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PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS,

CONTRIBUTED BY

OFFICERS OF THE ROYAL ENGINEERS.

NEW SERIES.

VOL. XII.

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PREFACE.

The present Volume of the Professional Papers is again late in making its appearance; while I apologise to the Subscribers for such being the case, I may at the same time remark that its earlier publication would have deprived it of some of its most interesting articles.

The bulk of Papers I, III, VII, VIII, X, XI, XII, XIII, XVI, XVII, and XVIII, has been already read at the Chatham Meetings, and supplied in the form of Pamphlets to a limited number of officers. These latter must kindly excuse their re-appearance, as in their original form they are not procurable by the majority of our officers.

Matter of great interest will be found in Paper XIX, and we must all feel much indebted to Major General Hamilton and Colonel Nelson, for having procured for us such valuable information. I take this opportunity of thanking Professor Feiling, R.M.A., for the kind assistance he afforded me in the translation of part of the Paper.

Many Officers may not be aware that in 1849-50, prior to the commencement of the present series of the "Professional Papers," three numbers of "Corps Papers" were published. These have been bound together so as to form a Volume uniform with the present series, and can be obtained (price £1) on application to S. B. Howlett, Esq., at the War Office. The Book contains 41 Papers and 64 Plates, besides numerous Woodcuts; a list of these will be found on a loose sheet, accompanying the present Volume.

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

Woolwich, October, 1863.

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MEMOIR

OF

GENERAL SIR CHARLES WILLIAM PASLEY, K.C.B.

General Sir Charles William Pasley, K.C.B., of the Royal Engineers, was born at Eskdale-Muir, Dumfries, on the 8th of September, 1780. In his early years he displayed the impetuosity and high courage which distinguished him in after life, as well as the perseverance, ability, and liberality for which he became no less remarkable.

His first instruction was at a "lassies'" school, and he was next taught Latin, Greek, and French by Mr. Andrew Little, of the "new town" of Langholm, who had lost his sight by lightning while surgeon of a Liverpool vessel on the west coast of Africa. He progressed so rapidly with his studies under this gentleman that he was able to read the Greek Testament at eight years of age. He never walked to school by the roadway of the Esk Bridge, but always along the top of the parapet. Energetic alike at work and play, he asked prematurely to be taught "counting," and was told that he must wait until he grew old enough to understand it. Stung by the fortunate refusal, he borrowed a book on arithmetic from the housekeeper of a neighbouring nobleman, and made himself master of its contents; and when he was told at a later period that he might begin to learn, he had the gratification of informing his teacher that he was ready to be examined in the different rules.

When twelve or thirteen years old, he took an active part and great interest in the boy-conflicts between the Langholmers and the Mucklemholmers, who were drilled and armed with sticks, and who occasionally invaded each other's territories on opposite sides of the Esk. He was the best swimmer in "a' Eskdale," and would at great risk plunge into the flooded river. He wrote a history about this period, of the "Wars of Langholm," and translated it into Latin in imitation of the style of Livy; and a poem which he composed upon Langholm Common Riding, in 1792, is said to have brought in some profit to a printer who published it, and to an old man who sold it. In the winter of 1794 he was sent to school at Selkirk with some of his cousins, the Malcolms*, and he remained there till the summer of 1795, when he returned to Langholm. He joined the Royal Military Academy at Woolwich in August 1796, and obtained a commission in the Royal Artillery on the 1st of December, 1797. His prospects were all but ruined at this time, in consequence of his having, in the

* Of this family, Sir James Malcolm, K.C.B., Sir John Malcolm, G.C.B., Sir Pulteney Malcolm, G.C.B., and Sir Charles Malcolm, Knt., with another cousin, Sir James Little, were styled the five knights of Eskdale, before Sir Charles Pasley was added to their number.

exuberance of his spirits, assisted in a practical joke upon one of the masters. While expecting to be dismissed from the Royal Military Academy for this offence, he resolved upon working his way out to India, and making his own fortune, without communication with his friends; but in the mean time, happily, his reprieve arrived. He was transferred to the Royal Engineers on the 1st of April, 1798, and on the 2nd of August, 1799, he was gazetted as first lieutenant in that corps.

Between 1799 and 1807 he served in Minorca, Malta, Naples, and Sicily, and was employed on various important services and confidential missions. He continued his studies at this time in mathematics and languages, and is still remembered in Malta, both for his skill as an engineer and for his daring feats.

Lieutenant Pasley volunteered for the expedition to Egypt in 1801, and was much disappointed at not being ordered to join it. He was sent by General Villettes to communicate with Lord Nelson in 1804; and after having been promoted to the rank of second captain on the 1st of March, 1805, he served under the Prince of Hesse-Philippsthal in the defence of Gaeta against the French in 1806, and under Sir John Stuart at the battle of Maida (in Calabria) on the 4th of July in the same year. The experience of that battle confirmed the strong opinion which he had always maintained—in opposition at that time to many in the British army—that the English generals would beat the French marshals as soon as they got a chance of doing so. In the course of a reconnaissance towards the river Garigliano, in company with a younger officer of the name of McLeod, he was twice stopped by armed peasants, who looked at their buttons with longing eyes, and pretended to mistake them for deserters for the sake of robbing them. Small though he was in stature, he drew his sword and determined to defend himself to the last. The peasants threatened them both with death if they resisted; but Captain Pasley exhibited so much reckless courage, and represented to them so furiously the revenge that would be taken upon the whole neighbourhood if they injured them, that the peasants retired leaving them unscathed.

Captain Pasley took part in the siege of Copenhagen under Lord Cathcart in 1807, and joined Major General Leith at Oviedo, in the north of Spain, in September, 1808. He was employed to reconnoitre the Asturian frontier, and then to communicate with General Blake at Reynosa in November, and he left Soto on the 15th of that month at night, as the French entered it. After joining Colonel Robert Crawford's Brigade, he was retained on the 18th by Sir David Baird as his extra aide-de-camp, in consequence of his general attainments and knowledge of the Spanish language. On the 25th he joined Sir John Moore's staff in a similar capacity, and was attached to it during the retreat upon, and at the battle of Corunna. He lent his horse during this retreat to a lame soldier to carry him to Villa Franca, and did not see it again for several days: he had also to perform on foot, and for part of the time with only one shoe, some fatiguing marches. Though a great admirer of Sir John Moore, he was much annoyed at this retreat, and could never afterwards speak of it with patience—his conviction having been that the army ought to have turned round upon its pursuers whilst it was strong, and to have maintained a footing in the Peninsula, instead of waiting to fight at Corunna after it had been seriously weakened by its retreat, and then quitting the country. From his intercourse with the

Marquis of Romagna and others, he was also convinced that the Spanish troops might under improved arrangements have been made more useful.

Captain Pasley next accompanied the expedition to Walcheren; he was employed in reconnoitring the coasts of Cadsand and Walcheren under the fire of the enemy's batteries; and he was present at the siege of Flushing in 1809. Leading a storming party of 100 men under Colonel Pack, to obtain possession of a French battery on the dyke according to his own proposal, he was first wounded (though not disabled) by a bayonet in the thigh, and then, after reaching the top of the dyke, shot through the body by a French soldier from below, belonging to a fresh party of about sixty whom he challenged to surrender to twenty men. The bullet passed in at one side and out at the other, injuring the spine in its progress, and it was hardly expected at first that he could recover. Portions of bone, sash, and clothes came out of the wound afterwards by degrees, and it rendered him incapable of duty for more than a year*. In consequence of the exhaustion which exertion produced upon him, he almost despaired for many years afterwards of being able to continue in the service of his country.

In November, 1810, Captain Pasley published the first edition of his "Essay on the Military Policy and Institutions of the British Empire." He had written the first and second chapters of this work in the spring of 1808, but had been prevented from completing it by service in Spain and at Walcheren, and by ill health consequent upon his wounds. This work appeared in a time of great national despondency; and its principal objects were to advocate greater energy and perseverance in prosecuting the war with France, judicious offensive action in the conduct of that war, and especially a more vigorous policy in Spain, and to demonstrate that Great Britain had "sufficient force and a favourable opportunity for destroying the French empire." It attracted great attention, and was highly approved on account of the manly and patriotic spirit which it displayed, though the doctrines of political economy which it contained were disputed. It ran through four editions, the second having been prepared in March, 1811, the third in October, 1811, and the fourth in November, 1812. It was favourably noticed (by Mr. Canning as was supposed) in the "Quarterly Review," of May, 1811, and was stated to have been one of the most important political works that had ever fallen under the observation of the reviewer. The opinions it expressed were contrasted with the humiliating language then to be found in the pages of the English press, and with the principle of *husbanding* resources which was alike the watch-word and the fatal error of the despondents.

Whilst in command of the Plymouth Company of Royal Military Artificers, in 1811, Captain Pasley set himself to consider how improvements could best be made in the practice of Military Engineering. He had found on active service the serious disadvantage under which the Royal Engineers laboured, of having no properly educated men at their disposal, and no good system for regulating their operations; and the remainder of his life was chiefly devoted to the supply of these wants. He visited a Lancasterian school in August of that year, and commenced in the next month to teach his non-commissioned officers practical geometry, in order that they might thoroughly understand the use of plans and

* He took advantage of this opportunity to teach himself German amongst other things.

sections. Finding that the ordinary methods of instruction were unsuited to his object, he then composed an elaborate treatise on a similar principle to the systems of Dr. Bell and Mr. Lancaster, to enable the non-commissioned officers to teach themselves and their men without the assistance of mathematical masters, and to go through their courses of geometry in the same manner as their company drills or their small-arms exercises. The system thus organized was found so successful at Plymouth, that it was laid in March, 1812, before a Committee of Royal Engineers, who reported favourably upon it to the Inspector General of Fortifications; and it was afterwards introduced on an extended scale into the schools at Chatham in spite of some objections—one critic fearing that the men would become better educated than their officers, and might be consulted by the Generals commanding! His energy and success, backed by the representations of the Duke of Wellington from the Peninsula, as to the defective condition of the Engineer Department in the field, resulted in the formation of the Establishment for Field Instruction at Chatham, and in his appointment to the office of Director of that establishment by Lord Mulgrave, in June, 1812, with the rank of Brevet Major, back-dated to February of that year. He was promoted to the rank of Brevet Lieutenant Colonel in May, 1813, and he became a Lieutenant Colonel in the Royal Engineers in December, 1814. Following up his designs, he completed a work on "Military Instruction" in three volumes, of which the first was published in 1814, and the second and third in 1817. The former contained the course of practical geometry before referred to; the two latter a complete treatise on elementary fortification, including the principles of the science, and rules for construction, many of which apply to civil as well as to military works.

