment or base of a cutting in sand are not likely to give way. However, it should be remembered that tipped sand, when rammed, will subside, if saturated with water, nearly as much as it can be beaten down, which shows how greatly its bulk is affected by water, and, although its rapid consolidation is an advantage in embankments, it is of importance that percolation should be equal.

A few examples will now be mentioned of treatment of very treacherous foundations in silty and sandy soil. At the lock at the Inverness end of the Caledonian Canal the foundations were very bad, and Mr. Telford adopted the following method:—An embankment of earth to the extent of the proposed work. Upon it was laid a greater weight of earth than any it would have to bear from the lock and the water contained in it. It was allowed some months to consolidate, and then the whole of the top bank was removed and the excavation made for the lock. This artificial ground succeeded and caused little trouble. This shows what can be done by merely loading, and, therefore, pressing, a loose soil, and allowing it time to consolidate before making the permanent foundations.

In shifting sand, for the lock of a barge canal, sheet piles have been driven at its front and rear, and the lock made of framed timber, closely planked and caulked, with overhead struts and gates, so that it was like a box with the lid off when in place, the ends representing the gates. Overhead struts and ties bound the parts together. The embankments upon silty ground and morass on the Highland Railway were thus formed. Two parallel drains were cut outside the fences, about 50 feet apart, from 6 to 4 feet in depth, and with 1 to 1 slopes. This drained the surface water. Irregularities of the surface of the ground were filled with turf. The space for the railway, 15 feet in width, was covered with two or three layers of swarded or heather turf, having the sward side of the lower layer undermost, and that of the top layer uppermost, the joints breaking bond. A good sustaining surface had been so obtained. On the bed of turf the ballast was laid for 2 or 3 feet in depth. This was quite sufficient to support the traffic ; but, in some cases, the bed of moss was from 20 to 30 feet in depth, the railway merely floated on the surface, and yielded about 3 to 4 inches under the weight of a train. An additional sleeper was found preferable to any longitudinal timbers under the sleepers. By continually lifting the road as it settled, and depositing in many places 4, 5, or 6 feet in depth of additional gravel, and in one place 27 feet, the road became solid.

A part of the railway near Norwich is on a morass of very treacherous nature. Twenty-five feet in length fir poles were laid upon it, a layer of hurdles upon them, next a bed of fascines, and then, if it was found necessary to raise the so constructed bank, it was done by peat, upon which the ballast was laid. The laying was commenced at one end and gradually proceeded. In draining sandy peat bogs or soils, deep drainage, not less than about three feet, is necessary. Mere superficial drains are almost useless. A very simple drain in sandy, peat soil is shown in *Fig.* 5. The top turf is placed on the ledges at base, as shown. Water has hardly any effect in disintegrating peat, and drains made like this have succeeded and remained clear when tile drains, consequent upon settlement, became displaced in the soft places.

At the Barry Docks, where a railway embankment had to be constructed on a muddy foreshore, it was found that the most economical and expeditious method of construction, equally applicable to a loose, sandy shore, was to erect a staging of piles and to cast hard material as uniformly as possible over the site until the staging was buried, instead of by the usual method of end tipping. Thus the loose soil was pressed until it became sufficiently consolidated, instead of being upheaved and mixed in unequal layers with the hard material.

With regard to quicksands, when these are formed on a sea shore, as they frequently are, by the action of land springs, they should not be built upon until the springs are tapped and led away, and the ground has become consolidated to some extent. The finer the sand the easier it is brought into a state of fluidity, but a quicksand is generally a mixture of fine sand, silt and water. Mr. Wilfrid Airey, in Vol. CI., *Minutes of Proceedings of the Institute of Civil Engineers*, states that the results of many experiments made by him generally showed that clean and sharp sand, whether fine or coarse, such as fine, blown sand from the Norfolk coast, clean beach sand, washed Thames sand, etc., had few of the properties of a quicksand; but that when they contained an admixture of clayey matter, and were in a fine state of division, although the sands appeared to be clean, the particles will be readily held in suspension by the water, and may form a quicksand. He also showed that, notwithstanding the failure of a quicksand to sustain much weight, a ship would float in it on the water being agitated, although it offered great resistance to a vertical pull on the water subsiding, for the mass of sand and clayey matter settling prevents the water floating a ship by upward pressure on its bottom, and, therefore, it may become swamped unless the seal of quicksand is broken and the external water assisted to reach it. This shows what a peculiarly treacherous and dangerous soil it is to encounter, and is doubly so because, although it allows a ship to sink in it, it may prevent its flotation at high tide. As an instance of the gripping action of a quicksand, a 12 inches by 14 inches rock elm pile, 65 feet in length, driven 22 feet into quicksand, required a force equivalent to a frictional resistance of nearly 1,600lbs. per square foot of the surface of the pile to draw it, or, making allowance for the weight of the pile, of about 70 tons. Some methods of treatment of quicksands, provided they are of small area, may be stated to be:—By drainage; by loading them with suitable soil until it presses the quicksand into a comparatively firm mass; by so distributing the weight that it will sustain the load; by the insertion of a stand-pipe, and leading away any springs if they are the cause to be guarded against, for an ordinary vertical retaining wall generally gives way at the base.

Of course, the necessity of having a comparatively vertical and even face must prevent the adoption of front buttresses much above the surface of the ground in dock walls. The resistance of a wall to a forward movement may be almost reduced, if the foundations in a movable soil are not carried sufficiently deep, to that of the weight of the wall multiplied by the co-efficient of friction of the material of which it is composed upon the soil.

Two good sections of walls for docks, quays, etc., are shown in *Figs.* 7 and 8. *Fig.* 7 is a section of Sir John Rennie's Sheerness wall on loose silt. In *Fig.* 8 the level foundation A sustains the weight, and the sloping portion B acts as a front buttress and prevents a forward movement of the foundation.

The footings of retaining walls are frequently put in at right angles to the face when battered. The addition of counterforts to a retaining wall that has moved has restored it to stability. Frequent offsets at the back of walls should be avoided whenever the foundation is of a yielding nature, as sand, as the backing will not uniformly rest on the wall. If piles are inserted to counteract a forward movement of the toe of a wall upon its foundations, they should be driven with a batter inclined towards the wall. A wall A on the land side of a sea wall should be erected (*Fig.* 9), or spray and pools of water will soon wash away sandy soil and endanger the foundations.

Before commencing a dock or shore work, a good plan is to make a catch-water trench round the site, to lessen infiltration; the bottom, if necessary, being filled with clay. Within this area a system of drains can be cut, and the water conducted to the lowest level at a point conveniently selected, where a pump can be situated if required. It has frequently been found that if the pumping machinery is placed at a considerable distance from the site of foundations in fine sand, water can be pumped without disturbing the soil, the distance varying from 20 to about 70 feet, according to the nature of the sand, the height of the lift, and the quantity of water to be raised in a given time, the necessary precautions being taken to filter the water and exclude any particles of sand. Pumping near buildings which have foundations in sand produces settlement, and will most probably be dangerous.

A method adopted to prevent runs of sand during pumping operations, and when constructing the London main drainage works, and also the undergound railways, was to insert an iron or brick cylinder. At Deptford it was as large as 10 feet in diameter (*Fig.* 10) to about a level of 8 feet or so below the foundation. By means of two 15-inch pipes placed longitudinally below the foundation of the sewer, as shown, and a 15-inch connecting pipe, with the necessary fall to the cylinder, at a distance not less than 20 feet, and the perforated bottom of the cylinder, which was some 50 feet from the surface, being filled with iron slag or gravel to act as a filtering bed, very little sand was drawn away or pumped. If it was sunk below the foundation and the pumping within the cylinder was started some time before, the excavation of the trenches could easily be made without any risk of drawing the sand. The trenches were caused to be dug in lengths of about 100 yards at a time. Straw and litter placed behind planks admitting water at the joints has also been found to be effectual in separating sand from water and allowing pumping operations to proceed. At Calais it was found that the sand, being purer than the silty sand at Dunkirk, was drawn up by the pumps more readily, and that the amount dredged in one hour was three times greater. This shows the easily movable character of clean sand, and it is well to remember it in pumping operations.

A few words with regard to the foundations of breakwaters and piers in sandy soils. To merely consider the weight the sandy bed will sustain is not sufficient, for there are other matters which must be regarded, or failure of the foundations is likely to result. Time does not admit of reference being made to their direction as regards wind and waves and the form of section, still, they influence the stability of the foundations. In deep seas, which, as a rule, will be found on high and mountainous coasts, the vertical depth of agitation of the water has been measured to be such that no fixed engineering structure is likely to be erected beyond its range. It is, therefore, unadvisable to assume that in all cases the depth of agitation or more or less destructive effect of the waves extends to merely a few feet below the surface. The limit of the agitation depends upon the depth of the sea, the "fetch" or distance of the opposite shore, which may be many thousands of miles away, the currents, the power and duration of storms and prevailing winds, irregularity of the bed, and other minor causes. Consequently the degree of exposure must be considered in each case before deciding upon the system of foundations. There is a scouring action generated by the undulations of the sea conveying their own impressions to a depth, it has been observed, varying from 70 to as much as 90 feet in the generally more impure, owing to the less velocity of the current and the consequent deposition of muddy, silty, and lighter particles. Upon hard, rocky river beds, along the banks, and in the hollows, the sand is generally of variable and irregular thickness, for the water has not had sufficient power to make a regular channel. Such thin pockets of sand should not be built upon. In some countries, particularly in India, very great alterations in the beds of rivers take place during the flood season, great quantities of sand and organic matter being conveyed, the direction of the currents may be changed and a shoal become the deepest channel, and, therefore, care is required to obtain absolutely secure foundations. When there is a proper adjustment of the velocity of the stream to the tenacity of the channel the bed is stable, and, therefore, *in regimen*. A flood may at once alter the case, and usually does so in sandy soils. As each tributary stream increases the strength of a river, it may be advisable to erect a bridge or structure above it. It should be ascertained if the velocity of a stream is at all times such that it is insufficient to scour and move the bed, and sufficiently great to prevent the deposition of any matter in suspension. If any additional volume of water is turned into a river its condition below and above will be altered, and scour may result. Frequently, in great rivers, or those whose course is through a mountainous district, the chief difficulties in obtaining secure foundations in a sandy, muddy bed are its variableness and unreliability, the violence of the flow in times of flood, and the inclined position of the strata.

It is not easy to ascertain the greatest depth to which the bed of a river has been scoured, although the changes in the channel can be known. Many river beds are in a constant state of motion, depending upon the depth and velocity of the water. There is difficulty in sounding in times of flood, and, therefore, in knowing the actual limiting depth of scour during the height of a flood, for as the velocity of the river decreases suspensory matter will gradually become deposited and the scoured-out bed be filled, and although soundings may indicate the probable depth of the greatest scour, it can seldom be said that it is absolutely known. It may be increasing and deepening every flood; therefore, it may be advisable to place the foundations considerably below the greatest ascertained scouring depth. The determination of the safe depth at which to make the foundations is always a matter of paramount importance in all river structures in sandy or loose soil. Every foot of depth, unless the bearing area is increased, adds to the weight on the foundations, and there will always be a point at which they should be situated, taking all the circumstances into consideration, such as the bearing power, the safe depth from scour, the effects of weather, and disturbance of the stratum by subsoil waters. Unless the sand can be thoroughly protected from scour, the foundations should go beneath it, and care be taken that it is to a firm stratum, and not to one of clay or gravel between two layers of sand, even if it be 30 feet or more in depth below the bed of a river. Piers in sandy foundations in India have been carried to a depth of 70 feet. If the flow has a velocity of 5 or 6 feet per second, it has been found dangerous to the foundations of structures that do not rest on firm soil, or are not carried to such depths as 40 feet or more in rivers with sandy beds. Sand is liable to be moved by a gentle current, and by floods holes may be made and the sand torn up with resistless force. Therefore, in such situations it is necessary to secure the foundations by artificial means. The least obstruction to the current in all directions should be offered by a bridge pier. Generally, especially in deep foundations, the cylinder or well system is a good one to use in such cases, as few piers are necessary. For comparatively small span bridge piers in shallow rivers having a sandy bed, or for landing piers or jetties, iron piles sunk by the waterjet, or screw piles, can be adopted.

The stability of a superstructure being dependent upon the foundations, no thrust should be put upon any piers or abutments that have to be erected on yielding soil, such as sand, but the pressure should be as vertical as possible, and evenly distributed over as large an area as practicable. The nature of the foundation must therefore be considered in determining the type of superstructure, and not the form of girder only.

Through the sandy bottoms of rivers large bottomless timber caissons are sometimes sunk to a firm bed to form a pier, and are filled with concrete, or they are founded on concrete submerged within an enclosure of sheet piling. The river piers in sand of many Dutch bridges are erected upon a mass of driven piles, enclosed by a row of close piling, the footings of the piers being defended against scour by masses of broken stone. At the Crèvecœur Viaduct, over the Maas (*Fig.* 12), in place of driven bearing piles, the piers consist of sheet piling enclosing a concrete foundation upon which the masonry piers rest, protection against scour being secured by considerable masses of rough basalt stone being deposited around the pier, and frequently the river-bed is dredged into a regular form for some distance on either side. If such a system of foundations were used for piers in some of the Indian rivers, or in any loose sandy-bedded river liable to heavy floods, and having a considerable depth of water, the whole structure would most probably be undermined and swept away by the first heavy flood; but such piers founded at shallow depths answer well for the sandy Dutch river beds, the contour of the bed being known at any time. In the beds of shallow rivers, secured from scour, the systems used in Holland have been frequently employed elsewhere for many years. By way of contrast, compare *Figs.* 12 and 13, which show the frequently relative necessary depths of the foundations. The circular is the best form for wells for bridge piers. The proportion between the height of a well and the diameter is of importance, to prevent overturning during sinking. Experience appears to indicate that it should generally not be less than one-third of the height, and, in any case, not less than one-fourth in favourable situations.

No foundation can be considered as safe, or as even a foundation, until it is secured from scour. The extra scour that is likely to result from the erection of piers or a structure should always be calculated. It will vary in each case according to the obstruction offered, and may be anything from an inch to many feet, and two or three feet is not at all an uncommon extra depth in somewhat loose soils. A test of the head of water required to scour the bed of a river may be possible, and the velocity of a stream be so increased over a small enclosed portion of it as to determine the head and velocity required to scour the sand.

In works for the protection of a structure from the action of scour, a battle is maintained against constant natural action; time, therefore, considerably influences results, inasmuch as it allows many soils to become consolidated.

Most seas and rivers are not mere water expanses and channels, but actual removers and distributors of more or less light soil. Sand usually rolls along the bottom of a stream by force of the current, but wave action stirs it up, and causes it to be carried in suspension. The specific gravity of sand is from $1\frac{1}{2}$ to twice that of water, but loose mud being about the same as water, it is held in suspension; hence the weight of the sand should be considered with regard to that of the water.

To show the delicate state of equilibrium of a sandy bed. On the River Volga, to remove the shoals and banks that form, all that is done is to break them up by a harrow. The bars are placed 4 feet 6 inches apart, and have a length of 14 feet. They are towed at about seven miles an hour by a steam tug over a sand bank. The increased velocity of the water caused simply by the greater depth removes the sand when it is disturbed.

In India small sand islands have been removed by making cuts in them from 15 to 20 feet in width, and by men shaking bars, etc., inserted in the soil. The sand along the edge becomes loose, falls, and the current sweeps it away. In non-tidal rivers there will generally be deposits on the down-stream side of the piers, and to prevent any banking up of the water they should be removed, or not be allowed to accumulate, so as to avoid erosion of the bed of the river. A shoal is also generally formed between the piers of two bridges or structures near each other in a river. It is necessary to be very careful in straightening the bends of a river, because they may not be due to accidental causes, but to the connection between the gradient and the bed and the volume of water; for if the lower portions of a river are not proportionally increased, the level of the water will be raised, and floods and scouring of the previously stable portions of the bed will ensue, and, further, will cause a deposit where it meets the unaltered channel. To keep a river open to navigation, the object is to reduce the scour and the deposits to a minimum; hence if bridge piers are placed near the mouth of a river the channel may be altered, and charts and old-established lighthouse bearings be rendered misleading and probably dangerous. As an example of careful provision against such contingencies, at the Lowestoft lighthouse at Ness Point, where the tendency of the sandy foreshore is to move steadily in a fixed direction, Sir James Douglass so arranged the superstructure that it was independent of the bearing piles and foundation frame, which is buried in concrete, although secured to it by flanges and bolts. Thus the superstructure from the bed of the sea can be removed at any time. Erections curtailing water space in a tidal channel should be permitted only after full consideration and competent advice, for when any solid matter has been put in motion and a uniform flow is established, it will continue to flow until its velocity is checked, and its rate of progression is less than that of the stream.

With regard to scour of soil of an open, loose character, like sand, in a waveless river, or one having no motion but that of the current, it has been calculated that the scouring action varies as the cube of the fall, and as the sixth power of the velocity; thus a stream flowing five feet per second, but increased to six feet after the erection of a bridge pier, would move sand or silt of nearly three times the weight that it would if the original velocity had not been increased. However, it is modified according to the nature of the earth, for in cohesive soils the scouring action is considered to increase only as the square of the velocity, and a shallow river with a very high velocity is deemed to have far less scouring action than a deep river flowing at a less velocity.

All the foundations of the piers of a long river bridge are often not in the same soil; hence a different system of protection from scour may be necessary.

The usual means of protection employed are aprons or platforms around the piers and also between them, curtain walls, that is, a thin wall of ordinary construction, or of wells, the top being a few feet below the level of the bed of the river. Also sheet piling, rubble-stone, or small concrete block platforms, or small mounds around the piers, fascines, and combinations or modifications of them. Not one, however, should be universally applied, for in some cases there may be hardly any scour, whereas in the sandy beds of Indian rivers it has been known to extend to a depth of 50 feet below the normal bed. If the scour is very deep, curtain walls, aprons, or platforms may become useless by being undermined, and the cast-in-random or small concrete block system of protection may be necessary with deep foundations below the possible reach of scour. The stones or blocks can be thrown in around them, and allowed to sink till by frequent renewals they at length become consolidated and maintain a fixed level, but as during floods no material can be added, it is not a wholly satisfactory method; however, it is considered that random stone protection is the better system in rivers subject to be deeply scoured, because the stone will gradually protect the bed until its surface is reached. Sufficient stone should be deposited during the working season, and before the floods commence. When the sandy bed of a river is only a few feet in depth, and rests upon clay of a tenacious character, the piers of a bridge or river structure can be protected by a curtain wall, and by an apron of stone 30 feet or so in width extending across a river; also, where the water is comparatively shallow, curtain walls or a series of wells can be built across the river on the down-stream side to a certain depth below the bed. It is generally necessary that the top of the wall should be about five or six feet below the ordinary bed of the river. No open spaces should be left if rows of wells are sunk for such purposes, or scour between the joints will be created instead of prevented. In India they can be erected in the dry season.

Wells forming a structure have been sunk to a shallow depth in the sand, even as little as six feet, the piers being connected together by a line of wells acting as a curtain wall to prevent scour, a concrete or masonry floor being laid between the piers to protect the foundation; but as the stability of the structure is then entirely dependent upon the unalterable resistance of the curtain wall wells, it is not so desirable a system to generally pursue as to make it secure without such aid. A structure that is secure without help is always to be preferred to one that requires auxiliary support and protection to cause it to be.

It is better to evenly distribute any random rubblestones or small concrete block protection over the surface of the bed of a river than heap them round or in front of the piers. A layer of stones or boulders to a depth of one foot or two feet always affords some protection against erosion of the bed.

At the Ravi Bridge, Lahore, the piers are protected from scour by 1 foot $2\frac{1}{2}$ inches square concrete blocks, to a depth of about 5 feet, cast in around them, blocks being added from time to time as required. The apron extends 100 yards, and the site upon which the blocks rest was dredged to a depth of 12 feet below low-water level.

Trees laid flat and stones in nets have also been placed in river beds to direct the course of the stream, and have succeeded, the interstices becoming filled with sand and silt by percolation. The effect of river embankments is to compel the stream to preserve the same channel as much as possible by maintaining a constant current in the same direction. In rough protective works the object should be to catch the shingle, sand, and other deposits, as in a net. A mat of grass or fine branches woven together prevents percolation to a great extent, and causes a deposition of material. At the Memphis Bridge over the Mississipi, scouring of the sand around the piers has been prevented by mats covered with stone. A mat 240 feet by 400 feet was sunk around each pier, and covered with 2 or 3 feet of rough stone. The piers and abutments of the Kieff Suspension Bridge, which pass through a shifting quicksand, are protected for a breadth of 100 feet by fascine mattresses laden with gravel, stones and broken bricks, and during many years no movement has occurred.

The piers of the Jhelum Bridge, Punjab Northern State Railway, are in sand, and were encircled by a shield of boulders with a width on the top of two feet, and a slope formed naturally by the stones. In India it is found the stones sink into the sand in a strong current, and that such scour-preventing aprons require to be replenished frequently so as to maintain them at a safe level. At this bridge it was ascertained by probing in the strong currents that the stones slipped down from 30 to 40 feet below the piers, and that their lateral motion is slight. On the up-stream side the stones sink the deeper. If deposited during floods, the stones must be very large, or be put in bags or rope nets. All holes scoured out should be filled as soon as possible, and a stock of material kept ready for emergencies if it cannot be readily obtained near the site of the bridge.