Finding, in 1817, that his men had been "most grossly ill-treated by the Army Bread Contractor," he was led to inquire into the system under which the army was supplied with provisions; and he printed and circulated, but abstained from publishing, in 1825, a volume containing the result of his investigations, entitled, "An Inquiry into the System of General or Commissariat Contracts for supplying His Majesty's Forces in Great Britain with Bread and Meat, as compared with that of Regimental Purchases, with a recommendation that the former shall be entirely abolished." The exposure which he thus afforded to abuses that were prejudicial to the soldier, and the improvements that he suggested and was partly the means of introducing, were in themselves services of great value. In 1818, he published a volume of "Standing Orders," containing a perfect code of military rules for the duties of all ranks in the army.

Colonel Pasley organised, during his residence at Chatham*, improved systems of telegraphing, sapping, mining, pontooning, and exploding gunpowder on land and in water, and laid down rules which, being founded on careful experiment, will always endure, besides preparing pamphlets and courses of instruction on these and other subjects. The volume which contained his "Course of Practical Architecture" was especially valuable. He was on terms of intimate communication with the Duke of Clarence before his accession to the throne, and with his royal brothers; but he was not sufficiently a courtier to profit as he might otherwise have done by that intercourse. His work on the "Practical Opera-

* In addition to these various occupations, he employed privates of Sappers to teach him the native Welsh and Irish languages.

tions of a Siege," of which the first part was published in 1829, and the second in 1832, is still a text-book, and the best that has been written in any language on that subject. Every operation in it was treated as a separate study; and it exposed various mistakes into which the German authors had fallen. It was translated into French, and published in Paris in 1847.

Early in 1831 Colonel Pasley prepared a pamphlet, and in May 1834 he completed a volume of 320 pages, entitled "Observations on the Expediency and Practibility of simplifying and improving the Measures, Weights, and Money used in this country, without materially altering the present standards." He hoped to assist by means of this work in bringing about the desirable result that there should, in the words of sect. 2 of the Act, cap. x., 27th of George the Third (ordinacio stapulorum), be "only one weight, one measure, and one yard throughout all the land." In pursuance of this subject, he strongly advocated, for a great part of his life, the adoption of the decimal principle of division in all its simplicity for our coinage, as well as for our weights and measures, and opposed with equal ardour the introduction of the French units into this country.

He sent to the press in May, 1836, the first sheets of a work containing "Observations on Limes, Calcareous Cements, Mortars, Stuccos, and Concrete, and on Puzzolannas, natural and artificial, together with rules deduced from numerous experiments for making an Artificial Water Cement, equal in efficiency to the best natural cements of England, improperly termed Roman Cements, and an abstract of the opinions of former authors on the same subjects," of which the first edition was published in September, 1838. It contained considerable discoveries, the results of experiments at Chatham, and led at once to the manufacture, in large quantities, of artificial cements, under the different names of "Portland Cement," "Patent Lithic Cement," and "Blue Lias Cement." A second edition of this work, which had long been wanted, was published in August, 1847.

In connexion with experiments on the explosion of gunpowder under water, Colonel Pasley was led to undertake, and successfully to carry out, the removal of the brig "William" and the schooner "Glenmorgan," from the bed of the Thames near Gravesend, in the year 1838. He received for this service the thanks of the municipal authorities, and was presented with the freedom of the City of London in a gold snuff-box of the value of fifty guineas. Emboldened by the success of these operations, he proceeded to execute the more formidable tasks of clearing away the wreck of the "Royal George" from the anchorage at Spithead, and that of the "Edgar" from St. Helen's. The value of the materials recovered from these vessels was more than equal to the expense incurred in their removal. Portions of six successive summers, from 1839 to 1844 inclusive, were devoted by him to this work; but he never asked for nor received from the Admiralty any remuneration for the important services that he rendered in this manner to the navy and the nation.

Colonel Pasley remained at Chatham till the end of the year 1841, when he was appointed, at the age of 61, to the office of Inspector General of Railways. During the 29½ years that he was at the head of the Royal Engineer Establishment, there was hardly any subject connected with his professions as a military man and an engineer—of instruction, construction, or destruction—that did not benefit by his attention. His presence there was of the greatest advantage to his country as well as to his corps. The corps of Royal Engineers owes, in fact, its existence in its present condition, as well as its high state of efficiency, to his energy, his example, and his exertions; and the success of the British army in many a field has been due in no small degree to the system of instruction at which he laboured so devotedly, and which he rendered so perfect. Lord Keane was indebted to that system for his brilliant exploit at Ghuznee in 1839*; and, as the latest example, it may be stated that the recent war in New Zealand was only brought to a close after its adoption by officers (one of them his own son) who had received instruction from him at Chatham. The easy and bloodless capture of the native pahs, which resulted from a systematic employment of the spade, proved at once to their defenders the hopelessness of further resistance.

He became a Brevet Colonel on the 22nd of July, 1830, a Colonel of Engineers on the 12th of November, 1831, and a Major General in the Army on the 23rd of November, 1841. He received the honorary distinction of D.C.L. at Oxford in 1844; and in 1846, on relinquishing the appointment of Inspector General of Railways, he was made a K.C.B. for general services. He held the appointment of Public Examiner at the East India Company's Military Seminary at Addiscombe for sixteen years, up to the year 1855, and took an active part in its management, contributing materially to the high standard which it reached and at which it was maintained. He was elected a Fellow of the Royal Society as far back as 1816; he was also of old standing in the Astronomical, the Geological, the Geographical, the Statistical, and other societies; and he lost no opportunity of contributing to the advancement of practical science. He was also a liberal subscriber to a great number of charitable institutions.

He courted what other people considered risk to the end of his days. On one occasion he went to the bottom of the Medway in a diving bell, to arrange and test a code of signals for use under water. A brother officer who accompanied him noticed, to his horror, that the bell was fast sinking in the soft mud on which they had alighted, and first requested, and afterwards implored him to make the sign for hoisting it to the surface. He declined, however, to do so until he had deliberately completed his code of communications, and until his companion had almost given up all hope of avoiding subaqueous interment.

He had no public office after 1855, but occupied himself chiefly in re-editing his works, superintending the construction of pontoon equipages, and in other matters connected with his profession, as well as in advocating the introduction of decimal coinage, devoting a large proportion of his time to the benefit or advancement of his friends and relations. Absorbed in these occupations, he frequently neglected to take the air and exercise necessary for health, which would probably have prolonged his valuable life. He was promoted to the

* During the debate in the House of Commons on the 6th of February, 1840, on the vote of thanks to the army after the capture of Ghuznee, Sir H. Hardinge observed:—"With respect to Major Thompson, it is not from any wish on my part to underrate the merits of that able officer, that I feel it right to state that the merit of the invention (by the use of which the gate of Ghuznee had been blown open) so admirably employed by him, is due to Colonel Pasley, under whom the gallant officer to whom I referred, and others, also distinguished officers, received instruction." Sir Hussey Vivian, who followed, said:—"I concur with my Right Honourable and gallant friend opposite in stating that to Colonel Pasley is due the merit of the discovery."

rank of Lieutenant General on the 11th of November, 1851, and to that of General on the 20th of September, 1860.

He was twice married. His first wife died of consumption in a few months. His second wife died in 1848, and was a serious loss to him. Of six children, three survive him. He was well and hearty up to within a week of his death; but his long life of labour was brought to a close at his residence at 12, Norfolk Crescent, Hyde Park, from congestion of the lungs, on the 19th of April, 1861.

Sir Charles Pasley's was no common character. Its principal feature was perseverance, amounting to pertinacity, in carrying through whatever he undertook, almost without consideration for time, trouble, or risk. From first to last he evidently experienced that intense desire for distinction which incites to noble deeds, emulates to constant labour, and leaves no room for timidity or mistrust. He had none of that jealousy of others which such feelings produce in less exalted minds, and which induces them to oppose their progress or to abstain from rendering them assistance. He was accustomed to volunteer himself in his early years for all services in which danger was to be encountered or credit to be obtained; and nothing gratified him more in his old age than to see his sons and other young men adopting a similar course. He appreciated so highly the little assistance he received, and the education that was afforded to him in commencing his own life, that he never tired afterwards in employing his influence and his purse in promoting the interests of those who required them. It was a touching spectacle to those who were nearly associated with him at the close of his career to observe, that while he was still engaged in launching young friends and connexions into the world (preparing them for examination, advancing their outfits, or providing for their education), he was at the same time receiving expressions of gratitude for similar favours from men who were retiring, or had retired, from their professions at the end of their term of service, and who did not hesitate to acknowledge that they owed their success in life to his timely assistance and his large-minded liberality.

H. W. TYLER,
Captain, Royal Engineers.

PROFESSIONAL PAPERS.

PAPER I.

A LETTER FROM

COLONEL SIR WILLIAM DENISON, K.C.B., R.E.,

TO

COLONEL HARNESS, C.B., R.E.,

ON THE INFLUENCE OF RIFLED CANNON AND SMALL ARMS ON THE ATTACK AND DEFENCE.

MY DEAR HARNESS,

By the last mail I received no fewer than four of the Papers read at your meetings at Chatham, and among them one by Colonel Nelson, on Vaulted Revetments, which not only recalled to my memory some ideas of my own with reference to the construction of Revetments and Ramparts at points in the enceinte of a work liable to be breached, but also led me to think that some observations upon the effect of the late improvements in the construction and use of both cannon and small arms, in the attack and defence of fortified places, would not be unacceptable to you.

I must, however, preface these observations by a statement that they are principally suggestive; I do not propose, indeed the time at my disposal would not allow me to attempt, to go fully into the subject, but the sketch which I am about to give can easily be corrected, and the details filled in by officers who have more time at their disposal, and who will be able, therefore, to investigate more closely the relations which will hereafter exist between the attack and the defence of fortified positions

As a general rule we find that a fortified town, defended by a competent garrison, adequately provided with ammunition, will succumb after the trenches have been opened some six weeks or two months, if it be left to its own resources solely, and cannot procure aid from without. The question we have to consider, therefore, is whether, in consequence of the improvement in weapons of offence, the length of the siege of any given town will be materially lessened or prolonged. It is admitted that, with perhaps some few exceptions, no place is impregnable; that the besieger, if left to himself, will eventually take the place. What we wish to determine is, whether the use of improved weapons, both by besieged and besieger, will modify the relation which exists at present between the attack and defence. The first thing we have to consider is the actual improvement in cannon and small arms. In what does this consist? The reply would, I conceive, be to the effect that the range of the missiles projected from both cannon and musketry is very much increased, while the direction of the fire from them is much more accurate than heretofore. This additional range is obtained, not by any increase in the initial velocity of the projectile, but simply by increasing the weight of the ball and diminishing the surface of resistance, so that while the latter is less, the power of overcoming it is greater. The accuracy of direction is secured by rifling both small arms and ordnance, but to the mode of obtaining the results before stated, it is not necessary that I should further allude, and I may sum up the improvements on weapons of offence briefly as follows:—

Projectiles range further, are more accurately directed, and produce a greater effect upon the objects against which they are directed, than was the case till within the last few years.

These qualities, however, of course appertain to the weapons used in the defence as well as to those used in the attack, and we have now, therefore, to think over the action of musketry and cannon both in the attack and defence, in order to determine on which side the advantage will preponderate. Before, however, I enter upon the discussion, I must premise that I intend my remarks to have reference to fortresses of such a size, and occupied in such a manner, as would justify a general in detaching a portion of his force to carry on the siege. I do not think that we can safely reason upon facts which were established during the siege of Sebastopol. This place was occupied—not by a garrison—but by an army, and should be considered more as a fortified camp than a garrison town. Again, the attacking force had its magazines close at hand, it had not to provide transport for stores and ammunition from any distance, and would, therefore, venture to expend an amount of ammunition which, under ordinary circumstances, could never be brought up except by water transport.

I propose then to go through the operations of the siege of a place which, having its scarps well covered so as to oblige the besieger to establish his breaching batteries on the crest of the glacis, would, under ordinary circumstances, probably be found, after six weeks or two months of open trenches, with a practicable breach in the body of the place, the besieger having a secure lodgment on the crest of the glacis, and being ready to carry the place by assault, should the defenders attempt to prolong their resistance. I shall not attempt to enter into any nice calculations of the time which would be absorbed in this or that portion of the attack, but shall assume that neither the assailants or defenders make any great blunders; that the approaches are carried on, subject only to the ordinary casualties from the fire of artillery and musketry; that the ground is of the ordinary description; in fact, I shall eliminate every circumstance which may be thought to give an advantage to one party or the other, and shall leave the assailants to make their way by the use of the pick and shovel, covering the workmen with a fire much more deadly and destructive than any hitherto experienced by a besieged town, while I shall suppose the besieged to be supplied with a reasonable proportion of military stores, and to be able to bring into action, with an ordinary degree of skill and dexterity, those resources which the improved quality of arms develops.

The first offensive operation is the opening of the trenches, that is, the construction of the first parallel and the communications to it from the rear.

The object of the besieger is to place the working parties under cover in the shortest possible time; it is not his wish to attract the notice of the besieged to work carrying on; he does not, therefore, make any use of musketry or cannon, but works in silence with the pick and shovel in hopes of having secured, by break of day, cover sufficient to protect the men employed during the day to widen the parallel and thicken the parapet. The usual distance of the first parallel from the works is about 600 yards, a distance established under the idea that troops would not be exposed to the fire of musketry or grape; that even if the working parties were discovered early in the night, the fire brought upon them would only be that of cannon with round shot, the result of which upon a thin line of workmen spread along a distance of 1,000 yards, more or less, could be but trifling, even should the besieged be willing to waste valuable ammunition for such petty results. As a general rule then, hitherto, the trenches have been opened, and the first parallel and the approaches to it perfected, without much difficulty or loss. What, however, will be the case hereafter? In the first place the camp of the besieger must be placed at a much greater distance from the fortress than heretofore, otherwise the stores of gabions and fascines allotted for the siege will be liable to be set on fire by shells. The approaches from the camp to the trenches will have to be carried much further to the rear in order to secure from the fire of the fortress the stores, ammunition, &c., which must be brought up to the batteries. It will be a question whether the first parallel can, without great risk, be opened at so short a distance from the place as 600 yards, at which the covering party and the workmen will equally be within easy rifle range of the covered way. The parallels and approaches will require to be widened and deepened, as the parapets must be thickened in order to secure the men in the trenches from the heavy shot, which would pass through the ordinary parapet of loose earth. Up to this point, therefore, the advantage is on the side of the besieged. The attacking party has further to march, further to bring stores and ammunition, has more work to do, and has less means of resisting any sortie which might be made, as he would be obliged to bring up and form his troops under the fire of the place.

The next step is the construction of the enfilading batteries, which are to keep under the fire of the place. I will suppose that the besieged have their guns mounted in the ordinary manner; that the embrasures are wide mouthed recipients of shot; that the guns are covered by a few traverses which hamper the movements of troops all along the ramparts. I might imagine the guns sunk into the body of the parapet, made to traverse upon centres under the muzzles, firing through an opening not bigger, nor so big, as the port-hole of a ship, and this secured further by a facing of wrought iron. I might suppose them covered with splinter-proofs, forming a sort of extemporary casemate, as they are quite as well adapted to the former state of things as to that which has replaced it. But all these advantages I will forego. The guns are worked in embrasures, the men being protected as best they might be from the fire of the riflemen who now occupy the parapet of the first parallel, and who do their best to keep down the fire of the artillery directed against the batteries in process of formation. The advantages here are pretty fairly balanced; if anything the scale preponderates in favour of the besieger, whose rifle fire upon the guns may be thought to more than counterbalance the greater accuracy of the fire of these, and the greater effect of the shot.

We will suppose the ricochet batteries constructed, and to open their fire. What will be the effect of their fire? At present the shot fired with a moderate velocity is pitched over the crest of the parapet and ricochets, with two or three bounds, along the face of the ravelin or bastion. With the heavy shot of the Armstrong gun, whose trajectory approximates much more closely to a straight line, it would be necessary to lessen the charge and diminish the initial velocity to a greater extent, or the shot which passes over the crest of the parapet will not touch the ground till it has ranged half the length of the face. To do this is to sacrifice the peculiar advantage which the weapon holds out, and I do not think that the fire would be so effective, while it would be far more expensive than that of the ordinary 24-pounder. This, however, is a matter which ought to be decided by experiment;* as to the expense, that is an established fact.

The first parallel and the enfilade batteries having been constructed, the approaches must be pushed on under cover of the fire of the batteries in various ways, principally, however, I suppose, by flying sap; it is needless to say much about this, or about the construction of the second parallel; the remarks made with reference to the first parallel apply still more strongly to the second, though, of course, the fire of the besieger has commenced to tell upon the garrison. From the second parallel, however, the approaches must be pushed forward by the sap, and to this the increased power of penetration of the rifle ball the weight of the shot, and the accuracy of the fire of such guns as remain, will present a very great obstacle; to resist a rifle ball the gabions must be made larger, and consequently heavier and more unmanageable; they will take a longer time to fill; the sapper will be exposed to fire longer, and the loss will, of course, be greater; a steady fire of a dozen riflemen and one or two guns upon the head of a sap would make the attempt to push it forward most difficult and dangerous; with the former weapon, the old smooth bore, it was impossible to fire with any amount of accuracy at objects more than 120 yards distant—that is 60 or 70 yards from the foot or the glacis,—but with the existing rifles the practice at 300 and 400 yards with picked men would be as good as that at 100 yards with the smooth bore. The nearer the approaches are pushed to the place the more deadly does the fire become, and it would be almost hopeless to attempt to form the third parallel by the sap. It is needless to press the comparison farther; it appears to me that the balance of advantage preponderates on the side of the defence; that the siege of any given place would take longer time, under existing circumstances, than when the arms used were the musket and the old 24-pounder, and the loss to the besieger would be greater. It must be remembered, however, that this opinion refers to the siege of a place where the scarps are properly covered; there is no doubt that a breach would be made more rapidly, and from a greater distance, by the existing guns, than by the old 24-pounder, supposing the scarp to be seen to the front. I have alluded to the mode in which the guns in the salients might be protected, on which I was called upon to send in a plan and estimate for a practice battery for the Marine Artillery at Portsmouth. I proposed to place the battery between Southsea

* A series of such experiments was carried on by the Ordnance Select Committee a short time since, and they reported as follows:—"Armstrong projectiles can be fired at high angles with reduced charges, and still retain precision of direction and uniformity of range, and are therefore well adapted for silencing guns covered by traverses, or for breaching caponiers and sunken defences, but not so well adapted as round shot, for making small bounds in a work." (See Paper IV of this volume)—Ed.

Castle and the entrance of Langstone harbour, so as to form an addition to the coast defence on that side, and as it was intended to protect the coast from the fire of shipping it became an object to place the guns in casemates, and to give to these casemates the smallest possible opening to the exterior; in order to do this, and at the same time to give to the guns the maximum amount of lateral deviation, I proposed to make them traverse upon a pivot or point under the muzzle, and to trust to the quality of the stone, which I proposed to use in very massive blocks, to secure the men and guns from the fire of the shipping.

When I went to Sydney, in 1856, I had to discuss the question of the defence of the harbour of Port Jackson, and as the use of iron was then under discussion both for ships and batteries, I proposed to face the embrasure with a plate of 4-inch iron, six feet square, making the opening for the gun two feet square or thereabouts, by which I obtained a lateral deviation of 25° on each side of the axis of the embrasure, and a power of elevating the gun 5° and depressing it 3°; I could not, however, get the iron plate forged at Sydney. I am now having a model made of the gun and embrasure, and propose to give 15° deviation on each side of the axis, to bring the muzzle just flush with the iron facing of the embrasure, so that the whole will be sunk within an 18-feet parapet, the height of which will admit of a splinter-proof cover being placed over the gun, so that this will, practically, be in a casemate with an opening not more than 18 or 20 inches square. My idea is, that in a fortress liable to be attacked, a number of these plates sufficient for, say, 3 fronts, should be kept in store, and only placed on the front actually attacked and on those collateral with it.