The upper end, or up-stream side, of an apron is the most exposed, and it is well to protect the bed of a river beyond it for a little distance by loose stones or fascines, and gradually end it so that the waters glide over and are not obstructed or deflected. As the aprons are expensive, it becomes a question whether the foundation should be at a lower depth and less protection be required. Light, permeable structures, such as a combination of piles, fascine work, mattresses and brushwood, and usual groyne work, cause a deposit of sediment, and, therefore, prevent scour. At the South Pass Jetties, Mississipi, fascine mattresses and fascine work have been employed; the silt filled the interstices in the brushwood, and preserved the mattresses from the ravages of the *teredo navalis*, and concrete blocks placed upon them prevented their disturbance by the waves. Willow mattresses form a cheap and effective method of construction for river-training jetties.

The upward pressure of water on foundations, aprons, or floors, wiers, locks, irrigation, and other works should be considered, for a floor may become dry, and there may be a head of water upon it. For instance, with a 10 feet head, the pressure per square foot would be 624lbs., a not inconsiderable upward pressure. It should, therefore, be regarded in designing protecting floors, aprons, or fascine coverings, or they may be blown up or fractured. It can readily be judged that the protection of a foundation in sand is an all-important point, and might be said to be *the* most important, for the unstable nature of sand or silt causes it to be stirred up by the least agitation, and sand foundations, therefore, differ from those in most other soils, and require special care.

In conclusion, with respect to grouting sand with a view to hardening and consolidating it, some 40 years ago it was proposed to sink perforated pipes into a quicksand, and to inject into it through them a sufficient quantity of iron water to agglutinate the whole mass. There is a part of the River Thames, above Blackwall Stairs, and below the entrance to the West India Docks, where an eddy of the stream accumulated a shoal through which some agglutinating springs rose that converted the sand into a kind of rock which required to be blasted to excavate it.

Mr. Kinipple, in a lecture delivered before you a few years ago, explicitly and fully explained what could be done by a judicious use of Portland cement grout in sea works.

The time may come when in gravel or sand, or any porous soil, *if it be sufficiently clean*, instead of making foundations as we now do, clusters of perforated pipes will be sunk around the site of a river or other foundation, and by injecting Portland cement grout a sufficient mass of earth be consolidated without any excavation other than the loose top soil. Everything would be dependent upon the efficiency of the grouting pipes and apparatus, equal diffusion, and proper quality of the grout. Thus a solid pier, as it were, could be made by aid of the soil, for gravel and sand form some 90 per cent. of the bulk of a mass of concrete before mixing. Its certain conversion into Portland cement concrete is the problem to be solved. Grouting or agglutinating soil is no recent invention, for it has been practised for, perhaps, countless ages, and some rocks are naturally partly so formed. As you know, the mason-bee constructs by its aid the cells she requires for the larvæ, and the despised stickleback his nest. The nests of many birds are also made more or less on the same principle, and so are the huts, causeways, and dykes of the beaver. Truly! "there is no new thing under the sun;" and as the intelligence, for it is nothing less, of these creatures, who are placed under man, the divinely commissioned chief of the whole animal world, enables them to so construct their dwellings, man may ere long so perfect the system that any porous soil, such as gravel, sand, etc., *if sufficiently clean*, may be consolidated by the injection of the necessary cementing material, so that foundations in many cases may be made in a few days, and at much less cost than by the present methods of construction. By first adopting such a system for works of secondary importance, it would gradually be thoroughly understood in a similar way to that in which good Portland cement concrete has become known as one of the best and soundest materials to employ, for even in my recollection it was once regarded, except by the few who knew its value, as a kind of inferior or doubtful substance, It is certain the possibilities of Portland cement grout have not yet been nearly attained. In addition to the consolidation of foundations, a pebbly or sandy shore, and sandy roads or footpaths, might be made by it as hard as rock, and instead of pitching or slope protection to a sandy embankment, its surface might in a day be caused to be uniformly hard.

NDATIONS

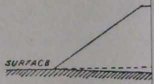


Fig 4.

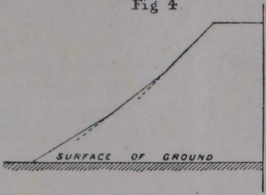


Fig 8

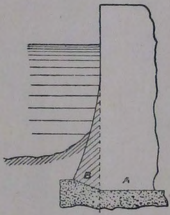


Fig 13

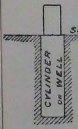
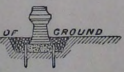


Fig 12



PAPER VI.

EXPLORATION SURVEY WORK.

By Lieut.-Colonel H. H. Godwin-Austen, F.R.S., Etc.

The subject that I have the honour to address you on this evening, viz., "Exploration Survey Work," is the most engrossing and captivating that can fall to the lot of any officer to take part in, and it is a duty which many of those in this room may, at some period of their service, be called on to perform. There is no work on which more distinction can be gained, or more fruitful in usefulness, from both a military and economic point of view. For the first it enlarges the mind and gives that eye for ground and how it can be got over, and in what time it can be got over, which is so useful an aid when moving a force in the field; for the second it gives an officer the opportunity of studying many other branches of science besides the work of his survey. It gives him the tact also of dealing with all sorts and conditions of people. In the short time this evening I have, I think, not to address myself to those officers present, particularly of the Royal Engineers, who have quite as much knowledge of surveying as myself—probably more—but more particularly to those younger officers who are in the future to take up the work we, in our time, have had the good fortune to be employed upon. You never know when the opportunity may offer itself, but always be prepared for that opportunity, and ready to drop into an appointment when it does come, by passing examinations, and becoming proficient in all that appertains to a soldier's career. My own connection of nearly 20 years with the Indian Survey Department was a sort of accident. I had not the distinction or advantage of being in the scientific Corps. My military education was at Sandhurst, and from there I passed into the 24th Foot. To General Sir Peter Lumsden, in the Quartermaster-General's Department at Peshawur in 1856-57, I owe my first start in survey work. A compilation of a plane-table survey of the Kuram Valley was in progress in his office. Being full of other work, he handed the completion of it over to me, and the final map went on to the Surveyor-General of India. It was this small piece of work, due to the advantage I had taken of the surveying and topography then taught at the R.M.C., that affected materially my future career in the service.

There still remain large areas of the earth's surface waiting for the advent of the surveyor, and even in territories adjacent to our own, or which may soon be intimately connected with our rule. In Africa there are vast areas, much of which is mountainous and highly interesting from every scientific point of view. Lying beyond our Indian possessions there is Thibet, with Lhassa; Nepal, and all that great stretch of the Eastern Himalayas from Bhutan to North Burmah and China. Here is a field where many officers of the Royal Engineers will, no doubt, find ample scope for their powers of endurance and their talent for the surveyor's work. There is no duty that is more attractive. What interest so great or so absorbing as tracing out the run of a mountain range, or following to its many sources some great river system? What work so independent and so satisfactory when it is completed, and what work can be made so mathematically exact? I only wish I could begin again this pleasant life, and view once more the countries I have visited.

Surveying, moreover, is an employment on which many other sciences can, at the same time, be studied with success. I would particularly mention geology; then, as the surveyor is often thrown among wild tribes and new people, ethnology is sure to attract his attention, while botany or natural history can be cultivated; in fact, the eyes and hands of the surveyor need never be idle; but to work with effect he must possess the power of observation, which such opportunities cannot fail to stimulate.

Very important is the methodical writing up of his daily work and what he has observed, for the memory cannot be trusted long for details which are often important, though they may not appear so at the time. Lastly, and as important as anything else I have mentioned, is drawing, by which he will add to the pleasure of his travels for years to come. Good sketches convey a better idea of the scenery of a country than all the photographs that ever were taken, but if the surveyor cannot draw he should certainly take up photography. You will say I am piling the load pretty heavily on the surveyor's back, but if he will only take up one of the subjects I have mentioned, he will be interesting others, and giving himself something to do besides official work, for there is nothing like having a hobby as a relief to that work, and thus he may occupy to advantage many an idle hour.

I have found that the majority of young surveyors, as a rule trained to conduct route surveys with prismatic compass, have very narrow ideas when called upon for the first time to make a general map of a large extent of country; they cannot get away from the road they are on. They take all its bends with the greatest accuracy, all the side roads, all the houses and other minor details, but everything beyond a few hundred yards is a complete blank. Who has not seen dozens of such route surveys? and for certain purposes they are, of course, useful. To enlarge and expand the ideas of the young surveyor, commend me to the plane table, and get him off the road on to the adjacent country. Get a few points absolutely correct scattered over the plan, and then work down to the detail. How far less wearisome is such plane-table surveying; there is no constant counting of paces, or noting time, no taking of angles and recording the same, which, however carefully it is done, may be read off or put down wrong, while error is always accumulating. The mind can never be taken away from this incessant labour to observe anything else; the immediate surroundings absorb all the interest, all the time, and the main general features are lost sight of.

I shall attempt this evening, for it is the first time I have ever delivered a lecture of this kind, and on this subject, to show rapidly how the topographical work of the Survey of India is carried on, based, to commence with, on the most accurate system of triangulation (into the mathematical details of which I shall not enter) down to the last process of filling in the topographical details; and I shall then try to show you how this latter part can be executed with very great accuracy without the aid of any instrument more elaborate or weighty than the simplest form of plane table.

The survey work you may be called on to execute may be of every sort of character; and time is always the great factor in its accomplishment. Given time, when you are your own master, which seldom happens, and you may do anything and produce a most perfect map. But it generally happens the military surveyor is attached to a force in the field, he cannot go everywhere in face of the enemy, and some most desirable points are not accessible, or he may be deputed to go with some political mission, when he may have to contend with other drawbacks. The political officer in command may not have any interest in the survey work, and may consider a simple route survey quite sufficient for all purposes—there are people, and very intelligent people, in other lines of life, who cannot read a map when it is put before them—perhaps he may not have had the selection of the surveyor sent with him by the Government, and looks upon him as a dangerous adjunct, politically, who would be better employed in transport duty on the line of march, and grudges all carriers for the survey impedimenta, so that the surveyor may not find himself on a bed of roses. On the other hand, happy is the officer who has a chief of a different sort, who, from the first, takes a lively and even an active personal interest in the progress of the map, who ascends peaks with the surveyor, and will help recording angles and forwarding the work. It has been my good fortune and my pride to have travelled with such political officers. Everything depends on such interest; it is invaluable, for the surveyor is consulted as the best place for a halt, and one may be made in order to visit some peak off the road—not, as in some cases, the halts are made on Sunday when Monday would do as well, or else a forced march is made to get into some place ahead, and thereby losing the opportunity of securing many square miles of topography.

I propose to divide the subject of the lecture into two parts:—(1). A survey of a very mountainous region of lofty, rocky, well-marked peaks. (2). A survey of a tropical one, where dense forest covers the greater part of the country, and lower, flatter, less-defined features have to be contented with, and partaking more of the character of a reconnaissance.

PART I.

The basis of all good accurate work is systematic triangulation, whether it be executed with theodolite or plane table. When the time and means are afforded, the first instrument should always be employed, and the plane table can then follow, and when once a sufficient number of points are observed and computed, and well selected over the adjacent country, there is no further necessity for using or taking any other instrument.

When there is less time very excellent work can be done with this simple and portable instrument, if it be treated and used as a theodolite, working out and building up a system of triangulation. The great object to bear in view is not so much the placing of the different points in the survey in their true position at once of latitude and longitude, but that the whole map shall be accurate in itself, a complete whole, to avoid by every means in one's power the accumulation of error, and to carry it on with the least possibility of any creeping in. Work down from the longest base you can get to a final short one, which can then be measured, and any observations for latitude or longitude will place the survey in its proper place as regards some previously surveyed area.

As the best method of illustrating the subject of my lecture, and show how a survey should be carried on with the greatest amount of accuracy, however extended it may be, even over many hundred square miles of country, I here show (*Plate* I.) an actual piece of work carried out in a very lofty part of the Kashmir Himalayas in the summers of 1859-60 to 1861 by the party then in command of Captain T. G. Montgomerie, R.E. Without entering into the minor details of triangulation, I would point out that the principal stations shown in this chart form part of what was named the "Indus Series." The principal triangulation, brought up from the south, was extended towards the east all along the valley of the Indus, and into Ladak.

It will be noticed that these principal trigonometrical stations are all of very considerable elevation, and I take this opportunity of alluding to the great services of three assistants of the Kashmir party, viz., Messrs. Johnstone, Beverley, and Shelverton, who took so large a share in this triangulation at the expense of great toil and exposure. From these lofty stations were fixed the numerous snowy peaks to the north, lying on or near the main range of the Himalayas. There is not a more lofty, precipitous, ice-bound area in the world than this, for, as you see, the peaks are mostly 20,000 feet, and range up to 26,000 and 28,000 feet. I need hardly tell you that this triangulation was all conducted and completed on the most rigorous system with theodolites of not less than 12-inch diameter, the object being to cover the country with fixed points for the topographical work which followed.

In this chart all the thick lines and the stations in connection with them denote the primary triangulation.

I will now pass on to the work of the topographer, and I would first note to you that all the portion contained within the plate represents a plane-table section on the four miles to an inch scale enlarged, for the sake of clearness, to twice the size. It is, therefore, really two miles to the inch.* All the topography of this part of the Himalayas was sketched on the four miles to an inch scale—a very excellent one, and well adapted for such exploration work.

The latitude and longitude having been projected on the plane table from the geodetic tables, and the scales plotted, the trigonometrical stations and fixed points are projected by co-ordinates of latitude and longitude, and proved by their distances from the stations of observation. The plane table is now ready for the field. The surveyor begins by ascending some commanding principal station, say Biamchu. He then sets the plane table by some other well marked point, not too near; clamps it when all the rays to the surrounding fixed stations prove true, discarding those stations that may prove to be inaccurate. This may occasionally happen when distant peaks have been observed from only two stations, for, should any be wrong and not discovered in time, they may give him untold trouble. Next comes the setting of the compass, and this should be tested at every trigonometrical station visited, as its variation may not be constant over the whole area covered by the plane tabling.

The work of sketching now begins, and a good deal of method must be adopted to secure all the rays taken. The general run of the main ranges and valleys must be sketched in as a basis, so that the hundreds of rays that are drawn may fall as near as possible in their true position, and not require lengthening or shortening; they need not be drawn more than an inch in length, this depending on their distance. I may say complete success depends upon this work, on the diagrams of peaks (drawn either on the board or in the field book), etc., and the memory of the surveyor when he sees them again from future stations. It is a mistake to draw too many rays, or enter into great detail of the distant ranges, as these will be encountered eventually at closer quarters. In a mountainous country try and get on the top of a peak as early in the morning as possible, and begin with the distant ranges first, for clouds soon rise and cover them. Rays must be taken up or down the courses of valleys, ravines, streams and rivers that converge directly towards the station of observation, and to all marked depressions on the ridges and spurs, and to every physical feature that will be recognized afterwards from some other point. This work will keep a sur-

* For the purpose of reproduction, this plate has been drawn to a scale of 18 inches to 1 mile.

veyor, when on a lofty peak, standing at the plane table for hours, and the extent of work that can be executed can hardly be realized except by those who have sketched in this way, the object of the military topographer and explorer being not so much to enter into close detail, but to show the general features of the country, especially all the roads, and to show their accessibility for military purposes.

Having now shown how topography follows the exact work of the triangulation in a systematic survey of a country, some details of how this particular work was executed may interest you. Those trigonometrical stations marked with a shaded circle on the chart were all visited; those with a crossed circle were also visited and fixed by the orientation of the plane table by compass and the intersection of rays drawn from triangulation points, or set by a ray drawn from some such point. The circles with a central dot in them indicate the peaks fixed by the plane table alone, and when proved by three intersections are used as well for fixing position when trigonometrical points are not visible.

I now propose to give an account of the way in which a portion of the topography of this piece of country was filled in, and show the route that was taken, and what length of time it occupied, for this may convey to you a better idea of the work than any other method I could adopt. It is many days' journey from Srinagar, and I did not reach the ground until the end of July, 1860, and it was not before the 6th August everything was ready for the ascent of peak Biamchu; thence I followed the main spur to the north, ascending Kon-Kon, and crossing this high ridge at the pass marked Tuggo, over 16,000 feet; the passes at the head of the Thullé Valley were both visited, viz., the one of that name and the Tusserpola, 16,679 feet; from these points and Biamchu a magnificent view of the Zoah ridges and glaciers and the higher snowy range beyond was obtained. The greater part of it is inaccessible, but has well marked features. When I use the word inaccessible, I mean it in the sense that natives of the country do not go up on to the glaciers, and for a surveyor to do so, though practicable, would take a very long time; large supplies of food and a number of men would have to be collected, and the results in a more accurate map would not be worth the great expense it would incur. Next, the Thullé River was followed to its junction with the Shayok, here 8,867 feet. Monlong trigonometrical station was ascended, 14,905 feet; Kauchinokla, about 17,000 feet, and Chungoksi Go, 18,848 feet. Thence the Hushé Valley was traversed, and all the tributary glaciers at the head visited, a high point being ascended about six miles S.E.

of Masherbrum Peak. Retracing the route down the Hushé Valley, the Shayok was crossed to the left bank and followed to the starting point at Kiris, which was reached on the 28th of August. This would have taken much longer had I not been favoured with most lovely clear weather all the time.

To the S.E. of *Plate* I. you will see I have shown a small piece of the ground in more detail, the circles with a central dot in them denoting the peaks and spurs on the great mass of mountains that rise on the east of the Hushé Valley. I have not attempted to show all that were cut in from Kanchinokla, Chungoksi Go, Kon-Kon peaks, etc., but *Plate* II. will, I trust, show you how this detail was sketched, by fixing conspicuous peaks and crags, and running in the rest by eye.* The quality of the detail is in proportion to its distance from the points visited, the heads of the great side ravines near the crest of the range being often very far from true in all their details. You must also bear in mind that these high ranges from which the glaciers descend, as shown in the engraved sheets of the Indian atlas, are covered with snow, and are far less rocky than the representation of the ground indicates. The rest of the season of 1860 was occupied sketching the mountains north and south of the Indus near Skardo, which entailed ascending the peaks of Dindasgo, 15,882 feet, Gonmathanmigo and Thurigo. I failed to reach the summit of Mashkulla on the 10th September, 1860, owing to the fresh snow which had fallen ; I, however, effected the ascent the next year on the 19th July. Busper Peak, 14,940 feet, and Munbluk, were the farthest points reached in 1860. The remainder of the country to the north was taken up and completed in 1861, commencing by the ascent of Thalanka. But I shall not enter into any further details of that year, the system of surveying being the same in every respect.

We will now suppose that the surveyor has to deal with an area of country equal to that of the chart before us, or even larger, quite unknown, and lying beyond the limits of any survey. He only knows, very approximately, the latitude and longitude, and I assume he has a fair amount of time at his disposal.

* This *diagram* only gives a very faint idea of the stupendous view from such a point, 18,000 feet, and how the peaks and spurs are intersected, and the different rays distinguished. The surveyor soon establishes a set of symbols of his own whereby he may distinguish the rays he has taken. Whenever a name can be got from the guides it should be entered against a number in the *Field Book*, and work should be inked up frequently and while it is fresh in the memory.

It is evident that the whole of the area comprised in the chart could be surveyed with very considerable accuracy by plane table alone, and by carrying out a somewhat similar method of building up the triangulation, all the rays which are shown on the chart in black could be laid down. It would be better to defer any measurement of a base to a later period, and begin the survey at once. Two points commanding a great extent of country should be selected, and sufficiently distant from each other to give a good long base; represented on the chart by the dotted line uniting the stations *Biamchu* and *Mashkulla*, which are really 22 miles apart. The surveyor, however, would have to make an estimate of this distance, and on a suitable position on his plane table lay down Biamchu and proceed to that station, set his plane table as nearly on the meridian as possible, or north and south by compass, take a ray to Mashkulla, and, assuming the distance to be 20 miles, lay this off on the scale of 4 miles = 1 inch (5 inches exactly). He would take most careful rays to Shimshak and Thurigo, his first stations of extension, and get in all rays around; he would then proceed to Mashkulla, set the plane table by the base line, which should have been produced to the edge of the board in first instance, so that the sight rule may be re-laid with greater accuracy, and intersect Shimshak and Thurigo and all other rays previously taken and seen again. Thurigo would next be visited, and this initial quadrilateral completed he would commence carrying his work in any direction, and accumulation of error would be reduced to a minimum. Then, as a final piece of work, he would select some level piece of ground, or as level a bit as could be got, and measure a mile or two, fixing the ends of this base on the plane table, and, having obtained a true scale for the work, it could then be enlarged or reduced to exactly the four miles to an inch scale or the one most suitable to it. Finally, if the surveyor has the means, observations for latitude may be taken at this base or at other points of the survey.

With regard to other minor points, it is hardly necessary to say that the surveyor should erect poles with brushwood or straw bound round the top, set up on a cairn of stones, or simply the latter, on all points he may visit, in order that he may distinguish them when clouds hang about the mountains. At such a time it is very difficult to know whether the very highest point of a mountain is visible or not—a lower point to the side may be taken for it, and throw out the work.

Part II.

I will next take a piece of reconnaissance work of a very different character, where anything like surveying work was much impeded owing, 1st, to the unfriendliness of and distrust of the chiefs of the country and the people generally; 2nd, the fact that the greater portion of the route taken was through dense forests or in deep valleys. In *Plate* III. I again take an actual piece of work to show how these difficulties were met in practice, and that work on the plane table was of the greatest assistance. This plate shows that part of the Eastern Himalayas lying between Darjiling on the west, and Punakha, the capital of Bhutan, on the east. This great seat of Bhuddhism was last visited by European officers in 1864, when a mission was sent there under the late Sir Ashley Eden. Captain Lance commanded the escort of 100 Sepoys, which had, owing to difficulty of carriage, to be reduced to 15 Sikhs and 15 Ghoorkhas; Dr. Simpson was medical officer, and I myself surveyor and assistant to the political agent. The mission assembled in Darjiling in December, 1863, but owing to political differences we did not get away until 1st January, 1864. I got ready and prepared a plane table, and projected all the points that might prove useful, and began work at Senchal trigonometrical station and from other points in the neighbourhood. A plane table, prismatic compass, three boiling-point thermometers, and a sextant composed the survey outfit, and while waiting at Darjiling I practised taking every night observations, particularly to pole star.

The plane tabling I was enabled to carry as far as Damsong monastery, near Labar, beyond Kalingpoong on the Bhutan side. We then entered the dense forest between that and Dalingkote fort, and all points were lost to view for several marches. I had then to fall back on bearings taken with prismatic compass, and protracted on a larger scale on a sheet of paper fixed on the plane table, by which I could take rays to points whenever any distant view was to be obtained. Distances were taken by time, and estimate of ground got over. The day's work, reduced, was afterwards transferred to the plane table. When marching through very thick forest or high grass in narrow tracks which twist and turn and dip into hollows at every dozen yards, the best guide is a common compass held in the hand and glanced from time to time; a good general course is soon known, and by keeping well ahead of the porters and pack animals, or well behind them, an even pace can be kept, and time readings can be noted at any stream or any stoppage on the way. Sooner or later a good general ray back or forward from a clearing in the forest can be secured, or by good luck some previously protracted point may come into view.

Owing to serious differences with the Soobah of Dalingkote fort about supplies which had been promised but not laid in, I was ordered on the 16th of January, with a guard of 15 Sikhs, to proceed to Julpygori, then our frontier cantonment on the Teesta, 40 miles distant through the terai, to purchase and return with rice and other stores for the mission. The Bhutias would give no guide, but we reached Julpygori on the second day, and I was enabled to make a rough route survey to that place, and obtained a few useful bearings to points on the outer hills.

This was a serious delay, and we did not march again until the 29th January—we had three days through dense forest, and I did not see a point. At Sipchu an indistinct ray to Giepmochi checked the easting we had made so far. On the 5th February the Tuli La was crossed, but all was buried in cloud. On descending to the Tsangbè Valley, I, therefore, selected a base from a clearing (Yartukka) on the road to a conspicuous churten or temple in a village across the valley we were to pass through, and with this base I was enabled to sketch the mountains round and carry the survey up to the Tegong La as a separate piece of work; getting a meridian altitude of the sun on the 9th, which gave me its latitude. The mission crossed the Tegong La on the 12th February.

Could see nothing, again beaten by clouds, but I obtained permission from Mr. Eden to stay behind with some of my coolies and some supplies, and we bivouacked under a large overhanging rock. There we stayed the 13th and 14th, snowing most of the time. All our supplies being exhausted, the heavy snow finally drove us out on the 15th, and I lost two coolies in the deep snow near the pass. I failed to fix the position by peaks on the north, but got, one morning when it was clear towards the plains and Senchal, G.T.S., a good deal of detail, which was afterwards of use.

Although this was one of the highest passes we crossed on our route to Punakha, even on the return journey I was not fortunate in getting a clear day to see the distant snowy peaks. Route survey work was again taken up to Har. The Chi La, the next pass, was crossed in deep snow late in the evening, so no bearings were got there until the return. At Paro I was more fortunate; by ascending to Gorina very early, one very clear morning, before any of the

Bhutias were astir, I got a view of Chumularhi snowy peak, a fixed point on my plane table, and all the mountains around. On this ray I was enabled to set off the latitude computed from several nights' observations of the pole star, thus obtaining the position of Paro very fairly, and from a short base I was able to sketch the hills around the valley.

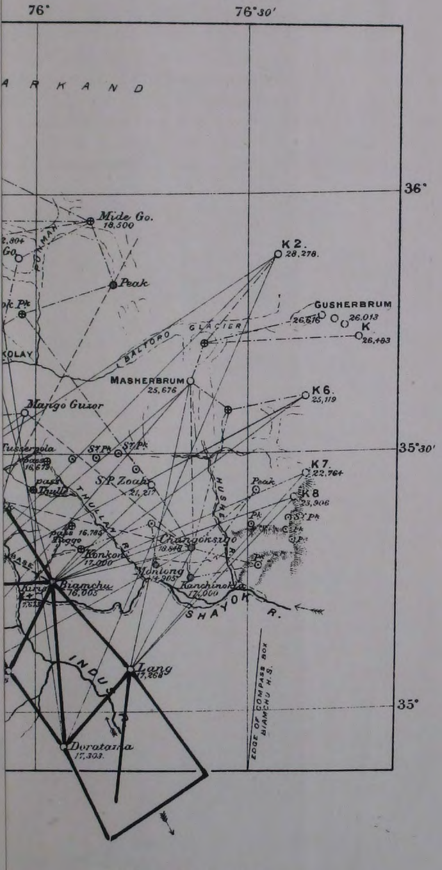
The day was splendid when we crossed the Bie La, and by lagging behind and getting off the road unseen I set up the plane table and got another ray from Chumularhi—which gave me a base of six miles to Gorina—and fixed the whole work into position, and it, moreover, enabled me to carry the survey on to the Dokieu La with very fair accuracy. From that pass into Punakha, which we reached on the 13th March, was a combined system of route survey and plane-table work, with points not so accurate, and the position of Punakha was again checked by pole star observations.

The route we followed was admirably adapted for surveying the country, as it lay directly across all the drainage; we crossed no less than five main ridges, given off from the great main range to the north, and had I been able to go freely about the country and spend more of the time near the passes instead of down in the valleys, *starting with the data I had*, a most accurate map might have been constructed. It can also be seen that, supposing no work had been done previously by the Indian survey in fixing the conspicuous peaks from Darjiling and other stations of the principal series in the plains, an excellent basis for the survey could have been made from the stations Darjiling-Rishisum and Tendong, from which the same regular system of work could have been carried on. In such a case, and a choice of route given him, the surveyor would not take the same line of country we were forced to, but he would work round by the north of Giepmochi, and so into the valley of the Am Mochu, and lay down, to begin with, a number of conspicuous points to the eastward. All this country of both Western and Eastern Bhutan still waits to be accurately mapped, and a splendid bit of work lies before the fortunate officer who may eventually do it. The country is of exceeding beauty and as interesting as any I have visited, but, on the other hand, the people are not all that one could desire, as those who took part in the last mission have every reason to remember.

/EY WORK. PLATE I.

TAN, KASHMIR TERRITORY.

and of Captain T. G. Montgomerie, R.E.



Scale; 18 Miles = 1 Inch.

10 5 0 10 20 30

ary.

of
n of
on
es.

PAPER VII.

NOTES ON ARMOUR PLATES AND THEIR BEHAVIOUR UNDER FIRE.

BY CAPTAIN TRESIDDER, C.M.G. (LATE R.E.).

Preliminary.

'HE following notes do not profess to be an exposition of the actions nd re-actions that take place between an armour plate and a shot in onflict, but only record, with a view to their being criticized, the heories that the writer has been led to form after making the ubject a special study for some years.

Hence whenever it is stated that such and such an action takes lace, or that the reason for such and such a fact is so and so, the ords, "according to the present views of the writer," are always to e understood if not expressed.

The time that elapses between the impact of a shot on a plate and he complete absorption of its energy—that is, the whole time of uration of the complicated actions attempted to be analyzed—is so rief that its sub-division in the way adopted can only be excused on he ground that no better method appeared available for systemati-ally pursuing the investigation.

As when minute objects have to be examined physically we mploy a material microscope, so it is proposed to magnify meta-hysically a minute fraction of a second till its smallest necessary ub-division becomes large enough to be grasped by the imagination.

Division of the action of penetration into stages.

Following out this plan, the writer divides the time taken by a rojectile in perforating an armour plate into the following stages:—

1*st Stage of Penetration.*—*Compression Stage.*—Before the commence-nent of the lip to the front in soft plates or the corresponding plintering of face in hard plates.

2nd Stage of Penetration.—Entering Stage.—The production of the lip or splintering to the front before commencement of back bulge.

3rd Stage of Penetration.—Punching Stage.—The production of the back bulge.

4th Stage of Penetration.—Clearing Stage.—The tearing asunder of the metal of back bulge, starting from its apex.

5th Stage of Penetration.—Clearing Stage.—The bending aside of the walls of back bulge to allow the shot to pass.

6th Stage of Penetration.—Clearing Stage.—Overcoming the friction of the sides of the hole in the plate (this is a small element also in the four last preceding stages), and the resistance of the backing to penetration.

Wood-backed homogeneous plate and unbreakable projectile.

Consider first a wrought-iron plate, not less than two calibres thick, and assume that it cannot crack, and that the shot is unbreakable; also that there is a wooden backing.

First stage.

During the 1st stage, the metal of the plate and the shot are exposed to a sudden and enormous compressing force, and, as the shot does not yield, the face of the plate undergoes crushing. The first effect of this crushing is to drive the nearest molecules of plate metal into the closest contact with the adjacent ones that the material will admit of, and then the 2nd stage begins by the metal commencing to "flow" as in wire drawing. Its easiest direction of flow is naturally to the front, and this is the direction it takes. A "lip," or "rose," or "fringe," is raised on the face of the plate, forming first a small raised annular bulge, then, as the point of the shot gets further in, a larger and larger annular bulge, more and more raised, till the diameter on the inside equals or slightly exceeds the outside diameter of the shot, and the total cubic content of the metal thus forced forward equals (after allowing for its increased specific gravity due to compression) the cubic content of that portion of the shot (point to shoulder) now imbedded beyond the original surface of the plate.

Second stage.

The formation of this front bulge (which naturally tears at the edges if carried too far) ceases to go on as soon as the resistance it occasions equals the effective effort of the shot to continue it. That effort obviously becomes less effective for the purpose as the penetration gets deeper, because it is exerted further from the surface. At the same time the resistance (to the formation of the lip) augments as the penetration gets deeper, because there is more metal to be moved. So resistance to this form of relief and effective effort to obtain it quickly become balanced, and then (as the splitting of

Third stage.

the plate is barred by hypothesis) the shot must stop or find relief in a new direction. It is assumed not to stop, and so enters on the 3rd stage of its work—the formation of the back bulge.

If the plate is less than a certain thickness in proportion to the calibre of the shot, it is evident that the latter may find relief by the incipient formation of the back bulge before the greatest possible amount of bulge to the front has been raised. Then the 3rd stage begins and quickly puts a stop to the second while that is still incomplete. Probably this is the case in wrought-iron plates under about $1\frac{1}{2}$ calibres thick, and as the proportional thickness of plate further diminishes the front bulge is less and less marked, till, at a certain proportional thickness (or rather thinness), no front bulge at all is formed and the 2nd stage of penetration is eliminated.

As soon as the 3rd stage is entered upon (whether before the greatest possible amount of work has been done at the 2nd stage or not—depending on the proportional thickness of the plate), the back bulge begins, and continues to get bigger and bigger, and to have its back or outer side more and more stretched, till the tensile holding power of the metal is exceeded and the back surface of the bulge commences tearing asunder, usually in three to five directions, from its centre or apex.

Fourth stage.
Fifth stage.
Sixth stage.

The tearing once started, the 4th and 5th stages begin almost simultaneously; the resistance experiences a sudden and considerable fall, further continuing to diminish till the 6th stage is reached, *i.e.*, when the shoulder of the shot has arrived at the margin of the broken bulge and its point is in the backing. Thenceforward the resistance of the plate is no more than is due to the friction between the body of the projectile and the tight-fitting walls of the hole made by its shoulder. The shot has, in addition, to punch its way into the wood backing; but for this, and to overcome the friction, a very small residual fraction of its original energy will suffice.

Proportions of resistances at various stages.

In the wood-backed wrought-iron plate under consideration it is probable that the resistance the shot encounters in the 1st and 6th stages is almost negligeable, and that in the 2nd, 4th and 5th it is not very great, so that perhaps some 80 per cent. of the total resistance has to be overcome at the 3rd stage. Here the thickness of the plate is evidently all-important, while the resistance at the other stages is much less dependent on that thickness.

Suppose now that a mild ductile steel plate, of say 25 tons tensile strength as against 17 or 18, takes the place of the wrought-iron one. Resistance at each stage except the last is proportionally increased, Effect of substituting progressively stronger homogeneous plates.

but the relative importance of the stages is not materially affected. This continues to be true when the mild steel is replaced by a stronger homogeneous steel, and that again by a stronger and a stronger, until the plate is unable to submit to the necessary sudden re-arrangement of its molecules without cracking.

It, therefore, follows that the harder the steel of a homogeneous armour plate, *i.e.*, the greater its breaking strain, the more resistance it will offer to a shot, provided it does not split.

Qualities required in homogeneous plates.

The problem with homogeneous plates has in consequence always been, and must always be, a steel-maker's problem—how to arrive at a steel with a maximum breaking strength combined with a maximum capacity of sudden (not slow) change of molecular arrangement without fracture ?

These requirements are so antagonistic that a comparatively early limit is placed on the resisting powers of homogeneous steel plates.

Chromo-nickel steel.

The "Montgolfier" plate made by the St. Chamond Works in France is probably the nearest approach to a commercial solution of the problem that has yet been arrived at, and a plate of this kind is meant whenever a tough homogeneous plate is spoken of in these notes.

Manganese steel.

It is thought that Hadfield's manganese steel combines the required qualities in a still more eminent degree, but unfortunately no method is at present known of temporarily divesting this material of its refractory nature so as to make it amenable, in the cold state, to the manufacturer's tools. Armour plates made from it would undoubtedly be magnificent if they could only be commercially produced, but at present this is not the case.

Commercial condition governing all plates.

This brings us to another limiting condition of practical success in armour plate material—whether homogeneous or not—namely, that its hardness and toughness must not, at every stage of its manufacture, be such as to defy all known cutting tools. Either (1) it must be normally hard, but capable of temporary softening sufficient to allow it to be machined ; or (2) it must be normally soft and have its ultimate hardness (whether of surface only or of mass) conferred after all machining is finished ; or (3) it must not be unmachineable even in its finished state.

Limits within which homogeneous plates satisfy this condition.

Hadfield's manganese steel satisfies the condition in no way. St. Chamond's "Montgolfier" steel probably satisfies it in the third way, but not without difficulty ; and as the third way of satisfying the condition definitely limits ultimate resisting powers, it is likely that the St. Chamond plate pretty nearly represents the absolute limit of excellence in the homogeneous ultimately machineable class ; so that, to get still better results, recourse must be had to plates that are not ultimately machineable, whether homogeneous or not.

As Hadfield's manganese steel is the only iron alloy yet known which possesses unmachineable hardness without brittleness, and as this, at present, is not commercially suitable for armour plates, it follows (assuming, as is practically the case, that our choice of material is limited to alloys of iron) that unmachineable plates, if homogeneous, must be brittle. Homogeneous plates cannot be unmachineably hard without being brittle.

Now suppose the plate under attack is not homogeneous, but has an unmachineably hard face and a tough body and back. We do not get the vastly increased resistance to punching that intense hardness throughout would give us; but we get some of it, in proportion to the thickness of the hard layer. And we do not get the almost entire immunity from cracking that toughness throughout would give us; but we get some of it, in proportion to the thickness of the tough portion. The result is a compromise, and, so far, it is doubtful if we have gained on the one hand more than we have lost on the other. No real advance has been made if the assumption that for simplicity's sake we began with, namely, that the shot was strong enough to stand the strain put upon it at the first stage, is a necessary one. Effect of substituting a non-homogeneous plate.

In other words, looked at simply with regard to its resistance to an *unbreakable* punching tool, our hard-faced plate may or may not be an improvement on the best homogeneous one. It is more difficult to punch it cleanly, but it is a little easier to break or split it, and so permit the shot to pass without clean punching. Everything depends upon the proportions between energy and calibre of shot and dimensions of plate. Against some kinds of attack the hard face will do more good by its hardness than harm by its brittleness, and against other kinds the reverse may be the case.

On the assumption that the attacking shot is *unbreakable*, the hard-faced plate and the tough homogeneous plate would be likely to run a dead heat.

But this assumption is not a practical one. The best steel shot yet known have shown themselves breakable under practical conditions even when they strike quite fair, so that the initial resistance they encounter may be presumed to compress them in their strongest longitudinal direction, namely, in the line of the axis. Assumption that the shot is unbreakable is an untenable one.

That being so, let us go back to the consideration of the stages of penetration, substituting for the tough homogeneous plate a non-homogeneous plate similar in the mass, but differing by having at its face a comparatively thin layer of intensely hard steel. Wood-backed hard-faced plate and breakable shot.

First stage.

Now the resistance at the first stage, which before was dismissed as of small importance, is very great, and the compressing force brought to bear on the shot in consequence, before it has obtained any penetration, and, therefore, while its point is without any lateral support, such as would be afforded by the walls of the indent after it had got a little way in, causes it to split itself on its own point thus:—

How pulverization on impact is effected.

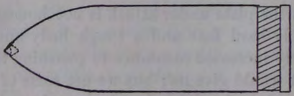


Fig. 1.

A cleavage occurs in the metal round the point, causing a minute fragment of the latter to become detached in the form of a double cone, shown magnified in *Fig.* 2.

Fig. 2.

One apex of this double cone is the original point of the shot, and the other a new point in the opposite direction, splitting up the head like a wedge. Experiments, which the writer is not at liberty to publish, make it certain that this is the nature of the initial damage suffered by a shot which is pulverized on striking fair on a very hard face.

The initial split is succeeded by a thousand others which follow each other in the order of the numbers in *Fig.* 3, and maintain a

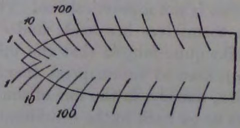


Fig. 3.

direction parallel approximately to the rear surface of the originally formed double cone. The idea is that when the point is arrested it causes a surface of cleavage, say at 1, 1, *Fig.* 4; nevertheless the

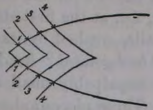


Fig. 4.

point enters the plate and the shot is again arrested at the points 2, 2, 3, 3, and so on, each time cleaving along a new conical surface, extremely near the previous one at first, and a little more widely spaced later on. The resulting conical laminæ thus initiated must obviously break up and fly tangentially to the plate as fast as they tend to form.*

Thus the rear part of the shot is "piled up" on the front part. *Fig.* 5, which was sketched from an actual result, gives the idea, though it does not show a case of complete pulverization.

Fig. 5.

Reason why shot continues to penetrate after its pulverization has been initiated.

All this work is *initiated* on the shot and none on the plate at *the 1st stage of penetration.* Were the work *done* on the shot at this stage the plate would only suffer the blow of a shower of langridge; but the doing of work involves the element of time, and the time the fast-flying shot requires to traverse a few inches is less than that required for the work of its destruction to be *done.* Therefore, it goes

* It will be understood that this is an attempt to describe a rapid continuous action by imagining it to be performed slowly and intermittently.

on and achieves more or less penetration, not as an unbroken shot, but first with its point split, then shattered, and lastly pulverized, all these changes taking place during that minute fraction of a second* necessary for the *doing* on the shot of the work that was initiated at the instant of first impact, *i.e.*, at the first stage of penetration.

The body of the projectile, crushed by its own momentum against its own retarded and "*back-pointed*" head, is also shivered into minute pieces, which are impalpably small at the leading end, and larger towards the base. These pieces lodge and get consolidated in the indent as far as there is room for them, and when the indent is full and piled up, as shown in section in *Fig.* 6, the succeeding frag-

Fig. 6.

"White plash.'

ments fly off tangentially in the direction of the arrows, causing a "white splash" on the plate if they graze its surface, which they commonly, but not invariably, do. If these fragments encounter anything (such as a projecting piece of frame as at A), the marks they leave prove beyond all doubt the largeness of their number and the smallness of their size. By the time the base of the shot has

* A shot properly pulverized on impact seldom obtains so much as 6 inches penetration. At 2,000 foot seconds it would, if free, travel this distance in $\frac{1}{4000}$ of a second.

reached the plate, the energy is, as a rule, pretty well expended, so that a few fragments of the base usually escape pulverization and are found in front of the target.

Examples of pulverization on impact.

At Shoeburyness, on one occasion, out of five 6-inch Holtzer shot, weighing together 503½lbs., all the weight that could be picked up was 80lbs., and this was in 176 pieces. The remaining 423½lbs. had been pulverized, and the dust either scattered in all directions or kneaded into lumps which stuck in the plate. The latter did not probably account for more than about 50lbs.

Energy of blow has to be borne by plate in spite of pulverization of shot.

During the time occupied in the destruction of the shot, the plate suffers in proportion to the energy of the blow. That energy must be borne; it cannot be avoided; but the duty of the hard face is to alter the medium conveying the energy so that the plate may receive only the emasculated blow of a disintegrated lump instead of the penetrating thrust of a carefully designed tool.

It is thus evident that the addition to any plate of an intensely hard face, *which causes the shot to be pulverized on impact*, adds enormously to the resisting power.

Under two particular conditions, however, the hard face, though quite satisfactory in point of hardness, may fail to pulverize the shot on impact.

First condition under which a hard face fails to pulverize shot.