With reference to Colonel Nelson's paper upon Vaulted Revetments, I have a sort of idea that I wrote to you some years ago on the subject, proposing that the amount of masonry now distributed in a heavy revetment with counterforts 18 feet apart, or thereabouts, should be distributed in a thin face wall 1′ 6″ or 1′ 10½″ thick, with counterforts, placed so close together as to retain the earth between them from falling into the ditch by the action of the friction against the counterforts; if these counterforts were placed 3 feet apart from centre to centre, and 14 inches thick, and were tied to the face wall at certain intervals by bands of hoop iron laid in cement, they might be carried back 19 or 20 feet, making a capital foundation for the parapet, presenting great difficulty to the formation of a breach, affording an opportunity for the construction of a gallery, if desirable, in the middle of this mixed revetment some 8 feet distant from the face wall. The principle of the revetment *en décharge* could be applied to this with great facility, as brick arches or flat stones, if such are procurable, could be placed at intervals from counterfort to counterfort. I should adopt this principle generally as being the most economical, but at points where a breach is likely to be made I should add to the length of the counterforts, and take more especial care to ram the earth between them. It seems to me that this would be a good substitute for Nelson's Vaulted Revetments, the chambers of which have more the air of casemates.

I have written this off in a great hury in order to save the mail, and cannot make a copy of it; I place it at your disposal to make such use as you like of it; it is as I said, only suggestive, and I should be glad to see it fully treated by an officer capable of doing it justice; excuse scrawl, want of stops, &c.; I am in a hurry.

Yours very truly,

W. DENISON.

PAPER II.

MEMORANDUM
FOR THE
INSPECTOR GENERAL OF FORTIFICATIONS,

Of the Results of Examination into the Comparative Qualities and Fitness for Building Purposes, of Samples of Stone from different Quarries in the Island of Portland;

By F. A. ABEL, F.R.S.,
Chemist of the War Department.

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

A collection of twenty-eight specimens, representing the stone obtained from different quarries and beds on the Island of Portland, has been submitted :—

(1.) To a careful comparative inspection;

(2.) To experiments, having for their object the attainment of comparative data, regarding

(a.) The chemical composition of the stones;
(b.) Their strength and power of resisting wear from mechanical causes;
(c.) Their porosity, or absorbent power, and consequent susceptibility to the destructive effects, mechanical and chemical, of atmospheric agents.

As regards chemical composition, the differences, indicated by the analysis of the specimens of stone from different quarries, are only of a trifling description, and not calculated to influence in any definite manner the comparative durability of the different varieties of stone.

The properties which it is considered should, apart from the questions of chemical composition and facility of working in the mason's hands, be combined in a building-stone, capable of resisting effectually the fullest exposure to atmospheric influences, are,

(1.) Compactness of structure or a low degree of porosity;
(2.) Strength and hardness (to the greatest extent compatible with the working of the stone).
(3.) Uniformity of structure.

The results of my experiments show, that all the superior descriptions of "*Whit-bed*" stone combine strength and compactness in a considerably higher degree than the varieties of "*Base-bed*" stone. Some kinds of the "*Whit-bed*" stone, however (*i.e.* those from the New Maggot and Inmosthay Quarries), though ranking with the best as regards strength, exhibit a greater degree of porosity. Again, other "*Whit-bed*" stones (from Old Maggot, Waycroft, and Independent Quarries) exhibit but little superiority, in point either of strength or compactness, over the generality of the "*Base-bed*" stones; and are, indeed, inferior to the best "*Base-bed*" variety.

The "*Base-bed*" stones are, undoubtedly, more generally uniform in structure than those of the "*Whit-bed;*" this being mainly due to the comparative freedom of the former from distinct petrifactions. Though such petrifactions were shown, by the results of experiments, to impart, in many instances, great additional strength to the stone, they frequently give rise, by their existence, to cavities, sometimes of considerable size, which not only serve to weaken those particular portions of the stone, but may also, if they exist in proximity to exposed surfaces of a block of stone, promote its partial disintegration by the action of frost.

Greater care is, therefore, unquestionably required in the selection of "*Whit-bed*" stone, than need be employed in the case of all the better varieties of "*Base-bed*" stone.

I append to this Memorandum, in a tabular form, a statement of the comparative strength and compactness of the different varieties of stone, as represented by the specimens experimented upon, together with a description of the peculiarities noted, on examination of the specimens, many of which have an important bearing upon the results obtained in the experiments instituted with the blocks.*

The results of my experiments lead me to the following conclusions, regarding the comparative merits of the various descriptions of Portland stone in question, for building purposes.

The *Roach* stone from "*War Department*" *Quarry* is an invaluable stone for *external* work, in localities where very considerable strength, and power of resisting mechanical wear, are required (*e. g.* in connection with those portions of work which may become exposed to the continual abrasive action of water).

The *rough* "*Whit-bed*" stone from *Admiralty Quarry* (as represented by specimens 1 and 2, see table), is also a highly valuable stone for external work, of a similar kind, where great strength is required, and particularly where the numerous irregularities in the above *Roach stone* may be objectionable.

* These experiments consisted, chiefly, of careful determinations:—

(1.) Of the comparative absorbent power exhibited, under precisely similar conditions, by cubes of the different stones, and

(2.) Of the weight sustained, up to the point of fracture (*i.e.* the crushing weights), by accurately cut cubes of the stones. Three cubes of each variety of stone were crushed, and the conclusions, as to the comparative strength of the stones, were drawn from the mean results thus arrived at. These crushing experiments were carried out with the well-known American mechanical testing machine.—F. A. A.

The following varieties are all well calculated for *external* work, and I consider that the order of their relative value is as follows :—

1 { Stone from *War Department Quarry*, *Vern Hill.*
"*Whit-bed*" stone, *Admiralty Quarry.*

2 { "*Whit-bed*" stone, *New Maggot Quarry.*
"*Base-bed*" stone, *Admiralty Quarry.*
(This may be considered quite equal in quality to Whit-bed stone.)
"*Whit-bed*" stone, *Inmosthay Quarry.*
(Particularly adapted from its texture and uniformity for ornamental work.)

3 { Whit-bed stone, *Old Maggot Quarry.*
(a.) Marked L I.
(b.) Marked I T and I E.

For *internal* work, the following rank highest, on account of their uniformity and comparative strength :—

"*Base-bed*" stone, *Old Maggot I T.*
"*Whit-bed*" stone, *Independent Quarry.*
"*Base-bed*" stone, *Waycroft Quarry.*
"*Base bed*" stone, *New Maggot Quarry.*

The following are inferior to those just named, in texture and uniformity :—

"*Whit-bed*" stone, *Waycroft Quarry.*
"*Base-bed*" stone, *Old Maggot Quarry I E.*
"*Base-bed*" stone, *Inmosthay Quarry.*

The "*Base-bed*" stone from *Old Maggot Quarry* marked L I, and that from *Independent Quarry*, are of low quality, as compared with the remainder; and no reliance can be placed on the durability of the *Roach stone* from *Independent Quarry*, judging from the specimen received.

I may observe that no definite conclusion can be drawn, from the comparative properties of the specimens of stone from one and the same locality (quarried at different periods of time), regarding the influence exerted by exposure, after quarrying, upon the quality of the stone.

In the instance of the examples of *rough* "*Whit-bed*" stones from *Admiralty Quarry*, the specimen quarried last autumn was decidedly the strongest (that quarried three years ago differed altogether in character from the other specimens). The specimens of "*Whit-bed*" stone from the *Admiralty Quarry* were very much alike in strength ; there being a slight difference in favour of that quarried three years ago. In the "*Base-bed*" specimens, from the same quarry, the strength was also found to increase somewhat with the age of the stone; but, of the specimens from the *War Department Quarry*, the one most recently quarried was considerably stronger than the others. Here again, however, the difference must be ascribed to a difference in structure ; the other two specimens, (quarried last autumn and three years ago) were in all respects alike.

On the whole, the evidence may be considered as a little in favour of the opinion, that an improvement in the strength of the stone is effected, to some extent, by seasoning.

F. A. ABEL.

Woolwich, October, 1861.

TABLE

Shewing the comparative orders of *strength* and *compactness* of samples of *Stone from different Quarries* in the *Island of Portland.*

Description of Stone.	Order of Compactness.	Order of Strength.	Peculiar Features of each Stone.
ROACH.			
War Department, Vern Hill Quarry.....	One. (The compactness of these is about as high again as those next in order.)	One.	Light coloured, very hard, and compact, one of the heaviest stones of the series; its weight being very much greater than that of the *Roach* from Independent Quarry. Its strength is not uniform, as it contains numerous shells and cavities.
ROUGH WHIT-BED.			
Admiralty Quarry.			
Quarried recently	Two.	Two.	Rough but compact; contains numerous small shells.
Ditto last autumn	Two.	One.	Containing only few cavities.
Ditto 3 years ago	Between six and seven.	Between four and five.	Very rough and irregular, containing large shells; differing, therefore, greatly from the other samples from Admiralty Quarry.
War Department Quarry, Vern Hill.			
(Bed not specified, evidently WHIT-BED)			
Quarried recently	Three.	One.	Hard and very compact; containing, however, some large cavities.
Ditto last autumn	Four.	Three.	A very hard light-coloured stone containing numerous pin-hole cavities.
Ditto 3 years ago................	Four.	Three.	Similar to No. 1 from this quarry, though somewhat less compact, apparently free from cavities.
WHIT-BED.			
Admiralty Quarry.			
Quarried recently	Four.	Three.	All these samples very similar. Light-coloured compact stones, containing a few small shells. Apparently free from cavities.
Ditto last autumn	Four.	Three.	
Ditto 3 years ago................	Four.	Two.	
Inmosthay Quarry	Six.	One.	Fine-grain, moderately compact, almost destitute of shells; one of the most uniform of the Whit-bed series.
New Maggot Quarry........	Five.	Two.	Light coloured, compact, and very uniform.