The first condition is when the velocity of the shot is so small in proportion to its strength that it is able to bear, without splitting, the longitudinal compressing force exerted on it at the instant of impact.

In such a case the hard-faced plate gains no advantage at the 1st stage; it behaves much the same as if the hard face were absent, except that the shot has more difficulty at the 2nd stage in causing the forward "flow" of the metal, which, being so hard, breaks and crumbles as it is displaced instead of remaining attached to the mass as an annular bulge.

The energy absorbed in causing the "flow" of this refractory metal may be judged from the violence with which fragments of it are projected towards the firing point. A piece weighing about two pounds has been known to go through an iron roof some half mile off.

The hard face gives, therefore, under this condition, a considerable advantage, but not an overwhelming one, in the 2nd stage; and in the further stages it plays no part.

Example.

This condition was perfectly illustrated at the competitive trials of August, 1893, in Holland, where five 5-inch Krupp steel shots with gradually increasing velocities were fired at each of six 6-inch plates, four being hard-faced and two homogeneous. Taking typical examples of each class, the results were as follows, and are graphically recorded in *Plate* II.* :—

Striking velocity.	Hard-faced Plate.	Homogeneous Plate.
1444 f.s.	Indent 6·89″ rebounded intact.	Indent 6·39″ rebounded intact.
1575 ,,	Indent 8·07″ rebounded intact.	Indent 7·38″ rebounded intact.
1640 ,,	Splashed and pulverized.	Indent 7·68″ rebounded intact.
1771 ,,	Splashed and pulverized.	Indent 17·5″ lodged, broken in two.
1880 ,,	Splashed and pulverized, and plate cracked.	Perforated, badly broken.

The homogeneous plate cited was of "Montgolfier" steel, and offered more resistance than the hard-faced (Vicker's) plate at all the stages except the first two. As long, then, as the velocity did not entail more compression on the shot at the 1st stage than it could bear, the homogeneous plate, which was a splendid specimen of its class, had the best of it—as evidenced by the penetrations of the two first rounds. Immediately, however, the striking velocity passed a certain limit (apparently about 1,600 f.s.), the hard-faced plate put a strain on the shot at the 1st stage, to which it succumbed, and the tables were completely turned.

These two plates have been selected from the six tried as the best examples to the point, but their teaching was fully corroborated by the rest of the trial. To make assurance doubly sure, the Dutch authorities subsequently fired two more of the lower velocity rounds at the Vicker's plate, and the results of rounds 1 and 2 were repeated.

Second condition under which a hard face fails to pulverize shot.

The second condition is when the thickness of the plate is so small in proportion to the energy of the blow that the hard face does not receive from the mass of the plate and from the rigidity of the backing sufficient support, but "gives back" at the point of impact during the 1st stage, and thereby relieves the shot of part of the compressing force that would otherwise have split it.

This case has been amply exemplified. A hard-faced wood-backed plate, 10 inches thick, may be relied on to repeatedly pulverize, with less than 5 inches penetration, 6-inch steel shot that would, at the same velocity, pass *unbroken* through a 5-inch plate similarly backed, though the depth and hardness of the hard layer, and, in fact, the first five inches of the target, were identical in each case. Under ordinary

* The horizontal lines in *Plate* II. are lines of distance from face of plate; the vertical lines are lines of velocity; the full-line "locus" is that of the point of the 12-c.m. shot at a homogeneous plate of 6″ thickness when the ordinates of x and y correspond to f.s. velocity and inches penetration respectively; the dotted-line "locus" is the same at a hard-faced plate.

conditions, if the hard face is really hard, and adequately supported in proportion to the energy of the blow, the unbroken shot never gets a chance to know how thick the plate is, being an incipient ruin before it has achieved any penetration whatever; and the reason why a steel shot, pulverized on impact, never gets through a target, is because the hard face can only be sufficiently supported to bring about the pulverization of the shot on impact by the presence of more than enough body in the target to withstand complete perforation by the disintegrated fragments. In other words, pulverization on impact and complete perforation are incompatible things.

Reason why pulverization on impact and complete perforation are incompatible.

A target, *i.e.*, plate and backing together, is here mentioned because, as will be argued further on, a thin plate may have its face nearly as well held up by rigid backing as by increase in its own mass.

This "giving back" of the face at the point of impact may be local, or may involve the movement of the whole plate or substantially heavy parts of it. If it is local the shot is saved from pulverization. The back bulge, belonging to the 3rd stage, starts forming immediately on impact (the plate being so thin), whereas, if the plate were of suitable proportional thickness, or if the formation of the back bulge were resisted by adequate rigidity in the backing, the 3rd stage could not be arrived at till resistances at the first two had been overcome. The premature readiness of the back bulge to form, however, renders the resistances at the first two stages almost negligeable, and pulverization on impact can only be effected by overpowering resistance at the 1st stage.

Two ways in which face may "give back" at the point of impact.

Shot saved from pulverization by local yielding of point of impact.

But if the retirement of the point of impact is not local—if, for example, the plate "gives back" bodily, or breaks in three or four pieces, which retire at the point of impact by rotating round their edges—the strain on the shot at the 1st stage will not be appreciably relieved.

Shot not saved from pulverization by non-local yielding of point of impact.

The reason is that the time required to initiate the motion of the whole plate, or of its large fragments, is likely to exceed that required to initiate the splitting of the shot. The yielding of the point of impact, in short, occurs too late to save the shot. The following case exemplifies this:—A 4-inch hard-faced plate erected without backing, except along its top and bottom margin, was fired at with a 5-inch Palliser shot of 50lbs., striking with a velocity of 1,200 f.s., and an energy of 499 f.t.

Reason.

Example.

At the 1st stage the resistance of the hard face pulverized the shot. The plate broke under the energy of the blow in four directions, radiating from the point of impact, which retired about

$1\frac{1}{2}$ inches by each section of the broken plate hinging on its edge (*Plate* I.).

Deductions. There was *no* penetration. From this it may be argued :—

(1). That the pulverization was initiated at the 1st stage (as there were no other stages). This is always the case according to the writer's views, but here it occurred demonstrably.

(2). That the absence of any indent in the face of the plate was due to the circumstance that the point of impact (retiring as it was bound to do while the work initiated on the shot at the 1st stage was being done) did not retire locally, but took the surrounding masses of plate with it.

(3). That this yielding of the point of impact, involving as it did the setting in motion of considerable weights, did not occur quickly enough to save the shot.

A good tough homogeneous plate under this test would be indented from five to six inches, and would bend without breaking. Plates with really hard faces cannot be bent suddenly and substantially without fracture, and so are not suitable when the nature of the attack and their installation require this quality.

Now let us consider the part played by backing under various conditions.

Part played by backing in case of homogeneous plate. First, in the case of a homogeneous plate. Increased rigidity in the backing has little or no effect on the 1st stage of penetration, but adds directly to the resistance of the 3rd, and thus indirectly to that of the 2nd; because the greater difficulty the shot has in forming the back bulge the more work it will expend in getting the utmost relief out of the front one. The 4th stage again is not affected, but the resistance at the 5th stage, and the last part of the 6th, is increased in very high proportion.

Part played by backing in case of hard-faced plate. Next, in the case of a hard-faced plate. All the above advantages of more rigid backing are retained, and in addition to these, and to the increased resistance to bending, which is of great value to a hard plate, but not of much consequence to a soft one, there is an enormous advantage at the 1st stage; for if the plate is of insufficient thickness to give of itself adequate support to its hard face, a rigid backing tends to remedy this defect.

Assistance given by rigidity in backing. Generally, a rigid backing (not a thick one necessarily, but a hard, unyielding one) may be expected to add very largely to the resisting powers of any plate, but would benefit a hard-faced one most. A mathematically rigid backing, which would render the formation of a back bulge impossible, and compel the shot either to split the plate, or remove *to the front* all the metal in its way, would affect resistance enormously—probably multiply it many times rather than simply add to it.

This is in accordance with, and results from the writer's theories, but experimental confirmation is not wanting. In *Armour and its Attack by Artillery*, by Captain Orde Browne, R.A., Part I., pp. 139 to 146, is given an account of "Engineer Experiments on Shields fixed on Masonry," which tends to justify the general deductions arrived at above. The masonry backing in these experiments multiplied rather than added to the resistance of the shields. Captain Orde Browne's reasons for this are in accordance with the writer's views, and may be compared with them as follows:— Example.

In Captain Orde Browne's words (p. 145, lines 22 and 23)—"The plate, with its hard surface and hard backing, resisted the shot very sharply and rigidly." Again (p. 146, lines 3 to 5)—". . . but the shot was unable to bend it back," *i.e.*, walls of back bulge, "and tear open the remaining thickness from the opposite side, and so the blow was borne."

Translated into the phraseology employed by the writer in these notes, these comments amount to this—"The resistance at the 1st stage of penetration was much increased;" and this—"The resistance at the 3rd and 5th stages of penetration was much increased." (Note.—The 6th stage was not reached).

Most helpful classes of backing.

The ideal backing for any plate, but especially for a hard-faced plate, would be a mass of hardened steel or chilled cast iron. Of course, this is inadmissible. Next would come granite, hard concrete, brickwork or other form of masonry. This is admissible on land forts, but not on ships. The backing used on ships is always wood, which, as against penetration, is better than nothing, but not very much. Its principal use is to carry the bolts, which would keep the fragments of plates in place if they were broken, and to prevent bending or "non-local" retirement of the point of impact.

Wood backing nearly useless except to prevent bending of plate, and to hold up fragments if it is broken.

Whenever structural considerations require the use of bolts and backing, the one advantage of tough homogeneous plates is much modified; since, under these conditions, hard-faced plates may be cracked without any piece falling down or protection being seriously diminished.

Experiments in Russia have clearly shown how obstinately quite small fragments of a really hard-faced plate refuse to be perforated. The first plate of this class tried there was a compound one hardened on the writer's system. It consisted, as to thickness—two-thirds of

Example of obstinacy with which even quite small pieces of hard-faced plates resist penetration.

wrought iron, one-sixth of spongy steel of union (uniting face to back), and one-sixth of high carbon face-plate steel. That the union of face and back was perfect was proved by the plate permitting itself to be broken into fragments without any cleavage taking place along the planes of union; but the "uniting steel," though thoroughly attached to both face and back, was in itself spongy and unsound, and could not stand the strains incidental to "hardening" without cracking in numerous places. The occurrence of these cracks announced itself during the hardening process by a series of sharp reports or "clinks," but as no defects could be discovered by a minute examination of the exterior of the plate, the clinks, though mysterious and suspicious, were thought to be unimportant. Under high velocity fire, however, with 6-inch steel shot, the plate broke at every round, so that the fifth round was fired at quite a small detached piece. Subsequently several additional rounds were fired, until no piece large enough to attack remained. To the last the shots were pulverized on impact, and though they always broke the piece fired at, they did not get far into it. This trial was a triumph for the face-hardening system, but a failure for the particular plate. It affords an excellent example of the resistance that a broken hard-faced plate is capable of as long as its fragments are held up; and it teaches the desirability of numerous small bolts instead of a few large ones.

Resistance to perforation is paramount, and absence of cracks secondary.

To keep the shot out is everything, and to avoid cracks in plates is quite secondary. When it is possible to add a certain amount of immunity from cracking—as is done in the most modern hard-faced plates—to a maximum resistance to penetration, well and good, but the first must not be substituted for the second—even much of the first for a little of the second. A ship can fight perfectly with any number of cracks in her armour, but can she when even a single shell has burst in her vitals?

Modifications of backing should aim to render more difficult the formation of the back bulge.

As long, then, as increased resistance to penetration can be obtained by the use of hard-faced plates, these are the plates to be used. More rigidity of backing than they receive at present is desirable for them, and it remains to be seen if some improvement in this direction cannot be effected. Portland cement between plate and wood backing has given promising results, but ship-builders do not see their way to practically employing it. They use red lead to bed the plates on, and this is useful to deaden the vibrations set up by the racking energy of the blows, but it attains no rigidity to speak of. It does not make the formation of the back bulge more difficult, which is the thing to be desired.

In certain positions, such as in shields of gun mountings, backing is usually dispensed with, and in these positions hard-faced plates are not to be recommended, as their good qualities are not brought out and their defect of inability to bend substantially without fracture is accentuated.*

Hard-faced plates not suitable if backing is altogether absent.

For plates, such as tough homogeneous plates, that are sure to be perforated rather than broken by artillery fire, a thin wood backing may as well be dispensed with, if not required for structural purposes; and it may be that a thick wood backing will hardly compensate for its weight and cost by the benefit it confers. But when plates are of such a nature that they will break rather than be perforated, a backing of some sort is indispensable to hold the fragments up.

In support of the assertion that ordinary wood backing adds but slightly to the resistance of a plate to penetration, the Gâvre formula for the perforation of wrought iron backed with wood may be referred to. This is

Uselessness of wood backing to diminish penetration illustrated by reference to the Gâvre formula.

$$\frac{PV^2}{a} = 95\,E^2 + 1600^2\,\Sigma^{1\cdot4}$$

where P = weight of shot in kilogrammes.

a = calibre in decimètres.

E = thickness of backing in decimètres.

Σ = thickness of plate in decimètres.

V = striking velocity in mètres per second.

Take a case in which $P = 45{\cdot}36$, $a = 1{\cdot}525$, $\Sigma = 2{\cdot}5$, and find V in the three cases when E, the thickness of wood backing, equals respectively zero, 1·525 and 10. The results are :—

	Mètres.
When there is no backing the perforating velocity is	557·155
When there is six inches of backing the perforating velocity is	557·162
When there is one mètre of backing the perforating velocity is	557·440

If this is correct the assistance afforded by wood backing even three feet three inches thick against perforation is microscopic.

Up to this point we have, for simplicity's sake, left the possible cracking or splitting of the plate out of consideration in investigating the stages of penetration. It is known that cracking will not occur

Cracking of plates.

* Since this was written a direct comparative trial has been made of two portions of the same plate, both unbacked, but one face-hardened and the other toughened throughout. The result was overwhelmingly in favour of the hard-faced sample, in spite of the absence of backing.

in a good tough homogeneous plate even under repeated perforations, but with hard-faced plates this is not the case. Modern plates of this class will often stand, and claim to be able to stand, without either perforation or cracking, blows that would completely perforate the best homogeneous plate of considerably greater thickness, but when the power of the blows or their number is further increased such plates must crack sooner or later. It is, therefore, as well to consider how cracking—which is not an unpardonable sin—affects perforation—which is.

How cracking may influence penetration in three ways.

It may affect it in three ways :—

First way.

First, by facilitating the passage of the shot which causes it. Experience with the most modern hard-faced plates* is against there being much danger here, since such plates commonly require a more severe blow to perforate *and* crack them than to perforate them simply. If they permit perforation it is generally because their hard face is not sufficiently hard or not adequately supported, and in either of these cases they behave rather as tough homogeneous plates than as hard-faced ones.

Second way.

Secondly, by isolating a small part of the plate from the rest and so making it easier for a subsequent shot which strikes this isolated part to perforate. That there is not much to be feared in this direction has been already shown by reference to conclusive experiments in Russia.

Third way.

Thirdly, by isolating and throwing down a part of the plate so that the backing behind this part becomes exposed. Leaving out of account the plausible argument that in a naval action the chances are against the occurrence of two hits on the area covered by one plate, this requires looking into; and it will be well here to digress slightly in order to discuss the ways in which cracking may be brought about, and then to return and examine how far it tends to break bolts and dislodge fragments of plate.

Causes of cracks in plates.

There are two effects of impact which tend to crack plates, namely "racking" and "wedging."

Racking.

Racking may be described as the general "shaking up" a plate receives under a blow that is heavy in proportion to the weight of plate that has to share it. The term "wedging" explains itself.

Energy available for racking.

The energy that is available for racking may be considered as the total energy of the blow less the amount (if any) expended in doing work on the shot. The racking intensity of the same available

* Hardened built-up compound plates are not included in this term.

energy is less in proportion as penetration is greater. Both these statements may be illustrated by the case of a hard-faced plate which partially saves itself from racking by diverting some of the striking energy to the destruction of the shot, and intensifies the racking effect of the remainder by arresting the shot so suddenly. A soft plate, on the other hand, would accept the whole energy, but dispose of it, comparatively speaking, so gradually as much to reduce its racking effect, which, unlike wedging, can hardly be given a place in the stages of penetration.

Ordinary method of comparing the racking effects of various tests.

The racking effect of a blow on a particular plate is generally spoken of as proportional to $\frac{\text{striking energy of shot in foot tons}}{\text{weight of plate in tons}}$, but to this the writer takes exception. For suppose two similar plates, each 2 feet wide and 10 inches thick, but one 12 feet and the other 6 feet long (or half the length, and, therefore, half the weight), are similarly struck by a blow of the same energy in the same position —centrally as to width, but only one foot from one end. Evidently each plate stands about the same chance of failing by racking, but by the usual method of comparing racking strains the short plate would have borne double as much as the other.* The writer would prefer to take the distance—call it A—from point of impact to nearest edge, or to nearest previous point of impact (whichever is least), and, after calculating the weight the plate would have for an area of surface represented by $4A^2$, to consider the racking energy for purposes of comparison proportional to $\frac{\text{striking energy of shot in foot tons}}{\text{weight of plate in tons for area } 4A^2}$.

Suggested improved method of comparing racking effects.

This is not quite sound, but it would form a fairer method of comparison than the ordinary one, and in these matters absolute accuracy is not attainable. It is right to take the total energy for purposes of comparison between two plates, because a plate is entitled to credit if it diverts some of the energy to the destruction of the shot; but it would not be fair to consider a plate that had been perforated by a 6-inch shot as equally racked with one of equal weight that had stopped the same, and still less with one of equal weight that had stopped a 12-inch shot of equal energy.

Racking and penetration are approximately in inverse proportion to each other.

A heavy shot at low velocity is likely to rack more, *because* it is likely to penetrate less, than a light shot having the necessary extra velocity to give it the same energy. As extreme examples, it might

* Capt. Orde Browne has taken the same exception to the usual method of comparing racking energies, but has not, to the writer's knowledge, proposed an alternative.

be observed that a plate of butter could be racked excessively little because it could be penetrated excessively much, while a plate of hardened steel would be racked proportionately more, as it was more difficult to penetrate.

In short, if you want a projectile to rack as much as possible you must shape it so as to penetrate as little as possible.

Numerous bolts desirable against racking attack.

Against racking attack numerous bolts are very desirable, and so is perfectly continuous and hard contact with the backing ; but the most modern hard-faced plates claim that the toughness of their mass renders them nearly as difficult to crack as homogeneous plates, in spite of the necessarily brittle character of their hard faces.

Wedging.

Next, as to "wedging" action. In addition to squeezing metal out to the front and driving it to the back, a shot that has obtained a lodgment is always trying to expand the hole made by its point so as to make it large enough for its body ; and the more resistance the plate-metal offers to displacement forwards and backwards the greater the lateral effort.

Therefore, the harder a plate is the more wedging strain it has to bear (assuming the shot does not break up), and extra rigidity in the backing has the same effect. This strain begins with the second stage of penetration, at the end of which it is a maximum, and it probably continues with diminishing force through all the remaining stages.

Wedging strain minimized if shot penetrates but slightly.

Wedging strain is nearly entirely avoided if the shot is pulverized on impact, for then its efficient shape as a wedge is lost, and though the point goes on and obtains some penetration in virtue of its velocity during the time taken for the absorption of the energy, it will be found imbedded in the plate in an utterly shapeless mass —not flattened, as a soft projectile might be (it is too hard for that, even at the heat it acquires from the sudden stoppage of its motion), but as a mass that has been first crushed to powder and then reconsolidated in a new shape by the continuation of the same pressure that destroyed it.

Loose phraseology usually employed in connection with pulverization on impact.

Such a mass is often spoken of as being "welded into the face of the plate." This is a phrase that will not bear examination. It is certain that the point of shot does not get welded to the plate in any sense, for these reasons :—

(1). The indications of a welding heat having been obtained at the point of impact are always absent, while the colour indications quite close to the point of impact are usually those corresponding at most to 600° F.

(2). When the plate is broken subsequently through the point of impact, the shot-point either falls out or is easily detached The indent made is then discovered to be flat-bottomed, and no trace of the original outline of the shot-point is to be found.

As a hard plate, then, has more tendency to crack than a soft one, and also has both more racking and more wedging strain to bear, *unless it breaks up the shot*, it is clear that this "breaking up" power is the great weapon of hard plates, and when that power can be secured in plates which, being tough in the mass instead of hard throughout, have a minimum liability to cracking, the advantages of such plates seem to completely outweigh their drawbacks.

Shot-breaking power is the principal weapon of hard-faced plates.

Having come to the end of this digression, let us return to the question quitted at page 190:—How far do racking and wedging tend to break bolts and dislodge fragments of plate?

Racking, whether it cracks the plate or not, and more when it does not crack it, sets up a rapidly repeated or vibratory tugging action on the bolts, which, if they fail in consequence, fail in tension. The bolts of tough homogeneous plates are no more exempt from this strain than those of hard-faced ones; but, as previously explained, more energy is expended on racking in a hard plate than in a soft one. This tensional strain on the bolts is to be met by their design and material, and in practice there is no difficulty in so meeting it, it being unusual now-a-days for bolts to fail in tension—that is, by racking.*

Racking strains bolts in tension.

Wedging brings no strain on the bolts until it succeeds in splitting the plate in two or more parts. Then it goes on to try to force these parts asunder sideways, and in so doing brings a heavy cross strain on the bolts, which, being held in the piece of plate that moves sideways, and also close by in the backing which does not move, suffer a shearing strain, and fail—if they fail—by shearing.

Wedging does not strain bolts till it splits the plate, and then it strains them in shear.

All the bolts that failed in the Russian trial of the hardened com-

Example.

* Nine months after this was written nearly all the bolts of a 10-inch hard-faced plate, tested in Russia, failed in tension—that is, by racking. Subsequent examination proved that the material of the bolts was not in fault, so this is probably to be attributed to the want of "perfectly *continuous* and *hard* contact with the backing" referred to above. The plate being curved made "*continuous* contact," without the use of a bed of red lead difficult to secure; and the construction of the target made the nuts in rear so difficult of access that "*hard* contact," which depends upon the very tight screwing up of the nuts was probably wanting. The plate was not cracked, nor did it fall down, though only two bolts out of twelve remained unbroken after the sixth round.

pound plate previously alluded to were clean sheared. This plate, owing to its hard face and the abrupt manner in which it stopped all the projectiles, was exposed to a maximum amount of racking. Yet no bolt failed in tension. Probably the racking had as much to do as the wedging with splitting the plate (seeing how small the penetrations were), but it was clearly the brief continuation of the wedging action *after the plate was split* that broke the bolts; otherwise they would not have broken in shear.

Cracking only dangerous if plates liable to be split clean through and the fragments moved substantially sideways at the same blow.

It would seem, then, that with proper attention to design there is no fear of bolts giving way so as to expose the backing unless the plate is clean split through and the fragments can move (and by the same blow are made to move) sideways.

These two conditions demand attention. Modern hard-faced plates do not plead guilty to being liable to split clean through unless unreasonably overmatched, and at the same time they claim that it takes a heavier blow to overmatch them than to overmatch any other class of plate. Also, the possibility of side movement in the armour plates of a ship must not be judged of from the behaviour of small test-plates fired at without marginal support of any kind.

So the matter stands. The danger of backing being exposed during an action is not quite so remote with hard-faced plates as with tough homogeneous ones. It would be useless for the advocates of hard-faced plates to try to argue away that fact, and so they had better face it. They have an excellent case, and can well afford to admit being one degree nearer to a remote danger if they prove themselves, as they do, many degrees further from the most serious and most threatening one.*

Damages to projectile after 1st stage of penetration.

Hitherto the projectile has been considered as if it must either be pulverized on impact or not injured at all, the reason being that this hypothesis fully sufficed for comparing the advantages of hard-faced and tough homogeneous plates. For if the hard-faced plate does not pulverize the projectile on impact its face fails in its

* Acceptance trials of the larger armour-piercing projectiles which are made against compound plates of disproportionately small area almost invariably illustrate the wedging action of shot and the way in which it tends to shear bolts. If the frame in which the plate is placed is strong enough to hold together, it generally indicates by its bent and distorted condition the enormous bursting strain it has had to withstand; and if it is not strong enough (as occurred, for instance, on the 10th February, 1893, when, with a view to economy, a new design of light frame was experimentally used), large heavy sections of the plate are hurled sideways to a considerable distance.

characteristic function, and its mass, which is tough and homogeneous, asserts itself; so it becomes, to all intents and purposes, a plate of the latter class, and, in a modified degree, behaves like one.

Similarity of behaviour of hard-faced and homogeneous plates if pulverization on impact does not take place.

This was exemplified in the Dutch trial previously alluded to. When the velocity was insufficient to cause pulverization on impact with the hard-faced plates, the shot entered them without causing cracks, and was rejected by the elastic nipping action of the walls of the indent on its ogival head, just as in the case of the tough homogeneous plates. The only difference was that in the latter the tough face swelled up into a front bulge, torn round the margin, but not fractured; while in the former the hard metal of the face splintered in the act of trying to "flow," and threw back small pieces, sometimes to a great distance.

Example.

Characteristic difference of direction in which splinters of plate and of shot are respectively projected.

It may be remarked, in passing, that fragments of steel, which are projected with great velocity back towards the firing point, will always be found to be fragments of plate, and not of projectile. When a shot breaks up, its fragments fly, roughly speaking, in the plane of the face of the plate, *i.e.*, in a plane which, under usual test conditions, is about perpendicular to the line of fire. Pieces of the plate, on the other hand, which find themselves separated from the mass as they hurry to the front to form the front bulge naturally continue to move in the same direction they were following when the separation occurred; that is, the tangent to the initial direction of their trajectory will be approximately somewhere in the surface of a cone, whose axis is the line of fire, and whose vertical angle depends upon several conditions. Chief among these conditions is the calibre of the shot; but the shape of the shot's head, the distance it had entered when the fragment of plate separated, etc., also have influence.

Projectiles are often broken by all classes of plates, but are only pulverized on impact by hard-faced ones.

Any breaking up of the projectile which is not initiated at the 1st stage of penetration is not the characteristic work of a hard face, but may, and often does, occur in plates that are homogeneous and even soft.

Classification of injuries to shot that may be caused by collision with plates

The writer would class the damage projectiles are liable to on striking armour plates as follows :—

1. Setting up.
2. Mushrooming.
3. Pulverization on impact.
4. Breaking up.
5. Breaking.
6. Cracking.

Setting up almost inevitable and not important.

1. Setting up, or shortening in length and simultaneously expanding in diameter *to a very slight extent*, is a thing that even the best shot seldom escape if the plate is anywhere near a match for them. It is not important, and may be dismissed with simple mention.

Mushrooming condemns shot.

2. Mushrooming, which is setting up of a substantial and serious kind, never happens to a good shot. Any projectile that submits to it may be immediately condemned as a bad one, and no credit need be given to the plate for bringing it about. Nothing detracts more from a shot's perforating powers.

Pulverization on impact.

3. Pulverization on impact has already been dealt with.

"Breaking up" distinguished from pulverization on impact.

4. "Breaking up" is distinct from pulverization on impact in that, although the shot is shattered into many pieces, none of it is reduced to chips and powder; and, above all, the utter destruction of the very point is not accomplished. If the point of the shot is found not deformed out of all recognition, pulverization on impact has not taken place. "Breaking up" is not initiated at the 1st stage of penetration. The causes which produce "breaking up" are the same in kind as, but greater in degree than, those which produce "breaking," and are quite distinct from the cause which produces pulverization on impact.

"Breaking" distinguished from "breaking up."

5. The term "breaking" may be held to include all damage in the nature of fracture between the limits of a shot in two pieces on the one hand, and the mildest case of breaking up on the other. No hard-and-fast line can be drawn between a bad case of "breaking" and a mild case of "breaking up;" but a shot in four pieces could not properly be described as "broken up," while one in 20 pieces would be rather more than simply "broken."

Cracking.

6. Cracking hardly requires definition; it is incipient but incomplete fracture.

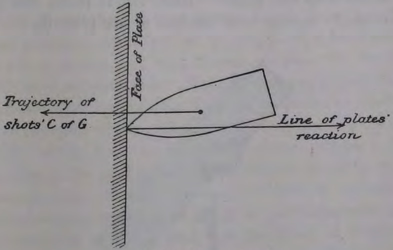
Causes of "breaking up," "breaking," and cracking are cross-breaking strain and torsion.

All these classes of damage have been disposed of except the last three, which may be taken together for the discussion of their causes. These are—"cross-breaking strain" and "torsion." Compression, *i.e.*, compression so symmetrical as not to involve cross-breaking strain, is not included, because this causes pulverization on impact or nothing.* If it is not sufficient to cause pulverization on impact when the delicate point of the shot is without lateral support, it cannot be sufficient to cause fracture at any later stage, as the compressing force is not increased during penetration in anything

* Pure compression may also cause "setting up" or "mushrooming," but the first is unimportant, and the second inadmissible.

like such rapid proportion as the shot is strengthened by the support of the walls of the indent it makes.

Cross-breaking strain does not occur when the shot strikes the plate with its axis steady and normal to the face. This condition is, however, a rare one. Even at the testing grounds, when the shot is aimed normally, the range is generally too short to allow it to get its axis steady in the line of the trajectory of its centre of gravity. The path of the point probably describes a spiral volute round that line, the radius of the spiral being greatest when the shot leaves the muzzle, and diminishing gradually to zero as it "goes to sleep." However that may be, the chances are that when, at short range, the point is suddenly held, the trajectory of the centre of gravity is not at that instant passing exactly through it. The result is that the action of the shot and the re-action of the plate form a "couple," tending to twist the axis still further out of coincidence with the trajectory (*Fig.* 7), thus clearly involving a cross-breaking strain on the shot immediately its head is held by the plate, that is, at the 2nd stage of penetration. Cross-breaking strain.



(*Obliquity Exaggerated*)

Fig. 7.

This twisting moment has nothing to do with the shape of the shot's point, and the unequal re-action at different sides of it due to the method of its presentation, because, though that is oblique, it is too slightly oblique to be of consequence.

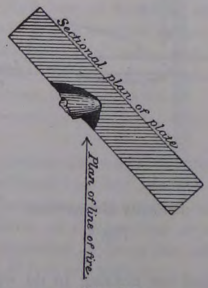
The case is very different, however, when the trajectory itself is substantially oblique to the surface of the plate. In that case, if the obliquity is not too great to allow the point to "bite," a slight Oblique impact.

groove-like penetration is first obtained and immediately friction arises which tries to arrest the axial revolution of the shot. This friction not only acts on the head while the body is free (as in the case of simple torsion, discussed further on), but acts on one side of it more than, or to the exclusion of, the other. The result is a confused jumble of compressional, torsional, and cross-breaking strains, which defy analysis, but are pretty certain between them to be fatal to the shot.

Examples of effect on shot and on plate of oblique impact.

Unfortunately, very few experiments on the oblique attack of armour plates are available, although that is, after all, the attack they would have to withstand 99 times out of 100 in action. The writer can only recall being present at two rounds fired under such conditions.* These were at two 12-inch compound plates, inclined at 45° to the line of fire, the projectiles being 12-inch Holtzers of 720lbs., and the striking velocity 1,880 f.s. This velocity, by Fairbairn's formula, would suffice to carry this shot through $22\frac{1}{2}$ inches of unbacked wrought iron, or, say 18 inches of compound plate. The results were :—

Round 1. Shot bit, but made an elongated indent of only seven or eight inches deep and broke. Head left in plate, but pointing in a direction nearly square with the line of fire (*Fig.* 8).



Round 2.
Fig. 8.

Round 2. Similar result, but shot more broken, and indent only about three inches deep. No fragments left in plate.

* Shoeburyness, 20th October, 1887.

Here it will be seen that the mere thickness of the 12-inch plate, as measured in the direction of the line of fire (about 17 inches) was not enough to have saved it from complete perforation, and so the oblique position must be credited with having very greatly added to the resisting power independently of the greater thickness presented.

Torsion.

Torsion is due to the effect of friction between the head of the shot and the walls of its indent, endeavouring to arrest the axial rotation communicated by the rifling, while the momentum of the unimbedded portion of the shot strives to maintain the rotation. Torsion, the writer is inclined to believe, is the principal cause of fracture when the shot breaks clean across in two pieces at or near the shoulder. Sometimes, but only when the shot has been much heated, and consequently softened, by impact, slight but unmistakeable symptoms of torsion having had to do with the fracture may be observed.

Extra advantage over homogeneous plates possessed by hard-faced plates when impact is oblique.

Hard-faced plates are generally considered to be likely to derive more benefit from oblique position than plates of the other class ; yet no credit ever appears to be given at competitive trials for this advantage, which, if real, is a very important one. The writer is quite convinced that it is real, and exists to a far greater extent than recognized by those who briefly account for it by saying "the shot has greater difficulty at biting at an angle on a hard-faced plate." Were this all, it would put both classes of plate on an equality in this respect at all angles when "glancing" takes place on neither, and would limit the advantage of the hard-faced plates to those degrees of obliquity between which glancing begins on the two classes respectively. This hardly does the hard-faced plates justice. Their aim and their claim is to initiate the destruction of the shot at the first stage of penetration ; that is, before any indent is commenced, and, therefore, before any question of biting or not biting can arise. All degrees of obliquity between zero and the limit at which glancing begins assist them to do this to a very great extent, because the sudden compression to which they subject the shot is no longer in its strongest direction (the line of the axis), but acts at a much greater advantage.

A really hard-faced plate never fails to pulverize a projectile on impact if its face is adequately held up in proportion to the energy of the blow and the strength of the shot. With weak shot, such as Palliser, less holding up will do. A shot that strikes obliquely is practically weaker than when it strikes direct ; therefore, for a shot striking obliquely, less holding up will do. But an obliquely presented plate has its face *better* held up (there being more thickness as measured along the line of fire, or, what is the same thing, less energy normal to the plate) than one presented perpendicularly. So the oblique position increases the power of the plate to produce pulverization on impact at the same time that it reduces the power of the shot to resist it.

The oblique position also assists the tough homogeneous plates to break shots, but does not confer upon them the power of producing pulverization on impact, nor does it increase their resistance at all, except it produces glancing, till after the 1st stage of penetration.

A modern hard-faced plate is a tough homogeneous plate with a bulwark. If the bulwark does not fail, it is better than any homogeneous plate; and if the bulwark does fail, it is a tough homogeneous plate still. The oblique position raises very considerably the limit of attack the bulwark can stand without failing.

Breaking strain on shot considered as a function of velocity and penetration.

It would seem reasonable to argue that the amount of breaking strain of one kind or another that a shot is exposed to on impact must be proportional to the suddenness of its arrest. In this connection the writer's observation has led him to conclude that the best 6-inch shot yet known will break when $\frac{V}{P}$ is as much as 2,180; V being the striking velocity in f.s., and P the penetration achieved in feet. As $\frac{V}{P}$ is increased the number of fragments increases; and when $\frac{V}{P} = 3{,}900$ or more the shot is practically pulverized.

One of the Holtzer shots at the plate previously alluded to as pulverizing five so completely, struck with a velocity of 1,950 f.s., and penetrated only 1·09 inches, or say ·09 feet. $\frac{V}{P}$, in this case, therefore, was $\frac{1{,}950}{\cdot 09}$, or 21,667, being about 10 times as much as necessary to ensure simple breakage. Of this shot none remained in the plate, and all the fragments that could be collected were 21 in number, and weighed together 7lbs. 5ozs. The original weight of the shot was 101½lbs.

For shot of less than 6-inch calibre the limit of $\frac{V}{P}$ would be more than 2,180; probably for 5-inch shot it would be about 2,600 or 2,700, as the smaller the calibre the more difficult to break does the shot become. Similarly, larger shot may be expected to break before $\frac{V}{P}$ reaches the value named.

To bring about the destruction of the shot, then, the thing to do is to increase $\frac{V}{P}$. It has been shown already that with hard-faced plates V and P do not increase together on the same plate as they would do in homogeneous plates, but that, after increasing together for all values of V between zero and a certain limit, P suddenly drops very considerably when a first critical value of V is reached. Experience further shows that P then goes on increasing with V, but at a much reduced proportional rate, until a second critical value of V is arrived at, and then P has a sudden large increase.

The characteristic advantage of hard-faced plates is only realized between two critical values of the striking velocity.

The first critical value of V is that just necessary to cause a compressional force at the first stage of penetration in excess of the compressional force the shot can stand without splitting.

Lower critical value of V.

The second critical value of V is that just necessary to give the shot more energy than the face of the plate can stand without "giving back" at the point of impact (due to want of adequate support from behind).

Higher critical value of V.

Between the two critical values of V the shot is pulverized on impact. Below the first it is not, because the strength of the shot is undermatched; and above the second it is not, because the stiffness of the plate is overmatched. *Plate* II. is intended to illustrate this.

The first critical value of V needs no attention, because in the range of lower values the plate is not threatened, though the shot is saved. The second critical value, however, is all-important, as it fixes the limit of the resistance of the plate to perforation—conquering it as a hard-faced plate, and, therefore, *a fortiori*, as a simple plate; because the second critical value of V is greater than its "perforating" value for a similar tough homogeneous plate.

The higher critical value of V limits the resistance of hard-faced plates.

The problem for the armour plate maker then becomes—how to raise the second critical value of V? Assuming he has done his best to make $\frac{1}{P}$ (the resisting power of the plate) a maximum, and, by adopting a very hard face, has distributed the total resistance to the best advantage, he can only do this by stiffening the plate against "giving back" at the point of impact. It is in this direction that the greatest immediate room for improvement seems to the writer to lie.

To raise the second critical value of V the backing should be studied.

Compound plates against chilled cast-iron shot are the prototypes of hard-faced plates against steel projectiles, and the W.I. cap to the shot, which was tried against the former, requires studying again with regard to the latter.

The power lately developed in hard-faced plates of pulverizing steel projectiles on impact, ordinary compound plates also possess, in some degree, against inferior projectiles, such as those of chilled cast iron. To this the compound plates owed their long-maintained high repute, and the decline of their reputation dates from the loss of this power in consequence of the general introduction of comparatively unbreakable steel shells.

Captain Orde Browne, R.A., has put on record, at pp. 82 and 83, Part I., of his book *Armour and its Attack by Artillery*, the following interesting circumstance :—

"The trial of a wrought-iron cap on the point of the projectile arose from the fact being discovered that a steel-faced armour plate lost its power of breaking up chilled shot, its resistance being diminished to less than that of wrought iron, by simply placing a $2\frac{1}{2}$-inch wrought-iron plate over the steel face of the plate. A Palliser projectile doing more work on the compound plate with this addition than without it, and the effect on the shot itself being quite different. General Inglis concurred with Captain English in thinking that a similar result might be produced, and a chilled projectile kept from breaking up, by applying a wrought-iron cap to the point when attacking steel-faced armour. This was tried. The effect of the first shot so fired encouraged further investigation of the subject, but further trial showed that no advantage was gained by the cap."

It is to be regretted that the nature of these further trials, and the reason for abandoning the cap, were not explained, as the subject has lately acquired renewed interest, owing to a modification of steel armour-piercing shot having been recently experimented on in Russia, with the alleged result of neutralizing the characteristic advantage of hard-faced plates. The nature of this modification is a jealously-guarded secret, but there is very strong reason to believe that it is no more nor less than the employment of our old friend, the wrought-iron cap.

The action of such a cap when the shot strikes normally is obvious. It tends to laterally support the delicate point of the shot in the same way that the walls of the indent do (if the shot makes one before its destruction is initiated), and consequently the initial splitting cannot be done without bursting the cap.

Now, although it might not take much power to do this if *time* were available, the difficulty of initiating pulverization in the infinitesimal fraction of a second occupied by the first stage of penetration is very much increased; and, as previously stated, pulverization must, according to the writer's view, be initiated at this stage or it will not occur at all.

It is, therefore, very probable that the use of some such device may, as alleged, neutralize to a great extent the advantage of hard-faced plates as long as they are only attacked normally to their surface. The moment, however, that the line of fire becomes oblique to the plate to a substantial extent (as it might always be expected to be in action), it is difficult to conceive that a shot will not be rather embarrassed than assisted by such an addition. As a matter of fact, the Russians have tried their device under conditions of oblique impact, and admit absence of success at present; but this they attribute to imperfections in the projectiles used, and not to any defect inherent in the secret modification.

General claim of hard-faced plates.

It will be observed that hard-faced plates aim to defeat the projectile, and tough homogeneous plates to defeat the gun. This is claimed as an advantage for the former; for whereas the power of the gun has plainly mapped out before it a large field for development, the cohesive strength of the projectile is without any margin for improvement at present visibly in hand.

The possibilities of the future may alter this; but, in the meantime, the claim would seem a reasonable one.

Sheffield, October, 1893.

The foregoing was written in October, 1893, and quite recently some very interesting trials have been made which throw further light on the subject under discussion. The trials referred to are the Russian trials of June and July, 1894, of which particulars are given at the end of this paper.

In these experiments it will be seen that two principal classes of projectiles were used, viz., the best known at the time the first part of this paper was written, and an improvement on that "best," amounting almost to the theoretical unbreakable projectile imagined at page 179.

The effect of impact at various angles of obliquity was also tested, and the surmises as to the nature of the secret Russian improvement, recorded at page 202, were confirmed. The expectation, however, that the cap on the projectile would do more harm than good when the impact was substantially oblique was not realized, and the cap will have to be seriously reckoned with both by those who make armour plates and those who use them. At the same time it must be borne in mind that the three hard-faced plates tested at these Russian trials were made more than a year ago, when the manufacture of this class of plate was in its infancy, and that since that time this manufacture has been going steadily forward, and much experience has been gained. Two of the plates at least were face-hardened to a less depth than would be the practice now; but this is by the way.

These trials afford illustration of points on which the early part of this paper was obliged, for want of examples, to confine itself to theories. Those theories are presented as they were recorded nine months ago; nothing has been altered in them. The alterations—if any—necessitated by the recent Russian trials have yet to be considered.

Sheffield, July, 1894.

MEMORANDUM ON RUSSIAN TRIALS AT OCHTA, NEAR ST. PETERSBURG, WITH THE OBUCHOFF 6″ GUN OF 45 CALIBRES, 28TH JUNE, 1894, 3RD JULY, 1894, AND 6TH JULY, 1894.

28th June, 1894.

1st hard faced plate $8' \times 8' \times 6''$ backed by 11″ of soft pine and three $\frac{1}{2}''$ Boiler-plates.