Table continued.

Description of Stone.	Order of Compactness.	Order of Strength.	Peculiar Features of each Stone.
BASE-BED.			
Admiralty Quarry			
Quarried recently	Four.	Three.	Nos. 1 and 3 are similar; light-coloured, compact, and very uniform. No. 2 is somewhat darker, and exhibits patches of closer texture. They exhibit more indications of shells than any other Base-bed stones; and are, in appearance and properties, very similar indeed to Whit-bed stone.
Ditto last autumn		Two.	
Ditto 3 years ago		Two.	
WHIT-BED.			
Old Maggot Quarry,			
marked I T	Between six and seven.	Four.	Nos. 1 and 3 are much rougher in texture than No. 2, which is a little superior to them in compactness, but is somewhat less uniform.
„ L I	Six.	Three.	
„ I E	Between six and seven.	Four.	
Waycroft Quarry	Seven.	Four.	Rough in texture and porous.
Independent Quarry	Between seven and eight.	Four.	Fine grained but porous.
BASE-BED.			
Old Maggot Quarry,			
marked I T	Seven.	Three.	I T is uniform, but I E exhibits faint bands of stratification. L I is about the lowest quality of Base-bed stone examined. It is very soft and porous.
„ I E	Seven.	Five.	
„ L I	Ten.	Six.	
Waycroft Quarry	Eight.	Four.	Light-coloured and uniform.
Inmosthay Quarry	Eight.	Four.	Exhibits considerable want of uniformity.
New Maggot Quarry	Nine.	Three.	Very uniform; similar to I T Old Maggot Quarry, though more porous.
Independent Quarry	Nine.	Six.	A rough very porous stone, exhibiting considerable difference of strength in different portions; to be ascribed to the fossil markings observed here and there.
ROACH.			
Independent Quarry	....	....	A very inferior description of stone. Full of large loose petrifactions and cavities of considerable size. The strength [illegible]

PAPER III.

FORTIFICATION IN IRON.

By CAPTAIN E. F. DU CANE, R.E.

Any important change in the weapons of war must induce a corresponding change in the material and design of defensive works. When the superior force of guns over the ancient weapons became fully evident, masonry ceased generally to give proper protection, but required itself to be protected or concealed, and the forms of works became materially changed. The increased range and perfect accuracy of modern artillery necessitate some better protection than earth can afford. The next development of the art of fortification will probably then ensue from the application of iron in military construction. If the change from earth to iron, as a material, is to be followed by as great changes in the designs of forts as followed the substitution of earth for masonry, our future works may be as unlike our present ones as the keep of Dover Castle is unlike the Citadel on the Western Heights.

It is not likely that the full extent of the changes necessary will be discovered or recognized immediately. It was not till a long while after the invention of cannon that the newer modes of construction of fortresses began to be adopted. Artillery received its great development as a siege weapon in the 15th century, but M. Viollet le Duc says, " forms and arrangements were preserved so late as the 16th century, nowise on a level with the new means of attack."

It is a fact worthy of being remembered that one of the most eventful passages in our history turns upon our having, at that time, fallen behind in the art of fortification, viz.:—our expulsion in the 15th century from the large possessions which we then held in France. Louis Napoleon, in tracing the progress of the power of artillery, says—"The towns defended by the English, and which at the time of the invasion they had taken months to besiege, were carried in as many weeks. They had spent 4 months in besieging Harfleur in 1440 ; 8 months in besieging Rouen in 1418 ; 10 months in taking Cherbourg in 1418 ; whilst in 1450, the conquest of the whole of Normandy, which it required 60 sieges to accomplish, was effected by Charles VII in 1 year and 6 days." This was due to our not having improved our defences to meet the increased power of the artillery. If ever it should happen that our modern fortifications were put to such a practical test, and they were found to be inferior to the weapons brought against them, it is not unlikely that the position of England might be lost beyond recovery ; and this consideration shows how important is the duty that devolves upon us in particular, to anticipate as far as possible the changes that may be rendered necessary in the designs of future works, and to endeavour to show in what way our existing defences may be brought up to a level with the improved weapons of attack; and the more freely ideas and discussion are invited on the subject, the better is our chance of arriving quickly at some practical result. It is not probable that the best manner in which to effect our object will be hit upon at once by any single mind. We must pour our ideas into a common stock and hope only that by our conjoint efforts the solution of this difficult problem may be found, as it ought to be, by the Corps of Engineers.

The first essential of a defensive work is to provide a screen, behind which the defenders can work their weapons in the greatest practicable security. It will be well to have some definite measure of the extent to which stone or earth effects this object. General Totten, of the United States Engineers, makes some calculations and experiments respecting the former. He found that, supposing a ship with a broadside of 50 guns to be engaged with a casemated battery in two tiers, mounting 48 guns, the guns being 8-inch, loaded with canister containing musket balls, and each firing 10 times in half an hour, each square foot of the surface of the battery would in that time receive 103 musket shots. A certain embrasure which had been measured had an exterior opening of 54 square feet; so, allowing only half the shot to hit the battery, there would be received within the exterior opening of each embrasure in half an hour 2,754 musket balls. Some of these, of course, would strike the cheeks, but with flaring cheeks it was found by experiment that 95 per cent. were deflected in; under those circumstances, in half an hour's firing 2,617 musket balls might be poured in among the 8 or 10 men serving the gun at each embrasure. These results are founded on the supposition of a battery, whether on land or sea, being able to establish itself within the range that will allow of grape and canister being fired; and, in the former case, at all events, this could always be done after a greater or less amount of work. But even this is not necessary with Armstrong's segment shells, which can be fired as great distances as shot; and with the result of delivering, in the case of a 20-pounder, upwards of 70 fragments in every discharge, precisely in the spot where they will produce the most effect.

With respect to earthen embrasures, a very short examination will show that the amount of real protection that they afford to the detachment working the gun, beyond that of screening them partially from view, is in reality very small indeed, and this part of the question is most important as respects land defences, because there are very few cases in which masonry embrasures now exist in works to oppose an attack by land.

The penetration of a smooth bore 30-pounder (French) into earth, at 1,000 yards, is about 6 feet. I do not know the penetration of a rifled gun, at the same distance, but the penetration into masonry of a rifled gun, at 1,000 yards, is three times that of a smooth bore of the same calibre; the penetration into earth is probably, at all events, somewhat greater than a smooth bore. Taking the plan and section of an earthen embrasure (Plate 1), giving a lateral range of 40° and a depression of 10°, it is easily seen that a man does not get the protection of even 10 feet of earth until he is 7 feet on either side away from the centre of the embrasure; and he must be 10 feet distant before he gets 15 feet of earth to cover him. Now, a gun detachment, all the time it is serving the gun, is within the former limits, and, therefore, is not in reality protected against siege guns very much more than it would be by a rope mantlet. An Armstrong 40-pounder, at 1,000 yards, can be depended upon to hit a target of 9 feet square nearly every time; and no shot would, therefore, miss a mark of 20 feet in width by 6 feet or so high, after having once got the range. Under such circumstances it is difficult to say how the artillery defence of a place would be carried on. It will be remembered, as an illustration of this point, that at the taking of the Taku Forts, in China, in 1860, the Tartar gunners were found killed at their guns by the Armstrong segment shells poured into the embrasures.

It is unnecessary to say any more to show that in future neither stone nor earth will answer our purpose, and that our only course will be to shelter our guns behind iron parapets to cover us against direct fire. But it may be added that the necessity of doing this in land defences, is even greater, if possible, though perhaps not more urgent than in sea defences, inasmuch as the fire from an attacking battery on land is more accurate than on board ship. Further than this, to protect us against rifle fire, which is now effective against such a mark as an embrasure would afford, at 600 yards at least, it is absolutely necessary that embrasures should be furnished with some form of mantlet closing the embrasure when not occupied by the gun.

The construction of iron parapets proposed is shown in Plates 1 and 2. They are fitted with shutters, constructed as will be explained further on. The mode of putting the iron together will be explained when speaking of the proposed iron forts.

It appears, then, that this is the main point in which existing works will require strengthening to meet the improvements in artillery; but it will be as well to mention certain particular portions of a work besides the general parapets where iron may be adopted with advantage.

We may take a detached fort of the description now being constructed in England, as an example. We are at present obliged to place our caponiers, or any casemates that flank the ditches, in such a position that an enemy on the exterior shall not be able to take up the prolongation of the ditch and destroy the caponiers (perhaps without even seeing them), by means of dropping fire; as has been repeatedly found to be possible. This restriction is often very inconvenient, and it gives rise to this disadvantage, that, as in general, in order to satisfy this condition, the flanking fire can come from only one end of the ditch, and besides this, it is rather low down, a good breach would hide a great part of the ditch altogether; so that by keeping on the reverse side of the breach, an assaulting party could get up, to a great extent, under cover. But if we can face these caponiers with, or construct them wholly of iron, we shall be able to place them at either or both ends of the ditch they flank.

In the case of a ditch running along the top of a steep slope, it is sometimes extremely difficult to place the flanking caponier satisfactorily, because the glacis falls away so rapidly that the end of the caponier is not covered in the ordinary way. If iron could be applied in such a position this difficulty would no longer exist.

There are cases in our old works where flanking casemates are exposed to destruction from ground, which, when the works were constructed, was probably thought too distant to be of any consequence. In such positions, and generally wherever artillery fire has to be provided against, iron should be applied to the front of a casemate.

In the keeps of our detached works iron will provide against many difficulties that have to be encountered. In the usual section given to the keeps, the lower tier of guns in casemates affords a fire over the whole interior of the work, the upper open battery commands the ramparts and ground outside. If the keep is looked at as an interior retrenchment, it seems not unlikely that by the time it becomes necessary to make use of it, the lower tier may be almost or entirely destroyed by shot dropped over the exterior parapet. A partial remedy for this would be to dispose the interior of the work in such way as to be seen from the top of the keep, by raising a glacis in front of the casemated tier, which would then only command a covered way running round the keep, the covered way facilitating the retreat into the keep; but by facing the casemates with iron they will be placed at once in perfect security. Iron will have to be made use of also for the parapets of the upper tier, for the same reasons as in the main work, and my impression is that the keep of a work, at all events the fighting part of it, should be entirely of iron.

Another good use of iron would be, to place small iron block-houses in the covered-way or in the chemin-des-rondes, large enough to contain five or six men, and with secure communications with the interior; these would be a great impediment to an attacking enemy.

The great mass of earthwork in a land fort, however, consists of the rampart, which in most cases must be raised to a certain height in order to get the command which enables the guns to sweep the ground around it. It will still be necessary to give this command, for without it the perfect accuracy and the long range of the gun, and the great security in which it is placed, will be utterly useless; and the cheapest and most effective means of providing it will be by earth, sometimes with casemates under it, as at present.

It will also probably still be necessary in many positions to form part of the parapets of earth, when the circumference of the space to be enclosed may be greater than is necessary to accommodate the number of guns to be mounted; the iron will in this case be used chiefly in those portions where batteries have to be made. In a work with earthen parapets each gun takes up a lineal space of about 40 feet, which is necessary in order that after the embrasures are cut there may be a merlon of about 10 feet thick at least. With iron parapets no more interval is required between the embrasures than is sufficient for the working of the gun. On board ship the space allowed hitherto has not been more than 12 or 14 feet, probably it may be increased to 16 feet; if we give them a space of 18 feet the perimeter of a work with iron parapets to accommodate a given number of guns would be less than one-half that of a work of similar strength with earthen parapets, and, therefore, the enclosed space considerably less, which might in many cases be a great inconvenience. In broken country, too, where the ground on which the works are situated is composed of hills with steep sides and comparatively flat tops, it is impossible to command the surrounding ground from a work of small circumference; the positions of the guns must be extended to those places where the form of the ground allows of its being seen, or else the whole power and effect of the work is entirely lost. With the same extent of parapet as with earthen embrasures, either the armament of a work may be greatly increased, or else instead of distributing the guns pretty equally throughout as at present in a detached fort, the guns may be distributed in groups of two or three, separated by an interval of earthen parapet, which may be provided with banquettes, and arranged for musketry fire. In these intervals will be placed traverses, bombproofs, expense magazines, fuze-fixing rooms, &c. There may appear one disadvantage in placing the guns in groups on a rampart instead of distributing them pretty equally, viz., that the fire of adjoining groups may not cross immediately in front of the work, so that some space close to the work will be deprived of artillery fire, but the extent of this space will be much less than with earthen embrasures, as the lateral range of guns firing through iron embrasures will be so much greater.

In cases where the above reasons do not compel the work to be spread out, and where the guns have to be protected from vertical fire, as in some sea defences, or in keeps or retrenchments, the best course, as it seems to me, will be to form the work wholly of iron, and not by combining iron and masonry.

There is great disadvantage in using iron for the embrasures of casemates of the ordinary description, composed of masonry piers and arches (Plate 2, Fig. 1). If only the front of the casemate is of iron, which is backed up by the masonry of the pier, the junction between the two materials is always a weak point; the corners of the masonry are liable to be easily knocked off, and the adjoining portions which form the backing to the iron plating get very much shaken, so as to deprive the latter of its support. The pier also has to be cut away so much to allow the working of the gun that the thickness on which the iron facing depends is not very great. In fact, that part of the work on which the whole efficiency of its protection depends, is the most vulnerable. If the piers are much damaged the iron facing may be driven in, although itself perhaps unhurt; and, of course, if the damage is carried very much further, the arches might come down and the whole structure be ruined.

It may be said that the piers are no weaker than in a sea battery or keep composed entirely of masonry; but in these cases the piers, which are, as has been said, the most important parts, are also the strongest. The strength of the work is measured by that of its weakest part, so that you have still only a masonry work a little stronger than before, not an iron one.

It would, of course, be possible to protect the masonry pier itself with iron; but this does not get over the difficulty that the iron facing is supported by a masonry pier, which gets more damaged by the shots that strike the screen than the screen itself; moreover, one feels reluctant to go to the immense expense of protecting great blocks of stone by so costly a material; and the suggestion forces itself on one, why should the fort be encumbered with this great helpless mass of masonry, a source of weakness and very much in the way? Can we not get rid of it altogether, and so render the whole space protected by the iron available for working the guns, &c., instead of filling up nearly one-fifth of the length by these massive piers? The difficulty that meets us here, is, how to carry the arches that protect the fort from vertical fire; and that suggests getting rid of the arches too, and forming the protection both against vertical and horizontal fire by iron alone.

It is proposed, therefore, to substitute for the masonry backing, iron pillars (Plate 2), about 4 feet in the clear apart, formed on the principle adopted in tubular girders, composed of iron plates, from 1 inch to $1\frac{1}{2}$ inch thick each, and 18 inches deep, connected by means of angle iron in the usual manner; against these will be placed the iron facing which will be connected to the tubular pillars by iron ties as shown: not by bolts. This iron wall is carried up 15 feet vertically, two tiers of guns being placed behind this portion; above that height it is carried at a slope of 45° on a framing of exactly similar description, and in this way the cover against vertical fire is obtained without any of the encumbrance of masonry piers in the battery. This mode of obtaining the cover from vertical fire has also the great advantage that it forms also a screen against horizontal fire, and a position from behind which both vertical and horizontal fire can be delivered.

At the back of the battery is a series of casemates of the ordinary construction, provided for the purpose of giving bombproof accommodation to the garrison, stores, and magazines. The floors or platforms, on which the guns work, are formed by brick or concrete arches turned between iron girders, the girders being at one end supported by the tubular pillars, with which they are connected by angle iron, and at the other by the walls of the casemates in rear, so that they act as ties to the front wall and roof of iron. The upper end of the frame of the roof rests against the solid mass of masonry or concrete on the top of the arch, an intermediate backing of wood being interposed to break the force of concussion. The top of the masonry casemates forms the terreplein of an open battery, the parapet of which is made of iron, and constructed similarly to the other part. In order to give a certain command to the lower tier of guns the fort is raised on masonry or concrete walls, the space thus gained under the battery is available for casemated stores, magazines, barracks, &c. These casemates are protected in front by a solid mass of earth.

The detached fort here shown (Plate 2) is assumed to be in a position where it could not be attacked by artillery in the rear, so that there is no object in making that part of iron. It could not be taken either by breaching or by escalade. It would be impossible for an enemy to get up the vertical part and then up the long steep slope; and even if they did, the defenders inside the fort would still remain equally secure. They could not creep in at the embrasures, of course, while the men were at the guns, and at other times these openings would be shut by the shutters. Moreover, if it were possible by some great chance or surprise to penetrate in this way within the iron screen, the whole of the battery is commanded from the casemates in rear, so that no result could arrive from their doing so. The only one of the modes of attack now in use that could be employed against such an iron fort, is that of mining. To provide against this it is proposed to dig a ditch 12 or 15 feet deep round the fort, and form a gallery round the counterscarp, from which countermines could be run out. As the fort would never be deprived of the command above ground, an enemy's miner would have to begin at a considerable distance, and this alone would, in some places render such an attack impossible at once; in other places their resistance would be so much prolonged, beyond even what is possible with countermines at present, that it would practically amount to the same thing.

With respect to the cost of a fort of this kind, I believe that it would not be more than that of one of the ordinary kind having the same armament, the same accommodation, and the highest degree of strength of which such a fort is capable. As compared with a fort wholly or mainly of masonry, that is in which the iron is applied only to the embrasures, the iron fort being very considerably less in area, requires proportionally smaller foundations, an immense advantage in respect of economy in some situations. The interior of the work is far more open and free than when each gun is separated off by thick walls of masonry, and this gives great advantage in facilitating communication, superintendence, &c., and may permit the space allotted to each gun to be diminished.

With respect to the connection of the facing with the supports in rear, almost all the experiments that have been made tend to show that bolting is a very great source of weakness and danger. The bolt-holes weaken the plates; the bolts break and fly about the casemates; if the heads of the bolts are wedge-shaped they split the plates under the great strain put upon them, and no perfect mode seems yet to have been contrived of providing against the strain on the bolts, caused by the deflection and reaction of the plates when struck by shot.

It seems very desirable that some measurement should be made of the deflection of plates under the shock of a shot. It would then be known what amount of play should be allowed in the fastening of the bolts. When once a correct idea on this subject is arrived at, it may probably be provided for as well as, and perhaps by somewhat similar means to those by which, the immense shocks the carriages and engines have to withstand in railway travelling are met, namely, by a powerful combination of springs and buffers. The bolts instead of being screwed up might be keyed, the keys being made as springs to allow some play. A thick layer of vulcanized india rubber might be interposed as a washer. This material is used for a similar purpose in the beds of mortars for sea service, in which 20 discs of india rubber, 3 inches thick, are placed under the bed to absorb the concussion.

It must, however, be remembered that most of the experiments that have taken place have been against $4\frac{1}{2}$-inch plates, such as are suitable for iron ships; but as the thickness of iron for forts must be much greater than this, the deflection, and the difficulty it causes in respect of fastening, must be much less.

There will, however, be great advantages in respect of strength and economy if the bolts can be diminished in number or done away with altogether. It also seems very desirable to contrive some plan by which the plates forming the facing shall be bonded together and support each other, and not be brought into action each by itself, with only the support it derives from the back.