1st Round, normal, left top corner, Holtzer new pattern, 16″ long, 90lbs., S.V. observed 1870 f.s. Shot broken into small pieces. A few fragments of base in front of target. Bulk of fragments in backing. Rear skin plate not pierced but said to be bulged about 1″. Plate dished at point of impact about $\frac{1}{4}''$ over 18″ square. One through crack to left edge and one to top edge. Fine radial hair crack upwards to right.

2nd Round, normal, right top corner, similar shot capped. S.V. observed 1843 f.s. Shot through target and considerably beyond. Entire. Previous cracks extended. No new ones.

3rd Round, 15° oblique, left bottom corner, similar shot capped. Shot through target and considerably beyond. Entire. Same charge but velocity not observed. No new cracks.

4th Round, 15° oblique, right bottom corner, similar shot not capped. Projectile broken up. Head lodged in plate in fragments. Penetration estimated 5 to 6 inches. Cracks from 1st impact much opened and one new hair crack downwards to left from 1st impact. Also fine hair crack near 2nd impact. Cracks from 4th impact—one through to right edge, one finer to bottom edge.

3rd July, 1894.

5th Round, 20° oblique, centre, similar shot capped. Shot through target, condition unknown, previous cracks very slightly opened. One new hair crack upwards to left from 4th impact.

6th July, 1894.

6th Round, 25° oblique, between impacts 3 and 4 and four inches higher, similar shot capped. Fragments just through backing. Cracks from 4th through 6th and 3rd impacts to left edge.

Velocities not observed after 2nd round, but charges unchanged.

28th June, 1894.

2nd hard faced plate $8' \times 8' \times 6''$ backed by 11″ of soft pine and three $\frac{1}{2}''$ Boiler-plates.

1st Round, normal, left top corner, Holtzer new pattern, 16″ long, 90lbs., S.V. observed 1856 f.s. Shot broken into small pieces. A few fragments of base in front of target. Bulk of fragments in backing. Rear skin plate not pierced but said to be bulged about $\frac{1}{4}''$. One rather wide through crack to left edge. One hair crack upwards to left, and one upwards to top edge.

2nd Round, normal, right top corner, similar shot capped. S.V. observed 1840 f.s. Shot through target and considerably beyond. Entire. Previous cracks extended, no new ones.

3rd July, 1894.

3rd Round, 25° oblique, left bottom corner, similar shot capped. Shot pulverised. Smooth indent in plate 3·4 inches deep. 5 severe radial cracks breaking plate badly.

4th Round, 25° oblique, right bottom corner, similar shot not capped. Shot pulverised. Smooth indent in plate 2·7 inches deep. No cracks at point of impact, but previous cracks much enlarged.

5th Round, 25° oblique, about one foot above centre, similar shot capped. Shot pulverised. Smooth indent in plate 3·4 inches deep. Cracks to impacts 1 and 2, and on to right edge. Previous cracks a little extended.

6th July, 1894.

6th Round, 20° oblique, near 4th impact, similar shot capped. Shot smashed. Penetration 3·3 inches. One through crack to lower edge, three radial cracks, previous cracks developed.

7th Round, 15° oblique, 10 inches above 5th impact, similar shot capped. Through target in pieces. Cracks developed.

Velocities not observed after 2nd round, but charges unchanged.

28th June, 1894.

3rd hard faced plate 8′ × 8′ × 10″ nickel, curved to 13′ 6″ radius backed by 13½″ of soft pine in two layers and three ½″ Boiler-plates.

1st Round, about 8° oblique owing to curvature of plate, right top corner, Holtzer new pattern, capped; velocity not observed, but charge same as 2nd round. Through target but broken, several pieces of the base being found just in rear.

2nd Round, about 10° oblique owing to curvature of plate, right bottom corner, Holtzer new pattern not capped, S.V. observed 2392 f.s. Shot pulverised. Fragments of head lodged in indent. Penetration estimated 6″ to 8″.

3rd July, 1894.

3rd Round, normal, similar shot capped, about one foot below centre. Velocity not taken but charge same as fourth round. Lodged unbroken. Base projecting about ½″ to front of plate. Estimated penetration 15½″.

4th Round, normal, similar shot not capped, about one foot above centre. S.V. observed 2211 f.s. Shot smashed. Head lodged in fragments. Estimated penetration 8″ to 9″.

(Two rounds to compare with 3 and 4 were then fired at a tough homogeneous 10″ plate. The penetrations of the capped and uncapped shots were about the same, 12″ to 13″).

5th Round, about 8° oblique, left bottom corner, Holtzer *old* pattern, capped. S.V. estimated 2390 f.s. Through target apparently unbroken.

6th Round, about 10° oblique, left top corner, Holtzer old pattern not capped. S.V. estimated 2390 f.s. Broke up. Head lodged broken. Penetration estimated 6″ to 8″.

6th July, 1894.

7th Round, normal, 10″ above 4th, Holtzer old pattern not capped. Pulverised. Estimated penetration 6″ to 8″.

No cracks in this plate.

Notes on the Projectiles.

The Holtzer old pattern shot are the same as were used at previous Russian trials. The quality of the steel and the temper are invariably excellent. These shot differ from the bulk of those in the English service by being $1\frac{1}{4}''$ shorter, 10lbs. lighter, and having the walls of chamber much thinner towards the base.

The lighter weight enables the same charge to give higher velocity, while the reduced length and the shape of the chamber make the form of the shot much stronger. The space for bursting charge is stated to be not less than in the English pattern.

The Holtzer new pattern shot differ in manufacture; a thin outside layer, say $\frac{1}{8}''$, being kept comparatively soft, probably by superficial decarburization. The idea being, of course, to reduce the brittleness. The trials showed no advantage to result from this alteration.

The Russian secret improvement is the addition of a cap made of wrought iron or very mild steel to the point of the shot. The following is the evidence on which this statement was based :—

1. No one was allowed to see the shot before firing; nor after firing until the Russian officers had handled it. From this it is argued that the improvement was of such a nature as to be visible, but that it did not form part and parcel of the shot.

2. The Russians jokingly called the shot magnetic, and said the secret was in magnetism. It is highly probable that to make the shot a magnet by passing an electric current round it would occur to anyone who wanted to attach an iron cup-shaped cap to its smooth and hard point. This method had probably undergone trial at least. One of the fired shot was tested for magnetism, but it contained none. This was two days after it was fired, however, and it might have been de-magnetized purposely, or have lost its magnetism in passing through the plate. An adhesive material like "Turner's cement" might answer for attaching such a cap.

3. One of the shot having been fired at a tough homogeneous plate broke in two, and left its head embedded. Projecting backwards

from that head was a strip of soft iron, or steel, as if the cap had been carried into the plate, and a strip had been squeezed from it to the rear.

4. By accident a momentary glimpse of a certain object was obtained, which was bright, of iron or steel, about 4″ or 5″ long, and pointed at one end, and there can be little doubt it was one of the caps. The point was probably to reduce resistance in flight.

The cap, as imagined then, is like this—

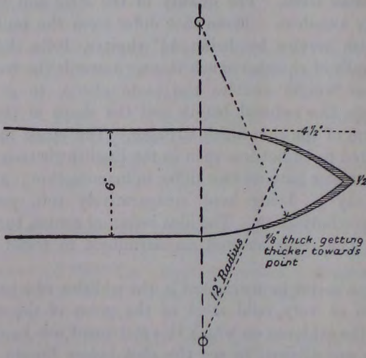


Fig. 9.

5. After the first two rounds at the 10″ plate the velocities were chalked on the plate, 2,350 (estimated) against the capped shot, and 2,393 (observed) against the uncapped one. It was asked why the unobserved velocity was not estimated to agree with the observed one, the charges being the same? The reply was that the *energies* were alike. This meant that the *weights* were different, as, of course, would be the case if one shot carried a cap and the other did not. Now the energy of a 90lb. shot at 2,393 f.s. being 3,573·9 ft. tons, it is easily calculated that the same energy would require a shot weighing 93·325lbs. if the velocity were only 2,350 f.s. This gives about 3⅓lbs. as the weight of the cap. It agrees with the apparent weight of the object seen.

Notes on the Velocities.

The failure to observe the velocity of every round introduces an unsatisfactory element of uncertainty into the trials. What powder was used against the 6″ plates was not stated, but if it was the same as against the 10″ it was smokeless powder.

In proving some guns with this powder the pressures ranged from 2,500 to 3,200 atmospheres. With such a powder it must be quite impossible to rely on the velocities obtained by any two rounds with the same charge being alike.

Notes on the Targets.

The backing was extremely thin, and composed of particularly soft wood. The bolts were probably badly screwed up, the nuts being, owing to the construction of the target, very difficult of access.

The method of determining the obliquity of the plates was very rough. A wooden square, with two sighting points, *a* and *b*, was used, with space for a man to put his head through at *c*, and sight

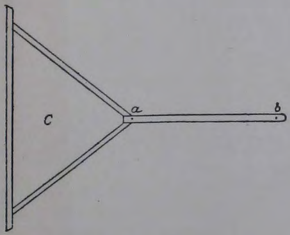


Fig. 10.

on some point a measured distance from the gun. This might have been near enough if the plates had been truly flat, but as they were slightly convex, the obliquities stated to exist cannot be relied on as accurate to 5°.

PAPER VIII.

DERBYSHIRE ROYAL INFIRMARY.

By Major W. F. N. Noel, R.E.

There has just been opened at Derby a new hospital embodying the latest ideas, and some description will be interesting, and may be useful to any R.E.'s engaged on similar work. It was found in the old hospital, fine and spacious building as it was, that cases had become more and more difficult to cure, and the governors decided to pull it down and build a new one.

The in-cases are chiefly accidents, and the general run of patients are really bad.

The following information is chiefly taken from an article in the *Quarterly Medical Journal* for April, 1894, written by E. Collier Green, M.R.C.S., L.R.C.P., Ophthalmic Surgeon to the Derbyshire Royal Infirmary, and from personal observation.

After visiting many hospitals, and examining plans of many others, the Committee recommended that Messrs. Young and Hall, the architects of the Great Northern Central Hospital in London, and of the hospital at Hastings, should be asked to submit plans; and a statement of the number and distribution of beds required, with a schedule of the rooms desirable in the various departments, and of certain conditions of construction to be observed by the architects, was drawn up and handed to these gentlemen for their guidance.

Any R.E. who has had to design a large building will feel envious of the architect who has not had to extract the above information for himself.

P 2

The foundation stone was laid by Her Majesty on May 21st, 1891.

The buildings occupy a fine site of about fourteen acres, near the Midland Station and the large railway works.

On referring to the block plan, it will be seen that the hospital will consist of 17 separate blocks; of these the two Administration Blocks (Nos. 1 & 2), the Laundry Block (No. 3), the Nurses' Home (No. 13), the Out-patients' Block (No. 9), the Mortuary (No. 14), and the Ward Blocks (Nos. 4 & 5), are complete, or nearly so. Ward Block (No. 6) and the Operation Block (No. 11) are in hand. The Eye, and Children's Block (No. 8), and the Lodges (Nos. 15 & 16) are deferred for the present. Ward Block (No. 7) will probably not be wanted for some years, the site being preserved for further extension. The plans for the Chapel (No. 10) are still under discussion.

The Front Administration Block (No. 1).

This is a three-story building. On the ground floor are the main entrance to the hospital, the secretary's office, the waiting-room for visitors, the porters' office, the dining-room for the resident staff, and the room for the honorary medical staff. The eastern part of the ground floor is devoted to the casualty department, and has its separate entrance, waiting-room, examining-rooms, and a small ward for cases of great urgency. The corridors are all very large, wide, and high. Glazed brickwork enters largely into the construction of every part. The corners of the rooms, and the angles between the floors and ceilings and the walls, are of special made glazed bricks; all sills, jambs, and soffits are bull-nosed, the springers, etc., being all specially made; every possible place where dust could lodge being easily accessible. This is very striking throughout the building. It may be also noted that all pipes for gas, water, steam, etc., are pinned out three inches from all walls and below ceilings.

On the first floor is the board-room, with residential quarters for the medical staff and the matron.

The second floor is devoted to bed-rooms for the servants. The quarters for the medical staff are much the same as the officers' quarters we build now, with similar fire-places, and supplied with telephones. The medical staff and servants have well-fitted bath-rooms. The rooms are ventilated by glazed hopper lights over the doors, protected at the sides with glazed quadrant cheeks, and further, the windows, which are double-hung sashes, have three-inch inner beading at the sill, so that the lower sash may be raised and air admitted between the meeting rails without letting in a draught between the bottom rail and the sill bead. Most of the staircases are stone, and all wooden stairs have hard wood treads. All corridor floors are either mosaic or terrazzo.

The Rear Administration Block (No. 2).

This is a two-story building. It is connected with the front administration block by a ground-floor corridor, the flat roof of which also affords a direct communication between the respective first floors. It contains on the ground floor the entrance for stores, the dining-rooms for nurses and servants, and a pantry.

On the upper floor are the kitchen and scullery, store-rooms, larders, milk-store, etc. ; all these are most sumptuous, and lined throughout with white glazed bricks ; the shelves are all of marble ; in fact, everything gives the idea that expense is of no moment whatever. The kitchens are filled with the most approved patterns of gas and steam cooking apparatus. A hydraulic lift connects the kitchen with the main corridor below.

The refuse finds its way on to an iron balcony, whence it is lowered and carted away.

The first floor of this block also contains the quarters for the porters, their rooms being approached by a separate staircase.

The main corridor of the hospital, off which the ward pavilions are placed, runs through this block at right angles to the one leading from the front administration block. It is a one-story structure, and has glazed brickwork walls about three feet high, the upper parts of the sides and the roof being of glass.

It has been kept as low as possible, so as to interfere but little with air currents passing over the site. There are no steps, but long slopes, so that patients can be easily wheeled about.

The Laundry Block (No. 3).

This block is connected with the rear administration block by a covered passage, with open sides. It contains receiving, distributing, and other rooms for linen and clothes, a wash-house, drying-room and laundry, with all the latest apparatus, a separate wash-house and laundry for infected linen, boiler-house and engine-house for power and steam heating, the disinfecting-house, and the cremator for refuse.

The Out-Patient Block (No 9).

This is really a large and well-arranged "Medical Inspection Room" and dispensary. On reference to the plan, it will be seen that the entrance for the patients is in the centre of the front. Immediately inside the entrance are two small waiting-lobbies, separated from each other by the porters' office; from these access is obtained to the general waiting-hall, which comfortably seats 230 persons. The seats are so arranged that the patients can only proceed in their proper turns to the consulting-rooms.

Of these consulting-rooms there are four, each with an examining-room attached, and a second door by which the patients enter the corridor leading to the medicine waiting-room, where they are seated as in the waiting-hall, and similarly reach in rotation the serving-hatches, where they receive their medicines from the dispensary, and then retire by a separate exit.

This dispensary is beautifully fitted, and the counters, the regular shelves of bottles, the innumerable little mahogany drawers and pigeon-holes, are quite a sight. By this arrangement all confusion among the patients waiting to be seen, and between them and those who have been, is avoided. Behind the dispensary is a small pathological department and a museum. This block is constructed mainly of glazed brickwork, and is warmed entirely by means of steam coils.

The Ward Pavilions (Nos. 4, 5, 6, 7, 8).

Each pavilion is of two stories, and is well raised above the ground on an open basement. This prevents any stagnation of air in the angle between the ground and the walls, and allows it to circulate freely underneath the block. Each ward is approached, both on the ground and first floor, from the staircase and lift block by a separate covered ventilated bridge, at both ends of which are swing doors. These bridges are each of a height sufficient only to give proper head-room, the object being to isolate each ward from aerial contact with the corridor and staircase, and so prevent these from being channels for the conveyance of air from one ward to another, and also to allow air to circulate freely round the inner ends of the pavilions. The upper and lower floors of pavilions Nos. 4 and 5, and the lower floor of pavilion No. 6, are exactly alike, so that a description of one will suffice for all. The upper floor of No. 6 is allotted to the gynæological department, and small rooms for sick nurses, and other special cases. It contains four small wards for one bed each, a ward for two beds, a general ward for ten beds, an operation-room, and the necessary ward offices.

At the entrance to each ward are stores for coal, for ward linen, and patients' clothes, and for food, a w.c. for the nurses, and a store for brooms, pails, etc., a separation ward for two beds, and a nurses' duty-room or ward-kitchen.

The wards are 127 feet long, 29 feet wide, and 14 feet 3 inches high, and they are arranged to hold 24 beds each. Each bed is separated from the next by a window. Each patient has 145 feet super. of floor space, and 2,066 cubic feet of air space. It will be observed on referring to the plan that there are no beds in the corners. The walls and ceilings are finished in Keene's cement, painted and varnished so as to give a surface as smooth as possible. The windows are double-hung sashes with hopper lights above, and with three-inch inner beads at the sill, as described for the rooms of staff. At the outer ends of the pavilions are towers placed diagonally at the corners, and connected with the wards by a covered ventilated bridge on each floor. Between the towers is a covered verandah, reached by doors from each ward.

These towers are lined throughout with white glazed bricks—one contains lavatories and a bath-room, beautifully fitted as in a London club, the other contains the sanitary offices, slop sinks, and a corner cupboard for utensils or basins containing matter to be kept for medical inspection. This cupboard is closed by iron doors, and ventilated to the outer air by ample gratings.

Ward Floors.

The construction of the floors of the pavilions is of iron and concrete. It was intended to floor the wards with oak or other hard wood bedded in bitumen directly on the concrete, but after inspecting many floors so made, and after a visit to the hospitals in Hamburg, it was decided to floor the pavilions and wards throughout with the form of marble mosaic known as "Terrazzo." This material is composed of chips of marble bedded in cement, rubbed smooth and polished. It is used largely for the purpose abroad, but this is the first time that large wards have been floored with it in this country.

The question of the best material for a ward floor is one upon which there is much difference of opinion. The floors chiefly used in this country are :—

(1). An ordinary boarded floor, nailed to wooden joists, the boards being of deal, pitch-pine, oak, teak, or other wood, and either polished with beeswax or kept clean by frequent scrubbing.

(2). Wooden blocks, usually of oak, bedded directly on the concrete substratum of the floors, and polished with beeswax. Boarded floors were strongly objected to by the medical staff, because of the air space which necessarily exists underneath them ; this air space must in time become foul, and, however well the floor be laid, cracks will appear, putting this air space in direct communication with the ward. A boarded floor is not fire-proof, and is very noisy.

Wood-block floors at first sight appear to have much to recommend them, but they do not seem to prove altogether a success in practice.

The blocks, especially in the neighbourhood of fires and steam coils, are apt to shrink, leaving cracks between the joints ; the bitumen in which they are bedded softens with the heat, the blocks tilt, and the floor becomes uneven. The blocks also have a tendency to tilt under the continued pressure of a heavy article of furniture.

The advantages claimed for mosaic floors are:—They have a smooth, and practically non-absorbent surface ; they can be readily cleaned with water ; they are not injured by fluids accidentally spilt, or by the water to wash down the walls at cleaning time ; they are not so slippery as polished wooden floors, and consequently are not so tiring to walk upon ; if cracks appear they can be cut out, and the floor made good; and they are absolutely fire-proof. These floors will take a fair polish, and it is hoped that they will wear well.

The objection urged against the use of mosaic floors in this country is that they will be cold to the feet.

In Berlin and Hamburg, both of which cities have a more severe winter than is usually found in England, many of such floors have been in use in the hospitals for years, and the authorities there do not regard this objection as one of any practical importance ; they say that there are never any complaints about them ; and they continue to put them down wherever they can afford to. The floors at Derby are made to *look* as warm as possible by the employment of warm-tinted marbles, and specially coloured cement, and all the chairs are to have wooden foot-rests.

In the finishing of the floors, walls, doors, and windows, all angles have been rounded as far as possible, so as to allow no avoidable lodging place for dust. The rounded angles between the walls and the floors are formed in the floor material.

Heating and Ventilation of the Wards.

In each ward are two double stoves, built of glazed *faience* ware the flues from which run horizontally in the thickness of the concrete floor to the chimneys placed on one side of the block. These stoves provide four open fires in each ward. The chief sources of heat are ten steam coils, placed under the windows in recesses, five on a side.

The coils have been designed and constructed by Messrs. James Slater and Co. to fulfil one of the conditions of construction laid down, viz., "that no channel for the passage of air to or from the wards shall be longer than the thickness of the walls, nor be so placed that it cannot be readily cleaned;" they are enclosed in cast-iron cases, which are provided with a channel for admission of air, passing straight through the thickness of the walls to the outside, at about the floor level. The amount of air admitted to each coil is regulated by a valve which is easily worked by a lever. The coils themselves are formed of copper tubes placed horizontally in three separate leaves, either of which can be used independently. The front of the coil case is of formed two iron doors, which, when opened, expose the whole of the coil to view; the leaves of the coil are hung on hinges at one end, to allow of each being swung out at right angles to the wall, thus giving free access to the back of the case and the air channels for the purpose of dusting and cleaning.

Short channels have been formed through the walls just above the floor level, one under each bed. They are fitted on the inside with Ellison's patent ventilators, and can admit a larger or smaller amount of fresh air as required. The lower sash of each window is fitted with a deep bottom rail, as in the dwelling-rooms described above. The hopper lights over the windows are placed as near the ceiling as possible, and will act either as inlets or outlets, according to the direction of the wind and the amount of air being admitted to the ward by other means.

In warm weather there should be no difficulty in keeping the wards well ventilated by means of the windows, the hopper lights, and the inlets under the beds. In cold weather, when it is not possible to have more than the hopper lights open, the steam coils will suck in an ample supply of fresh air, which will enter the ward ready-warmed. The four open fires will extract a large proportion of this air. and the rest will be got rid of by the hopper lights, a certain number of which will always be kept open.