These advantages will, it is thought, be gained by the principle of construction shown in Plate 1, where each plate of iron is shaped something like an ordinary girder, that is with two flanges connected by a web. The thickness of each of the flanges and depth of web is 4 inches, giving a total thickness to the facing of 16 inches, the length of the exterior flanges is about 14 inches, of the interior 10 or 11 inches, and of the web 3 inches. The form of these plates is the most advantageous in which iron can be disposed for bearing weight, and perhaps, therefore, for resisting impact. If a shot struck the joint of the outer plate it would be met by the full depth of 12 inches solid of the inner plate, and it would be quite impossible for a shot to get through by lifting a plate off the one below it, as it did on the Thorneycroft shield. It has been said of rolled plates that a certain disadvantage arises from the imperfection of the welding when the edges are presented to the blow of the shot; with this plan the face of the iron can, if necessary, be put outside instead of the edge; or if that opinion should be erroneous the plates can be formed so as to present the edge outside. I have ascertained from one of the largest iron manufacturers that these bars can be made without difficulty, and at a cost of £15 a ton. Ribs are placed behind these plates, so as to give a broad base to prevent the screen being knocked right over; and in order to connect the whole together vertically a thick plate is placed outside opposite each rib, bent through the wall, above and below, and fastened on to or around the rib in rear. These tying pieces can be made any thickness that may be necessary to secure them against damage, and they can be placed edge to front, so as to be as little damaged as possible by being struck. It will take a great deal of the greatest possible damage to render any of them perfectly useless. The number of them is too great to make the destruction of a few of them of any importance, and the construction of the facing is such that even if they were all damaged the strength of the shield would only be impaired to a very small extent. In the fort there are two sets of ties to each rib, which break joint, as it were, with each other; they are bent round the ribs and require no bolts. It will be easily seen that these plates can be put together to make up any thickness of facing that experiment may show to be necessary. There may be some advantage in placing sheets of lead between the different vertical layers of the facing, to break the concussion, and to make up for any irregularity of dimensions in the manufacture of the plates.

In the fort (Plate 2) the thickness of the vertical portion is 16 inches, that of the inclined part 12 inches; which gives an equal thickness of 16 inches in a vertical or a horizontal direction. As the velocity of a shell falling is never so great as the initial velocity of a shot fired horizontally with a full charge, the thickness that suffices against the latter is ample against the former.

There is another class of positions in which a great advantage will be gained by the use of iron for parapets, and in which a combination of iron and masonry may, with advantage, be employed. It frequently happens that it is desirable to occupy some ground by a small defensible work that shall mount three or four guns sweeping the ground in every direction, and contain also a certain amount of bomb-proof cover. For instance, where the object is merely to have a small defensible post on a certain spot to prevent an enemy from getting possession of it, or to have a post connecting two main works in a chain of forts. In many such cases, especially on the continent, well flanked towers, with parapets of masonry just sweeping the ground around them, have been placed in such positions, and as respects size, economy, and convenience of arrangement these answered the purpose very well. But for a land work a masonry parapet ought never to be used, and if earth is substituted the exterior diameter of the work must be at least doubled; perhaps, instead of being 50 or 60 feet exterior diameter it becomes 120 feet, a length which is too great to allow of the casemates being properly lighted and ventilated, and moderately convenient. The only alternative, then, seems to be to make the work still larger, so as to have some open space in the centre, and then it tends to become a work of a higher class and more expensive than the position requires. All these inconveniences are done away with by the small width taken up by an iron parapet.

Plate 3 shows how such a work might be built. The plan is almost that of four caponiers joined together, mutually flanking one another. The upper story has four additional sides, got by arching across the re-entering angles. The iron parapet follows the plan of the upper story; all the masonry is well sunk below the ground, and the iron battery at top is so formed as to give cover from vertical as well as from horizontal fire. The magazine is at bottom, and communicates with all the floors by a well, round which the stairs wind.

Supposing an effective screen or parapet to be provided for a fort or battery, there still remains something else to be done to make the detachment serving the guns properly secure, and that is to provide the smallest possible embrasure that will give the gun as much play laterally and vertically as is required, and a mantlet or shutter of some kind to close the embrasure when not occupied by the gun.

With respect to the width of the embrasure the smallest space will be obtained by supposing the gun to be trained right and left on a point about a foot behind the muzzle as a centre, and supposing the muzzle to project about 1 foot out of the embrazure when the gun is standing perpendicular to the parapet. This will insure the discharge being always made outside the opening and not against the cheeks. The width of the embrasure, then, is hardly more than the space actually occupied by the gun. But with respect to the height the case is different, because as the gun is elevated or depressed on the trunnions as an axis, the muzzle requires a considerably larger space to work in a vertical direction than it occupies in any one position. The dimensions, therefore, that are necessary for a heavy gun, say a 100-pounder Armstrong, to work in, having a lateral range of 60°, elevation of 10°, and a depression of 10°, are 2 feet wide by 3 feet 3 inches high, although for any one discharge no greater space than 2 feet by 2 feet is required. At 500 or 600 yards an Enfield rifle would make sure of such a mark every time.

The first thing that suggests itself is to try and make the space for elevation and depression, as close as that for lateral range, which might be done, if we could get a practicable plan for elevating and depressing on the muzzle as a centre. Methods of doing this have been suggested both in this country and on the continent; and if any should succeed, since a breech-loading gun mounted on a sliding carriage would not leave the embrasure unoccupied for more than a moment or so, there might be no great necessity for a shutter, for the gun itself would close nearly the whole opening; but at present it is necessary to provide some means of protecting the opening when not occupied by the gun. A shutter that opens, as most do, like a casement window, falling back against the cheeks of the embrasure, opens out the whole height of the embrasure every discharge, whether the gun may be firing with 10° elevation or 10° depression; it uncovers, in fact, almost twice as much space as is necessary for the gun to fire; it cannot, therefore, fulfil all the purposes of a shutter, which demand that there shall be no opening but what is filled by the gun. The only way to effect this object is to hang the shutters from the top and bottom of the embrasure in such a way that that part of the height, which is not required for the particular elevation the gun may be firing at, may remain closed even when the gun is run out.

It is proposed to attain this result in the following way. The iron plate, of which the shutter is composed, is divided horizontally into two parts of equal weight, and together a little larger than the embrasure opening, connected by a rope passing over a block fixed above the embrasure and working up and down in slides, which may be either of wood or of iron, at the sides of the embrasure (Plate 1). As the two parts of the shutter balance one another, the smallest possible pressure is sufficient to open or shut them, and in whatever position they may be placed they will remain. Supposing it is thought that it will be necessary to fire the gun both at low and high elevations, the shutters will be so hung that the shutters meet in the middle, and just as much will be opened as will admit the muzzle of the gun. But most probably, when an enemy is so near that the mantlet is necessary at all, the firing will be principally at low elevations, or point blank, or depressions, so that it ought to allow of the upper part of the embrasure being kept permanently closed. To do this it is only necessary to hang the lower shutter on the lower loop, and then when the shutters are opened to allow the gun to fire point blank or to have a depression, the upper portion of the embrasure will still be closed. It would be very easy, if it was thought worth while, to connect the shutters with the gun, so that they would be closed by the action of the recoil. A shutter of this kind has other great advantages over those working on hinges, that all its fixings are out of the way of damage, which it is impossible to effect in the latter description; and besides, if thought proper, it can be kept out of the way altogether, which may be very desirable under artillery fire, because if a shot strikes the shutter the fragments it carries in with it may do as much damage as the shot itself. I do not know why shutters like this should not be made of thick metal, strong enough to resist shot: those shown in the Plate are 4 inches thick.

In these few remarks I have endeavoured to show that we must be prepared to see radical changes in the designs of our land defences follow from the perfection to which artillery is now brought, that this necessitates the use of wrought iron as a principal material, not as an accessory; and I have endeavoured to show both how the iron may be put together and what form a fort of that material may take. It is to the solution of this problem that our attention ought now be bent. I shall be glad if I have contributed anything towards the desired result.

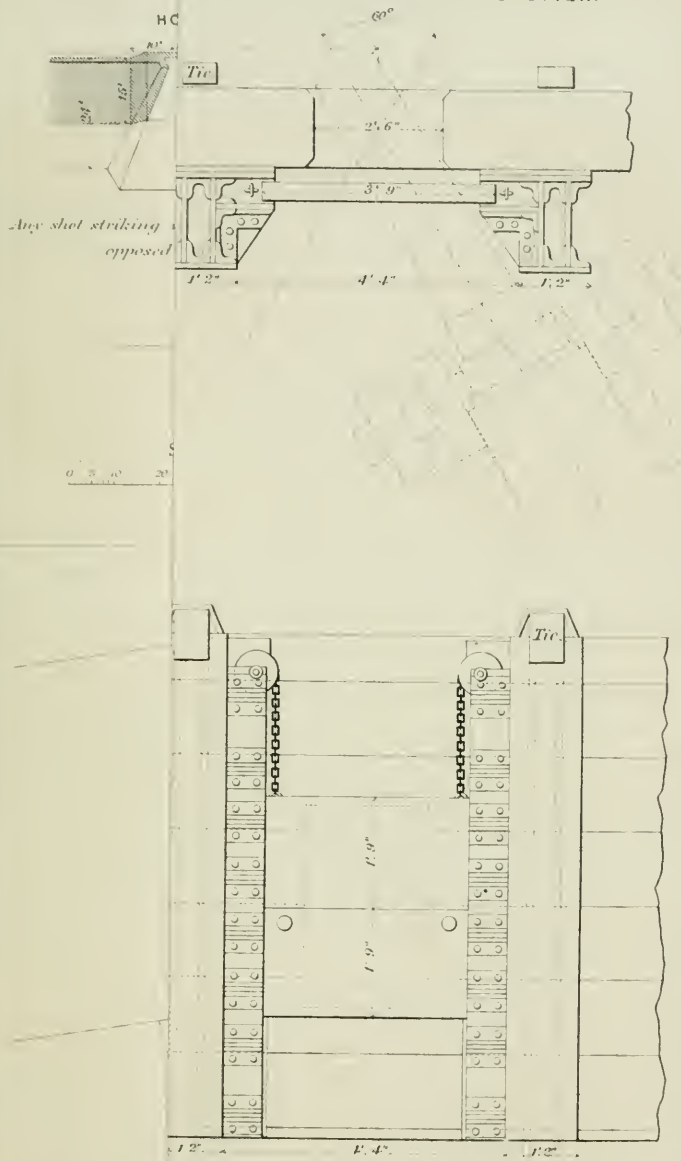
E. F. DU CANE,
Capt., R.E.

Pl: I.

PLAN OF EARTHE

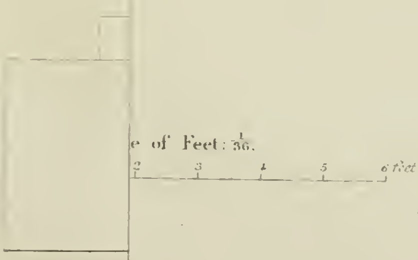
SHOWING THE POTTED WITH SELF_BALANCED SHUTTER.