It will be seen that the heating and ventilating arrangements are extremely simple. The blocks are placed 100 feet apart, and it is hoped that this distance and the large floor and cubic space provided will render any more elaborate system quite unnecessary.

The small wards and the ward kitchens are warmed by open fires, and the other ward offices by steam coils of simple construction.

The Operation Block (No. 11).

This is a one-story building, containing, besides the operation-room itself, a room for the staff. The operation-room is lined with marble slabs up to a height of seven feet, and above which the walls and ceiling are finished with Keene's cement, painted and varnished. The floor is laid with "mischiati," or marble cubes bedded in cement, forming a hard, impervious surface. The various tables are made of iron and glass, and a steam sterilizer is provided for instruments and dressings. The room and fittings are so arranged that the whole can be cleansed by means of a jet of water from a hose-pipe.

The Mortuary Block (No. 14).

This is a detached building, and contains a *post-mortem* room, with marble table, and ample water-supply, sinks, washing appliances, and so on. There is a separate mortuary chamber with glass shelves for bodies. Both these are floored and lined with white glazed tiles, amply ventilated, and lighted from above. There is also another room where a body can be decently placed for friends to view; the body being delivered from the mortuary chamber, where there might be several, through a hatch on to a table fitted with rollers. The stable and ambulance house are attached to this block.

The Isolation Block (No. 17).

This building will be constructed of wood, and is to contain small wards for the isolation of any cases of an infectious nature that may occur from time to time in the general wards of the hospital.

The Nurses' House (No. 13).

This block is completely detached from the rest of the hospital, and affords accommodation for 48 nurses. Each nurse has a separate bed-room, and separate sitting-rooms and reading-rooms are provided for the sisters, the staff nurses, and the probationers respectively.

Drainage.

There are two distinct systems of drainage: one for the conveyance of rain water from the various roofs to a large storage tank, whence it is pumped up for use in the laundries, etc.; the other for the conveyance of the soil drainage to the town sewers.

The Soil Drainage System.

This is constructed of salt-glazed tested pipes, laid on a bed of concrete, and grouted in cement. Inspection chambers or man-holes are placed at every point where one drain joins another, and every section of drain from one man-hole to another is laid in a straight line and with an even fall. Each section of drain is tested by being filled with water, and when it has proved absolutely water-tight more concrete is filled in round the pipes before they are covered in. The water is not allowed to be let off from the drain till the latter operation is completed, so that any damage to a pipe or joint from careless ramming should be at once detected. This water test is said to be in every case carried out under the personal supervision of the architects.

The bottoms of the man-holes are formed of curved white glazed channel pipes in the usual way.

The drainage leaves the site at different points, and at each a man-hole is placed with a Rogers Field disconnection trap, and a fresh-air inlet. Automatic flushing tanks are placed at the heads of all the different sections of drains. The soil pipes are all fixed outside the walls. They are of lead, and carried well above the roof.

The inside plumbing has been carried out by Messrs. Dent and Hellyer, and no expense or pains spared to make it perfect. Pedestal apparatus and three-gallon flushes are employed everywhere. All traps, syphons, etc., are of the latest approved patterns.

The Water Supply.

This is from the town mains, and as it is hard, all that is used in the steam boilers, and in the hot water circulation, is specially treated by a softening process.

The style of architecture is late Elizabethan. The buildings are faced externally with red brick of a good colour. The mullions, cornices, and other dressings are of Derbyshire grit, and while the general effect is certainly good, and the buildings bold and handsome, internal convenience has not been sacrificed to external effect.

PAPER IX.

NOTES ON BRIDGING.

BY MAJOR F. J. AYLMER, V.C., R.E.

NOTE BY COMMANDANT, BENGAL S. & M.

Major Aylmer went to Gilgit in 1891, and was employed under the British Agency for one year. He found a barren country generally destitute alike of material and skilled labour; large rivers hitherto unbridged, and smaller rivers spanned by bridges capable only of carrying one or two men, or an unloaded pony at one time. It was under these circumstances that he noticed a quantity of wire brought up on coolies' backs for a projected telegraph line, and with this he proceeded to construct a series of bridges of great span, which were remarkable as well for the boldness of the idea as for the carefulness of their construction. In the autumn of 1893 he brought this experience to bear at Kohala, where a flood had destroyed the permanent bridge on the only cart-road into Kashmir from India, and in a very short time he enabled traffic to be resumed.

(Sd.) H. P. LEACH, LIEUT.-COLONEL,
Commandant, B. S. & M., Roorkee.

8th April, 1894.

Introduction.

When at Gilgit in 1891–2, I was faced with the serious problem of establishing communications throughout that district.

In winter, with the exception of the Indus, most of the rivers are fordable; but in summer an immense volume of water from melting snows and glaciers comes down these valleys. The resulting rise of water is often as much as 25 feet, and the current is so great that it is nearly impossible to get central piers to stand. Hence some form of suspension bridge becomes necessary. The inhabitants make suspension bridges out of birch-twig ropes, but only foot passengers can cross, two or three at a time. These bridges are always dangerous and require frequent repairs. For spans up to 120 feet, cantilever bridges are used. Descriptions of these two classes of bridges are given later on. Owing to the fact that a new telegraph line was being made from Bunji to Skardu, there was a lot of good stout wire available in the Gilgit district in 1891–2, and nearly all the bridges constructed were made with this.

General Remarks.

Establishing Communication.

To get the first rope across a large current is often very difficult. The following methods can be employed:—

(*a*). A long thin bit of silk is attached to an arrow and shot across the stream by means of a bow, a stouter string is then pulled across, and so on.

(*b*). If men can swim in the torrent, two men, each with a thin string attached to him, on inflated skins, start from opposite sides a little up-stream. They plunge in and swim towards each other; when they meet they fasten the ends of the two pieces of string together, and men on either side pull the joined strings tight.

(*c*). By shooting across a string attached to some heavy body, by means of an improvised mortar.

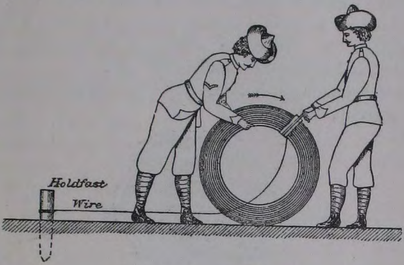
Using a hollowed-out log and a hand-grenade with a line attached, the hand-grenade can be fired up to 120 yards without breaking the line.

To Unroll Wire.

Wire is generally supplied in bundles a little over 80lbs. each. The wire must be properly unrolled, as follows:—

Two men take one bundle and attach one end of the wire to some holdfast, natural or artificial, and then roll the bundle along the ground and away from the holdfast (see sketch).

If the wire is merely pulled off from one face of a bundle, there will be one twist in each length equal to the circumference of the bundle. When stretched, kinks and a corresponding weakness are produced in the wire.



Construction of Cables.

(1). Calculate necessary thickness of cables according to length of bridge, dip, and load to be carried.

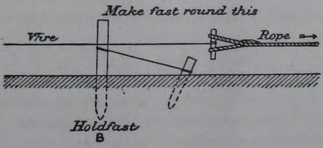
(2). Calculate necessary lengths of cables, allowing a margin of 10 per cent. If too long, the surplus length in the cables can be used for slings, etc.; but a cable would be nearly worthless if too short.

(3). Select a level piece of ground.

(4). Unroll wire from bundles, cutting to length calculated in the second paragraph.

(5). Take seven of these wires and attach to any holdfast (A).

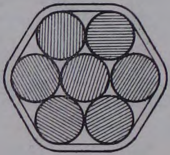
(6). Make another holdfast (B) at a distance from (A) equal to length of cables (less a foot or two).



(7). Take one of the wires, and having attached a rope to the far end, stretch it as tight as possible by men pulling on the rope ; about one man to each 100lbs. of breaking strain of wire. When as tight as it will go, make the men, still keeping the strain, walk round the holdfast (B) a couple of times, then make fast (see sketch). Stretch the remaining six wires in a similar manner all close to each other.

This method has the double advantage of stretching all to the same extent, and testing each individual wire.

(8). Now, beginning at holdfast (A), bind the seven wires at every foot into a group, thus :—



The wires must not ride anywhere throughout their length. The binding can be done with string or thin wire. The latter is better if obtainable.

(9). By this means any number of seven-strand cables can be made, and the main cables required for the bridge can then be constructed by binding together the required number of seven-strand cables at every three feet, after having stretched them well close together ; as a rule, the total number of wires in a main cable should be some multiple of seven, say 28, or 35, as then every wire is stretched uniformly.

Site.

There is often very little choice about a site. Of course, the best places are those where the banks are of solid rock and not too far apart. These kind of spots are rare, and where they exist would naturally be chosen. If a pier must be built exposed to the floods, a straight reach of the river should be chosen.

Form of Bridge.

This varies with the height of banks, material, and labour available, and rapidity with which it is desired to construct the bridge. Common sense will be the best guide. Other things being equal, the best form of suspension bridge is that in which the whole roadway hangs from the main cables.

Height of Roadway.

This should be at least five feet above the highest flood level. Local information concerning height of floods is generally worthless unless corroborated by marks. These should be very carefully examined.

In countries such as Gilgit, where glaciers abound, enormous floods come down the valleys suddenly every ten or twenty years. They are caused by the glaciers temporarily blocking the streams and forming a lake above them, which finally bursts through the obstruction. It is nearly always impossible to make a bridge proof against these floods.

Gilgit Suspension Bridge.

General Remarks.

This was the first wire bridge built, and the capabilities of the telegraph wire cables were not known, so a span of 200 feet only was considered possible.

There was no natural site, and large piers had to be constructed in the river bed to raise the roadway above flood level.

Small timbers, rarely more than 6-inch diameter, were available in considerable quantities, but the forests being under snow made it nearly impossible to get large timbers. The few required were only obtained after the expenditure of an enormous amount of labour.

Piers.

There were two main piers 200 feet from centre to centre. The up-stream toe of one was protected by a largish rock.

The foundations were dug out to a little below low-water level. The eight uprights were then got into position and lashed so as not to get out of shape. The sides of the piers were gradually built up with the available timbers (*Plate* I.). Keeping pace with the walls, the centre was well packed with large stones, so arranged that at the sides they were wedged in between the different rows of horizontal timbers, preventing any being knocked out. At every two feet of height the uprights were all lashed to each other with wire, preventing any outward splay. Large stones were finally packed round the piers at their bases.

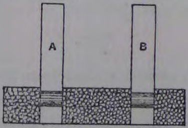
Trestles (*Fig.* 3, *Plate* I.).

The uprights were rough pine trees cut to lengths of 30 feet, and had a minimum diameter of 10 inches. The piers having been built up within $5\frac{1}{2}$ feet of the tops, bed-plates of wood were placed, and on these the main uprights rested. The uprights, having been tenoned at the thin ends, as shown, were then erected, the first by means of a small derrick, and the second by help of the first. The top cross-pieces having been morticed, were then fitted on the tops and fastened down to the uprights by flat iron straps. These straps

were 4 inches wide and $\frac{1}{2}$ inch thick, and served as a resting-place for the main cables. Diagonals, ledgers, and props were then fixed (*Fig.* 3, *Plate* I.), and the trestles set with a 6-inch lean towards the anchorages. When the bridge was completed the trestles were quite perpendicular. The piers were completed and the trestles securely fastened to the anchorages and each other.

Anchorages.

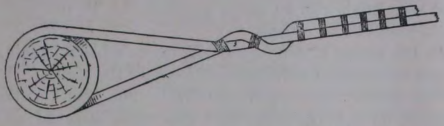
The two anchorages consisted of round pine logs 14 feet long, and about 15 inches diameter. As well as the excavation for the anchorage, two groves (A), (B), were left for the main cables. The



anchorage logs having been placed, were well built up except opposite the grooves, so as to leave room for the cables to be passed round them.

Placing Cables.

The two cables were first attached to the right bank anchorage by passing them twice round and binding the free end of each on to itself with a lot of wire lashings pulled very tight, and wedged up with wooden wedges. The free ends were now passed over the right trestle, pulled across the river, passed over the left trestle, and



passed round the left anchorage. The desired dip of the cables being $\frac{1}{10}$, they were now pulled tight to $\frac{1}{12}$ dip, and finally made fast, in the same way as they were on the right bank. It is quite easy to pull the cables by hand to a slope of $\frac{1}{12}$; no tackle required; about 25 men to a cable is sufficient.

It is very difficult to get the two cables to hang exactly to the same dip, so that every precaution should be taken at this period to ensure that the cables are equally stretched and perfectly secure.

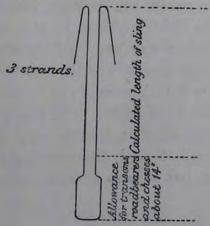
Construction of Roadway.

The length of the slings by which the transoms are hung from the cables must be calculated (see para. 178, Vol. 1, Part III., *Military Engineering*), and an additional allowance must be made to their length for the camber of the bridge.

Thus in a 200 feet bridge with dip of $\frac{1}{10}$, the sling at 50 feet from the centre, as calculated, is 5 feet long, but if a camber of 4 feet is desired for the bridge, it must be 2 feet longer, or 7 feet.

When in course of construction the roadway assumes various distorted forms, owing to there not being a uniformly distributed load, so that it is quite impossible to judge the length of the slings by eye. Another important point is that the construction of the roadway must progress equally from both ends.

Slings were made as follows :—

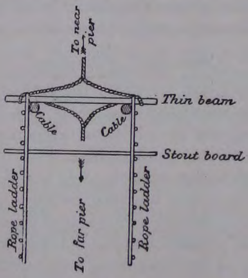


A thin cable was made by plaiting three strands of wire together. It was then bent into the shape shown. The total length of the sling was that calculated, with an extra allowance of 14 inches for transom, road bearers, and chesses.

To fix the slings, a thin beam with rope ladders hanging from either end was placed on the main cables near the trestle. The bottoms of the ladders were connected by a stout board, so that men could stand on it. The beam had also ropes attached so that it could be pulled backwards or forwards. Two of these cradles were used simultaneously, one at either end of the bridge.

To fix the slings, two sappers, each taking a sling, stand on the rope ladders, and are pulled out the required distance.

Each sling is then fixed by turning the ends a couple of times round the main cables and then three or four times round the sling



itself. The first two pairs of slings are generally tied back by a single wire to the trestle to prevent them from slipping forward. The two slings being fixed are then pulled towards the pier, and the first transom placed in the bottom loops, and secured. The road bearers are then lightly lashed to the transom, which is then shoved out till it is below the point of attachment of the slings to the main cables. A few chesses are then fastened down to this bay. In a practically similar way the roadway is made throughout, being equally worked at from both ends. The bridge is now cleared of all surplus stores and men, when it can be seen if the general curve of the roadway is correct. Small differences do not matter, as they can be corrected later, but if any sling is much too long or short it should be altered.

The roadway is now properly laid throughout, including fastening of road bearers and chesses. The curve of the roadway is again surveyed, and any sling requiring it can be tightened by means of a Spanish windlass, *i.e.*, by winding it up with a piece of wood. Ribands are next fastened down securely, and must break joint with the road bearers. Railings can now be added, and the leaning props (*aa*, *Fig.* 2, *Plate* I.), are added to prevent the roadway sinking when a concentrated load comes on at the end.

In the Gilgit bridge no chesses were available, and the roadway was composed of round pieces of wood touching each other. They did very well.

Stays.

There should at least be six stays on each side of the roadway leading to holdfasts up and down-stream.

See *Plate* I. for other particulars of the bridge.

Calculations of Gilgit Bridge.

Tensile strength of wire	=	1,500lbs.
Span	=	200 feet.
Dip of $\frac{1}{10}$	=	20 feet.
Weight of roadway per foot run	=	40lbs.

As the bridge was only intended for baggage animals, a concentrated load of two tons, or say four mules, was allowed for.

Referring to para. 174, Vol. I, Part III., we have :—

$$\begin{aligned} L &= wa + W. \\ &= 8{,}000\text{lbs.} + 4{,}480\text{lbs.} \\ &= 6 \text{ tons.} \end{aligned}$$

The maximum tension in one cable :—

$$= \tfrac{1}{4}\sqrt{L^2 + \left\{\frac{a}{4d}(L+W)\right\}^2}$$

$$= \tfrac{1}{4}\sqrt{6^2 + \left\{\frac{200}{4\times 20}(6+2)\right\}^2}$$

$$\begin{aligned} &= 5\tfrac{1}{4} \text{ tons.} \\ &= 11{,}760\text{lbs.} \end{aligned}$$

Allowing a factor of safety of $2\frac{1}{2}$, which is ample, as every wire has been tested, we have the required strength of cables = 29,400lbs., or, for convenience of manufacture of cables, 21 wires.

Assuming the whole concentrated load to be supported by one transom, the strain on the two slings would not exceed 5,000lbs.

Six wires are allowed in each sling, which gives a factor of safety of about $3\frac{1}{2}$.

The calculations for road bearers and transoms are quite simple.

Indus Suspension Bridge.

General Remarks.

Here the conditions were as follows :—

(1). Impossibility, with available labour, of obtaining any but the smallest scantlings.

(2). Rapidity of construction required. (The flying bridge was considered dangerous owing to the velocity of the current).

(3). Practically total absence of any trained labour.

It was settled to construct a bridge with a sloping roadway. Maximum gradient $\frac{1}{8}$ (*Fig.* 3, *Plate* II.).

Cables.

There were two main cables, each composed of 28 wires, each with a breaking strain of about 1,500lbs. The cables were made up of four lots of seven wires each. Allowing a maximum concentrated load of two tons, and taking the roadway at 30lbs. per foot run, this gave a factor of safety of $2\frac{1}{2}$.

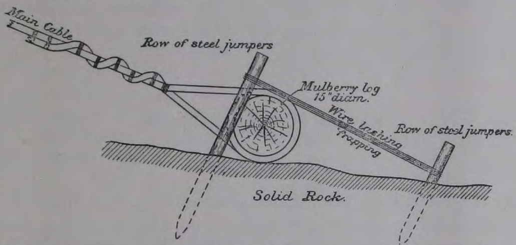
At the points of support the cables were 10 feet apart, but at 70 feet from both ends they were tied in to 3 feet 9 inches.

The cables were at first fastened to a dip of $\frac{1}{18}$, and finally settled down to $\frac{1}{14}$.

Anchorages.

These consisted of rough logs of mulberry. That on the right bank was fixed in the ordinary way, and well weighted down with stones.

Owing to the hard nature of the rock on the left bank, another plan was adopted, as shown :—

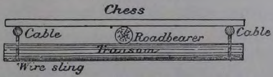


There were four steel jumpers or portions of jumpers in each row.

When completed, the anchorage was well covered up with large stones. The supports over which the main cables passed were logs of mulberry wood securely fastened to the rock.

Roadway.

For the first 70 feet on either side the roadway was hung from the main cables (*Fig.* 2, *Plate* II.). For the centre 200 feet the chesses rested directly on the main cables (*Fig.* 1, *Plate* II.). The chesses were 3 inches thick and 1 foot wide, and were of rough sawn pine. In the centre portion every tenth chess was $8\frac{1}{2}$ feet long, to allow for props for the railings. At the ends, the road leading on to the bridge was at right angles to the cables.



In a similar bridge, should a wider roadway be required, or only thin chesses be available, a central road bearer supported on a slung transom may be used. The bridge was well stayed up and down-stream.

Tashot Suspension Bridge.

General Remarks.

In this case the site did not permit of the roadway joining the bridge at a lower level than the point of support of the main cables.

Consequently trestles 12 feet high were erected. The roadway was hung for the first 60 feet out, and then the chesses rested directly on the cables, exactly the same as in the Indus bridge. The only wood available was poplar, and the chesses were made by splitting the poplar trees with wedges (*Fig.* 4, *Plate* II.).

Kohala Suspension Bridge.

General Remarks.

At the end of July, 1893, the suspension bridge over the Jhelum at Kohala having been washed away by an abnormally high flood, the sappers then stationed in the Murree Hills were ordered to restore the bridge for the passage of carts and tongas as quickly as possible.

There was nothing available for the main cables but telegraph wire, which was obtained from Rawal Pindi. Fortunately no damage had been done to the piers.

A bridge fit for the passage of tongas and empty carts was opened within a week of the receipt of the required materials.

The working parties consisted of the 6th Company, B. S. & M., the artificers of the 4th Company, and a detachment of 40 men of the B. S. & M. then on their way to Gilgit.

The Main Cables.

Each of these consisted of 69 strands of telegraph wire, with a breaking strain of 1,000lbs. each wire. The old cables had been made of links of iron, each 10 feet long. They were fastened together with 2-inch bolts. The anchorages had not been disturbed.

The new main cables were attached to the last visible set of links by the arrangement shown (*Plate* III., *Figs.* 3 and 4), an ingenious device of Lieut. Perceval, R.E.

The main cables passed over the tops of the piers and rested on a long iron bed-plate. The final dip of the cables was about $\frac{1}{10}$.

Roadway.

The slings were at 10 feet intervals, and exactly the same as in the Gilgit bridge.

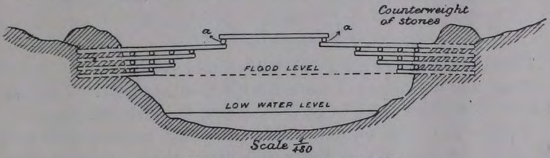
The section of the roadway was as shown in *Fig* 1, *Plate* I. The horizontal chesses were for the wheels of carts. The transoms were strengthened by the old iron links, as shown in *Fig.* 2, *Plate* III. For shape of links see *Plate* V., where some are seen sticking out behind the pier. This plate shows the bridge when nearly completed. Props at the ends, railings, and side stays were afterwards added.

To avoid the chance of any accident, horses were taken out of tongas, which were then passed over by hand.

The cost of materials for the new bridge was a little under Rs.2,000, including transport. The span from centre to centre of piers was 238 feet.

CANTILEVER BRIDGE.

These bridges are much used throughout Kashmir.



ORDINARY CANTILEVER BRIDGE.
Span 80 feet.

Advantages.

(1). No skilled labour required.

(2). No ironwork of any kind is necessary. Wooden pegs are used to keep the different timbers in position.

(3). If the site is a good one, the bridge, if well built, will last for many years.

(4). Blocks, heavy tackles, etc., are not required for construction.

(5). Can be used, at a pinch, up to a span of 120 feet.

Disadvantages.

(1). When over 80 feet long, these bridges are very shaky indeed, as a rule.

(2). A large quantity of very heavy timbers is required, so that this form of bridge should not be attempted unless trees are procurable near at hand.

(3). Large working parties are required for moving the timbers.

(4). The ordinary bridge has a high step getting on and off the central timbers.

(5). It is very difficult to get the two central timbers exactly level.

The figure sufficiently describes the construction of the ordinary bridge. The lower cantilevers are generally three in number at each side, but the upper ones two.

Great improvements can be effected in this form of bridge:—

(1). The two central cross timbers, *a a*, can be attached to the upper cantilevers below instead of above, if wire is available, so that the roadway will then be level.

(2). Fewer cantilevers can be used if their ends are stayed back by ties of wire.

Both these improvements are shown in the Ràmghàt bridge.

Ràmghàt Bridge.

Here the old bridge was in a terribly shaky condition.

Time was pressing, and no skilled labour available. The two bottom cantilevers, being in good condition, were left standing.

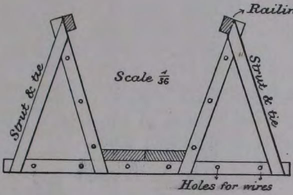
Another cantilever on either side was added, projecting 16 and 19 feet. At the ends of these, and below them, transoms were attached with wire, and both ends were tied back by stays as shown in *Fig.* 1, *Plate* IV. Each wire had a breaking strain of 1,500lbs. The trestles were 20 feet high. Spanish windlasses were attached to the stays for the purpose of tightening them. When all was ready, two timbers, each 32 feet long, were pulled across the central gap. The shore ends of the stayed cantilevers must abut against cross-bits of wood to prevent them being pulled in by the ties.

Birch-Twig Suspension Bridge.

These bridges are found throughout Kashmir, and are sometimes over 300 feet long. For particulars see *Figs.* 2 and 3, *Plate* IV.

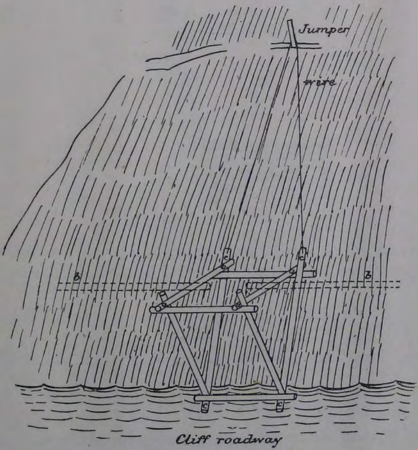
Each rope is about five or six inches in circumference, and is made out of birch twigs plaited together. The lower cable consists of six or seven of these ropes tied together at intervals. The two upper cables generally contain fewer ropes—four or five each. At intervals there are distance pieces, consisting of forked bits of wood with a cross-piece. A man crossing the bridge has to climb over these. The passenger walks on the lower cable and holds on by the upper cables.

At the ends, the upper cables pass over a beam supported on a forked upright. All the cables are attached to anchorages of large logs.



The above figure shows how the same principle can be applied to a light wire suspension bridge. Each wire is threaded through the ten holes in the above distance piece. The distance pieces are at five or six feet intervals, and are connected by boards for walking on, and light railings for holding on by.

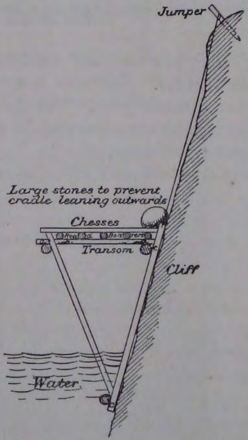
The number of holes would vary with the required strength of the bridge.



Cliff Bridge.

In very mountainous countries, such as Gilgit, the cliffs often descend quite perpendicularly into the rivers, and the paths in consequence have often to be made running over the tops of these cliffs, entailing sometimes a terrible ascent and descent of many hundred feet. The actual impassable places at the foot of the cliffs are often not more than 30 or 40 feet.

To make a temporary road rapidly, a cradle, as shown in the sketch on page 235, can be slung by wire from a jumping bar driven into the cliff at any convenient spot above.



The beams *cc*, *cc*, are in contact with the cliff; *aa*, *aa*, serve as transoms, and are horizontal; the road bearers *bb*, *bb*, rest in these transoms.

To prevent the cradle leaving the side of the cliff, large stones are placed on the inside of the roadway.

A piece of road made in this manner near Gilgit did excellently.

Bridge for Shallow River.

A good form of winter temporary bridge for places such as Gilgit, when the water does not exceed five feet deep, and skilled labour cannot be obtained, is made as follows :—

A small pier is built at the water's edge to about four feet above the water-level ; standing on this two picked men throw large stones out as far as possible ; they continue doing this till a pile of stones is made up to the surface of the water. Road bearers are then laid across the gap, and a few chesses put down. Large stones can now be added to the furthest out pier, and by aid of a frame or two of crib work, it can be raised to four feet above the surface. Another pier can now be made in a similar way, and so on. The piers will generally be about 25 feet from centre to centre.

At Gilgit, in 1891, a bridge of this description was made in three days. Work was carried on from both sides of the river, which was here about 330 feet broad. There was no skilled labour of any kind available. This bridge was in use for five months, and worked very well.

PAPER X.

THE INTERNATIONAL SYSTEM OF SEWAGE DISPOSAL AS ADOPTED AT CAHIR BARRACKS.

BY MAJOR W. H. GOLDNEY, R.E.

CAHIR is a small agricultural town situated about half-way between the towns of Clonmel and Tipperary. It has been for many years the headquarters of a regiment of cavalry, the barracks being about $1\frac{1}{2}$ miles south of the town. The occupation of the barracks may be taken roughly at 500 persons (including children) and about 270 horses. The latrines are on the dry earth system, with the exception of 12 w.c.'s in use in the officers' quarters and hospital.

The ground on which the barracks stand contains about 22 acres, and has a good fall towards the north. The surface drainage is partly conducted on surface channels to a drain on the county road but a considerable quantity finds its way into the barrack drains and thence to the sewage works, causing in wet weather a large increase in the quantity of sewage to be dealt with. For many years the drainage of the barracks flowed through a pair of deposit tanks and filters on the reserve ground just outside the barracks into a dry well, or soakage pit, where it was absorbed, the only attention required being the occasional cleaning of the filters and the removal of the solid matter deposited in the tanks. In 1892 this method of disposing of the sewage failed, owing to the incapacity of the soakage pit to absorb any more liquid. A most insanitary condition of things was thus set up, as the sewage overflowed into the ditch of a field just opposite the barracks, where it stagnated and caused an intolerable nuisance. An attempt was then made to deal with the sewage by constructing a new soakage pit about 200 yards distant from the barracks; but in the course of a few months this also ceased to act, the insanitary conditions became as bad as ever, and it was evident that it would be necessary to adopt some more effectual and permanent method of disposing of the sewage.

Under these circumstances, the "International" or "polarite" system of sewage disposal was selected as likely to be suitable to the conditions prevailing at Cahir, and steps were taken to collect information as to the working of this system by consulting the managing director of the "International Water and Sewage Purification Company, Limited," who kindly afforded facilities for visiting the sewage works established on this system at Hendon, and for obtaining all the information required. Independent and satisfactory testimony as to the successful working of the system was also obtained from Colonel Beamish, R.E., at the Home Office, and through his kindness an order was obtained for visiting the sewage works at Parkhurst, where much valuable information was acquired. From data thus obtained a design for sewage works at Cahir was prepared, embodying the latest improvement in the system in the shape of the patent improved iron precipitating tanks instead of the old concrete ones. The design was approved by the War Office in January, 1894, and the money authorized. The amount of the detail, including stores, was £327.

The main drain conveying the sewage from the barracks to the works is a 6-inch stoneware pipe, laid at a fall of about $\frac{1}{140}$, and provided at intervals with cleaning eyes, so that it can be swept with cleaning rods throughout its whole length; the pipe is also accessible at two points by man-holes.

It might appear at first sight that a 6-inch pipe would be insufficient to take the surface drainage from so large an area as 22 acres. But it must be borne in mind that a large part of the rainfall is lost by absorption and evaporation, and part flows along the surface channels into the drain on the county road, so that it may be reckoned that not more than about one-third of the actual rainfall would find its way into the main drain leading to the sewage works. A very heavy storm, yielding $\frac{1}{10}$-inch rainfall in an hour, would produce about 50,000 gallons distributed over the whole area, or a discharge into the main drain of about 17,000 gallons in the hour. The maximum discharge of a 6-inch pipe, with a fall of $\frac{1}{140}$, is 250 gallons a minute, or 15,000 gallons an hour; a storm overflow is therefore necessary to relieve the main drain during very heavy rain, and this has been provided in a man-hole just outside the barrack wall, the level of the overflow pipe being so arranged that the drain leading to the sewage works shall never run more than $\frac{3}{4}$ full. The overflow storm water, which would be so dilute as to be practically mere surface water, runs into the county drain on the Cahir road.

It is found in practice that the ordinary flow in fine weather is only half an inch in depth in the pipe; and the actual flow of sewage has been gauged at about 10,000 gallons a day, the maximum discharge being between 9 and 11 a.m., and the minimum after 5 p.m. The sewage, on entering the works, flows into a pair of concrete detritus tanks, or screening chambers, each provided with a scum-board to arrest floating scum, and an iron screen or grid to prevent solid substances from entering the tanks and filters. The grids consist of $\frac{1}{2}$-inch iron bars, $\frac{3}{8}$-inch apart. The sewage then passes through the ferozone box, where it receives a dose of from 6 to 8 grains of ferozone to the gallon. The box rests on stops, the bottom of it being a grating of $\frac{1}{4}$-inch iron bars, placed $\frac{1}{2}$-inch apart, through which the sewage rises, and in its passage dissolves a small quantity of the ferozone. The amount of the chemical dissolved depends on the height to which the liquid rises through the grating, so that the dose of ferozone can be regulated by adjusting the height of the stops on which the box rests. By this arrangement it is evident that the quantity of chemical dissolved varies with the flow of sewage, as the greater the quantity of sewage passing along the channel, the higher it rises in the box, and the more ferozone is dissolved. In the channel just in front of the box are five "baffling plates," which serve the double purpose of keeping the level of the liquid above the grating of the ferozone box, and of thoroughly mixing the chemical with the sewage, before it passes on to the tanks and filters.

The two chemicals used in this process are both compounds of iron. Ferozone is a magnetic ferrous carbon, and acts as a powerful precipitant and deodorant. The following is an analysis of it made by Sir Henry Roscoe, taken from Mr. Beloe's paper in Vol. XIV. of "Occasional Papers" (1888) :—

Ferrous sulphate	26·64
Aluminum sulphate	2·19
Calcium sulphate	3·30
Magnesium sulphate	5·17
Combined water	8·20
Moisture	24·14
Silicia	11·35
Magnetic oxide of iron	19·01
	100·00

According to Mr. Beloe, it "acts as an absorbent of some of the organic matter, and the particles of oxide, being porous and magnetic, part with their polarized oxygen, thereby assisting in the disinfection and deodorizing of the sewage and sludge."

Polarite is a magnetic spongy carbon, prepared by a patent process from carbonate of iron. Its great value as a filtering agent depends on its remarkable power of occluding and polarizing oxygen. The following is Sir Henry Roscoe's analysis of it :—

Magnetic oxide of iron	53·85
Alumina	5·68
Magnesia	7·55
Water with a trace of carbon	5·41
Silicia	25·50
Lime	2·01
	100·00

Owing to its affinity for oxygen, polarite has a remarkable recuperative power, and, if properly supplied with air by means of ærating pipes, will continue working permanently, requiring only to be periodically rested to enable it to take in a fresh supply of oxygen. The polarite in the filters need, therefore, never be renewed, or even cleaned, provided proper arrangements are made for supplying it with fresh air. These arrangements are shown in the plan and section, *Figs.* 2 and 3.

After receiving its dose of ferozone, the sewage passes on to the iron precipitating tanks, which are on an improved principle, patented by Mr. Pullen Candy, of the International Sewage Purification Company. The liquid passes down a central pipe to the bottom of the tank, receiving on its way a rotatory motion, which is said to promote precipitation. It then rises to the top of the tanks, and overflows into a channel running round them, whence it is conducted by concrete channels to the filter beds. At the bottom of the tank is a 2½-inch perforated arm, capable of being revolved round the centre of the tank by means of the cog wheels and handle as shown in the plate, *Figs.* 1 and 2. On opening the valve and turning the handle, the arm is made to revolve, and the sludge at the bottom of the tank is forced into the arm, whence it passes through the bottom of the tank, and rises by the pressure of the supernatant liquid up the sludge pipe to a level about a foot below the top of the tank; it is then conveyed by a concrete channel and a 3-inch drain pipe into the sludge well, where a chain pump is provided for pumping the sludge into carts for removal. The liquid rising on the top of the sludge in the well can be pumped back into the detritus tank, and treated a second time.

The filter beds are constructed entirely of concrete. The floors have a fall of 2 inches to the front, and communicate with each other by means of 3-inch pipes through the division walls on the floor level. The effluent, after passing through the filtering material, is conducted by covered channels and agricultural drain pipes laid on the floors (*Figs.* 1 and 2) into the outlet pipe in the centre filter, whence it passes to a 6-inch drain which conveys it to a stream at a point about 400 yards distant. The rate of filtration was calculated to be about 1,000 gallons to each yard super in 24 hours; with only two filters in use at a time, each of 6 yards super, these works should, therefore, be capable of filtering 12,000 gallons a day; an overflow is provided to prevent the filters being flooded during heavy rains. In order to ensure the even distribution of the sewage over the surface of the filter, an iron trough 6 inches by 3 inches is laid perfectly level in the top layer of sand, to receive the liquid which overflows and spreads itself over the surface of the sand; but for this arrangement scouring would take place, and the filter would work unevenly. A small concrete fillet runs round the inside of the walls about half-way down, to prevent the liquid percolating down the sides without passing through the polarite. The following is the arrangement of the filtering material recommended by the Sewage Purification Company, commencing with the bottom layer:—

5 inches broken stone to pass 1-inch ring.
3 inches pebbles walnut size.
2 inches pea gravel.
2 inches grit or coarse sand.
12 inches polarite and sand mixed in equal proportions.
9 inches pebbles walnut size.
3 inches pea gravel.
2 inches grit or coarse sand.
6 inches fine sand.

The fine sand, in fact, all the materials, must be well washed, and free from loam. The pea gravel and coarse sand were obtained from the beach at Tramore, near Waterford.

The ventilation of the polarite is a most important point, as from the supply of fresh air it derives its power of maintaining its efficiency. Three rows of agricultural drain pipes are laid just above the layer of polarite, the centre row being a few inches above the other two. These pipes are connected with 2½-inch down pipes, which are carried up about 2 feet above the top of the filters, and are provided with caps or cowls arranged so as to catch the wind from whatever direction it may be blowing, thus ensuring a free current of air being carried by the action of the water into the layer of polarite and sand. Ventilating pipes are also carried down to the covered channel on the floor of the filter as shown in *Figs.* 1 and 3.

It has been thought that the Cahir Sewage Works above described may fairly claim something more than merely local interest, owing to the fact that they were avowedly constructed not only as a solution of the problem presented by the insanitary conditions at Cahir, but also as an experiment to test the value of the International System as a means of disposing of barrack drainage generally, and with this object in view, the greatest attention has been paid to the minutest detail in the design and construction, reference being frequently made to the Sewage Purification Company, whose works at Swinton were visited for the purpose of obtaining information on certain points of detail. The works have been open sufficiently long to enable a fair idea to be formed of the efficiency of the system as applied to barracks, and of any modifications in the design which experience at Cahir would suggest as desirable. When we come to examine the results given by these works, it must be admitted that the working of the system at Cahir, though satisfactory as far as local requirements are concerned, falls somewhat short of the expectations which were formed of it in two important particulars, viz.:—(1), rate of filtration; and (2), purity of effluent.

(1). The rate of filtration, which formed the basis on which the design was made, was 1,000 gallons per yard super of filter in 24 hours, being the rate given by the International Sewage Purification Company as attainable, and actually attained in certain municipal works on the same system. In the case of Cahir the rate of filtration has been found to be somewhat less, which is attributed to the fact that the barrack sewage is found by analysis to be very much more concentrated, and less diluted with water, than that of the municipalities where the process has been adopted. The foulness of any sample of sewage is estimated chiefly by the quantity of albumenoid ammonia it contains. Taking this as the basis of comparison, it is found that the Cahir sewage contains 2·62, Acton ·70, Salford ·68, and Glasgow ·32 parts per 100,000 of albumenoid ammonia, showing that the Cahir sewage is nearly four times as strong as that of Acton or Salford; it would, therefore, require a larger area of filtration as compared with that which is found to be sufficient when dealing with a more dilute sewage Moreover, it has been found that the provision of three filters does not work satisfactorily, as each filter has to work two days and rest one, whereas it is desirable that each filter should rest a day after one day's working, which would necessitate the provision of 4 filters instead of 3. It has been proposed to meet this difficulty at Cahir, and at the same time to increase the area of filtration, by constructing a fourth filter, for which room was left on the site of the works.

(2). The effluent obtained from the filters shows that a very large degree of purification of the sewage is effected by the process to which it is subjected. The following is the result of an analysis of samples of the crude sewage and effluent, made by Dr. Arthur Angell, F.I.C.; the samples were taken on the 7th June, 1894, by Mr. C. W. Grey, T.C.W.:—

CRUDE SEWAGE.

	Grains per gall.
Free ammonia	8·218
Albumenoid ammonia	1·512
Chlorine	8·82
Suspended matter	93·1
Re-action	Neutral.

(This is a foul concentrated sewage).

EFFLUENT.

	Grains per gall.
Free ammonia	6·765
Albumenoid ammonia	0·287
Chlorine	14·14
Suspended matter	1·96
Re-action	Distinctly alkaline.

(*Signed*) ARTHUR ANGELL.

The effluent was slightly opaque in colour, and had a slight but perceptible smell. The analysis shows that the process is entirely satisfactory so far as the removal of the suspended matter is concerned, but the proportions of free and albumenoid ammonia remaining in the effluent leave much to be desired.

The efficiency of the process can be best judged from the following table of percentage of purification :—

	Purification.	
Free ammonia	18 per cent.	
Albumenoid ammonia	81 ,,	
Chlorine	$37\frac{1}{2}$,,	increase.
Suspended matter...	98 ,,	

The increase in the quantity of chlorine is, at first sight, remarkable, but it is accounted for by the fact that the samples of crude sewage and effluent were taken at the same time, and only proves that the sewage which produced the sample of effluent was more foul than that which was passing at the time the samples were taken. Had an interval of about four hours been allowed to elapse between the taking of the two samples, it is probable that better results would have been obtained. As it is, the analysis shows that a very considerable degree of purification has been attained, though in actual purity of effluent the result is not equal to that obtained at some municipal works where the system is in force. This is probably due to the unusual concentration of the sewage coming from the barracks, and to the fact that the filters have an insufficient area in proportion to the strength of the sewage, and are consequently over-worked. It may, however, fairly be expected that if the proposed increase in the area of filtration were carried out, the result would be an improvement in the purity of the effluent and in the rate of filtration over that which is at present attainable. The greater density and concentration of sewage derived from barracks as compared with the sewage of large towns is a fact that should be taken into consideration by officers who may have to design works for barracks, and due allowance for this fact must be made in calculating the area of filtration. In other respects the working has been satisfactory. The iron precipitating tanks have worked well, as is evidenced by the fact that 98 per cent. of the suspended matter has been removed. No difficulty has been experienced in transferring the sludge to the sludge well by means of the revolving arm; the quantity of sludge obtained is found to be very small, and there has been no difficulty in disposing of it.

There is every reason to believe that the International System is eminently suited to the case of barracks, the following being its principal advantages:—

(1). Purity of effluent.
(2). Simplicity and low cost of working.
(3). Small area required for the works.
(4). Small quantity of sludge.
(5). No public nuisance caused by works.
(6). Small cost of construction.

The annexed table gives the results produced by the International System as far as the albumenoid ammonia is concerned at various places:—

Place.	Albumenoid Ammonia.		
	Crude Sewage.	Effluent.	Percentage of Purification.
Acton	·70	·035	95
Glasgow	·32	·28	12½
Salford	·68	·06	91
Stirling Asylum	3·414	·056	98½
Cahir	2·62	·498	81½