HO



OR ELEVATION.

e of Feet: 1/36.

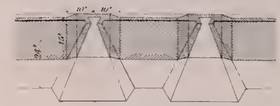


Ke.. Br.. Lith..

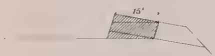
Pl: I.

FORTIFICATION IN IRON.

PLAN OF EARTHEN PARAPET WITH EMBRASURES SHOWING THE PORTION NOT PROTECTED AGAINST HORIZONTAL FIRE.



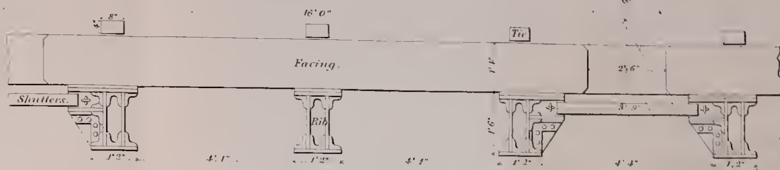
Any shot striking within the shaded portion would be opposed by less than 15 ft. of earth.



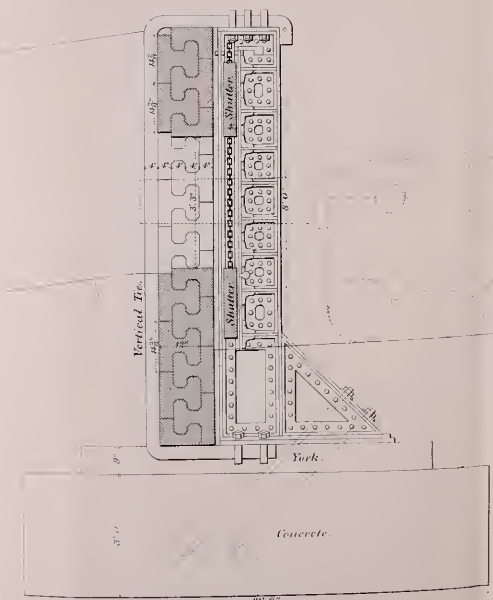
SECTION.

Scale of Feet : $\frac{1}{500}$.

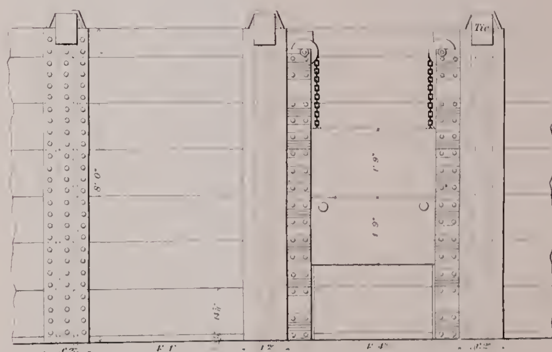
PLAN, SECTION AND INTERIOR ELEVATION OF AN IRON PARAPET FITTED WITH SELF-BALANCED SHUTTER.



PLAN.



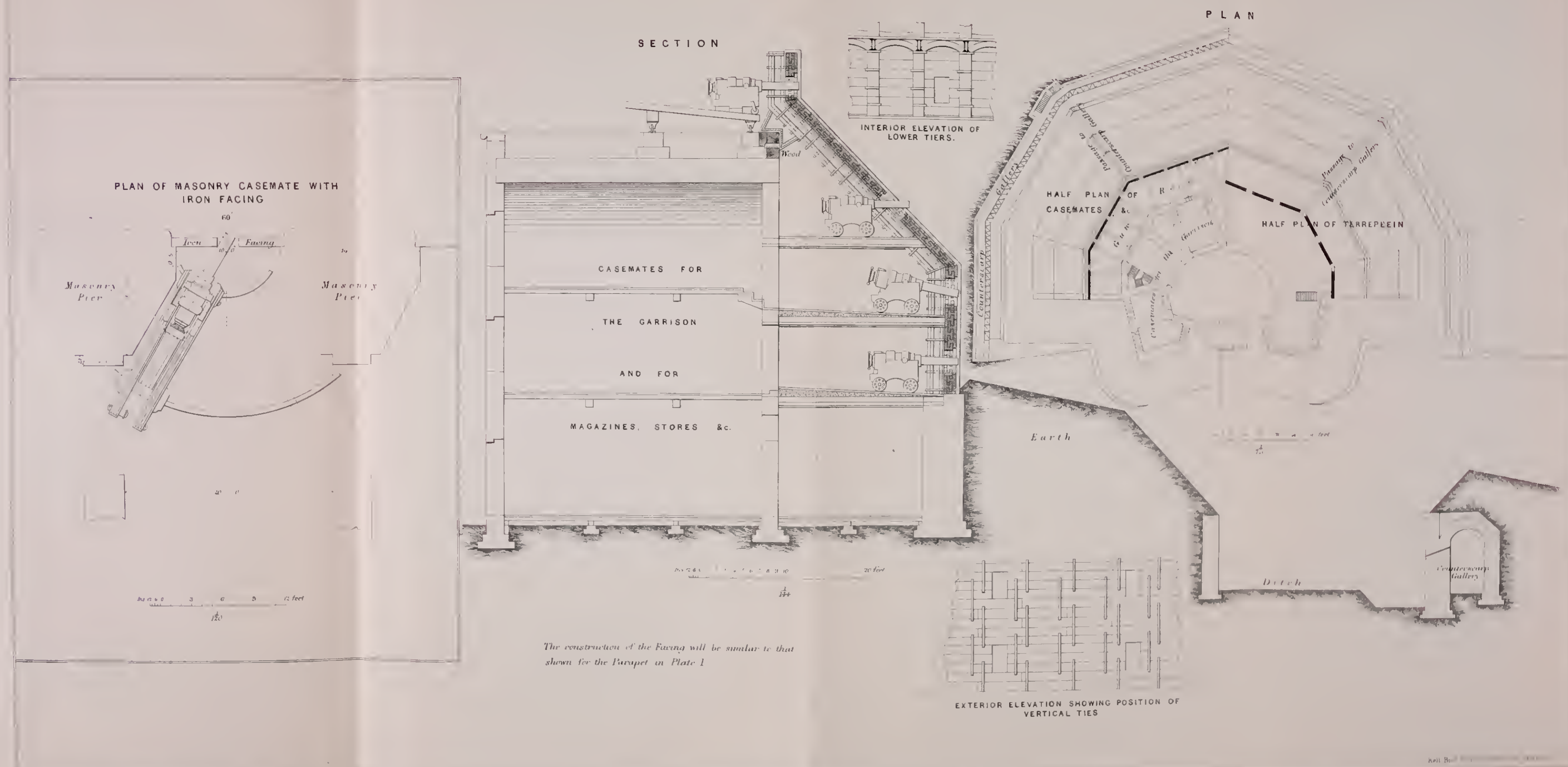
SECTION.



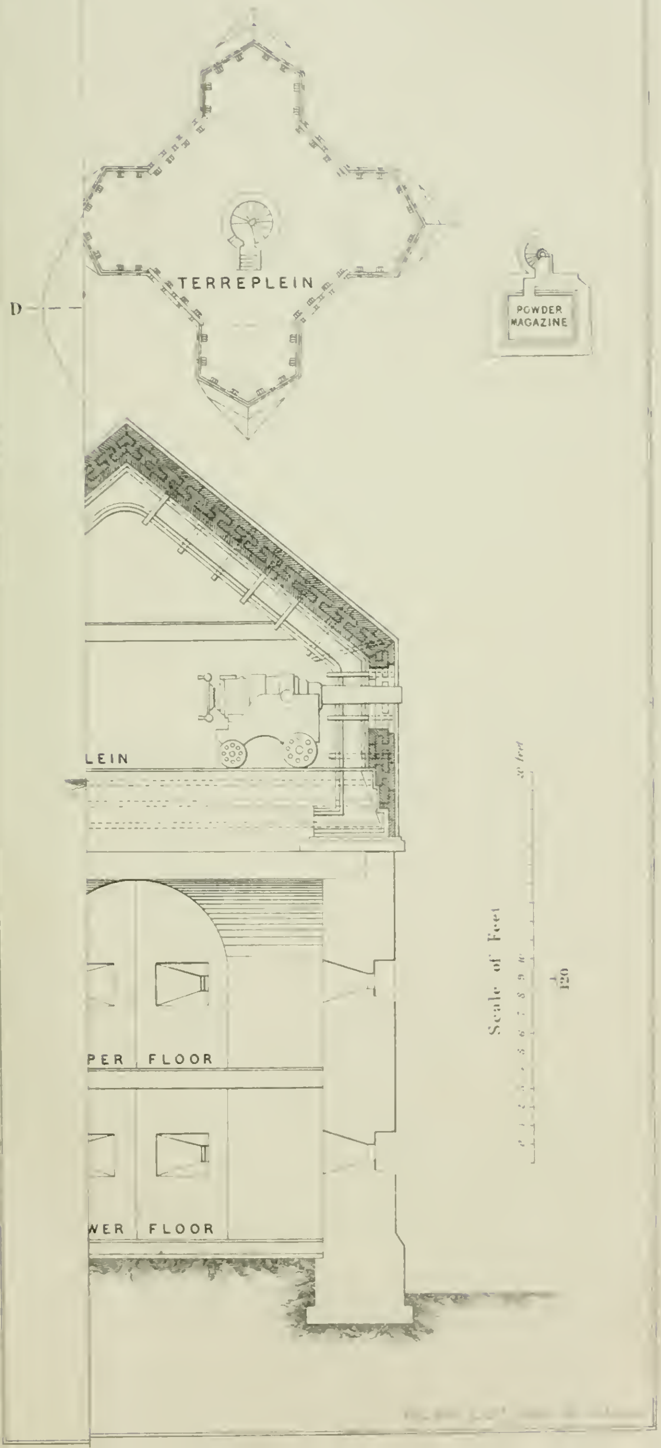
INTERIOR ELEVATION.

Scale of Feet $\frac{1}{36}$

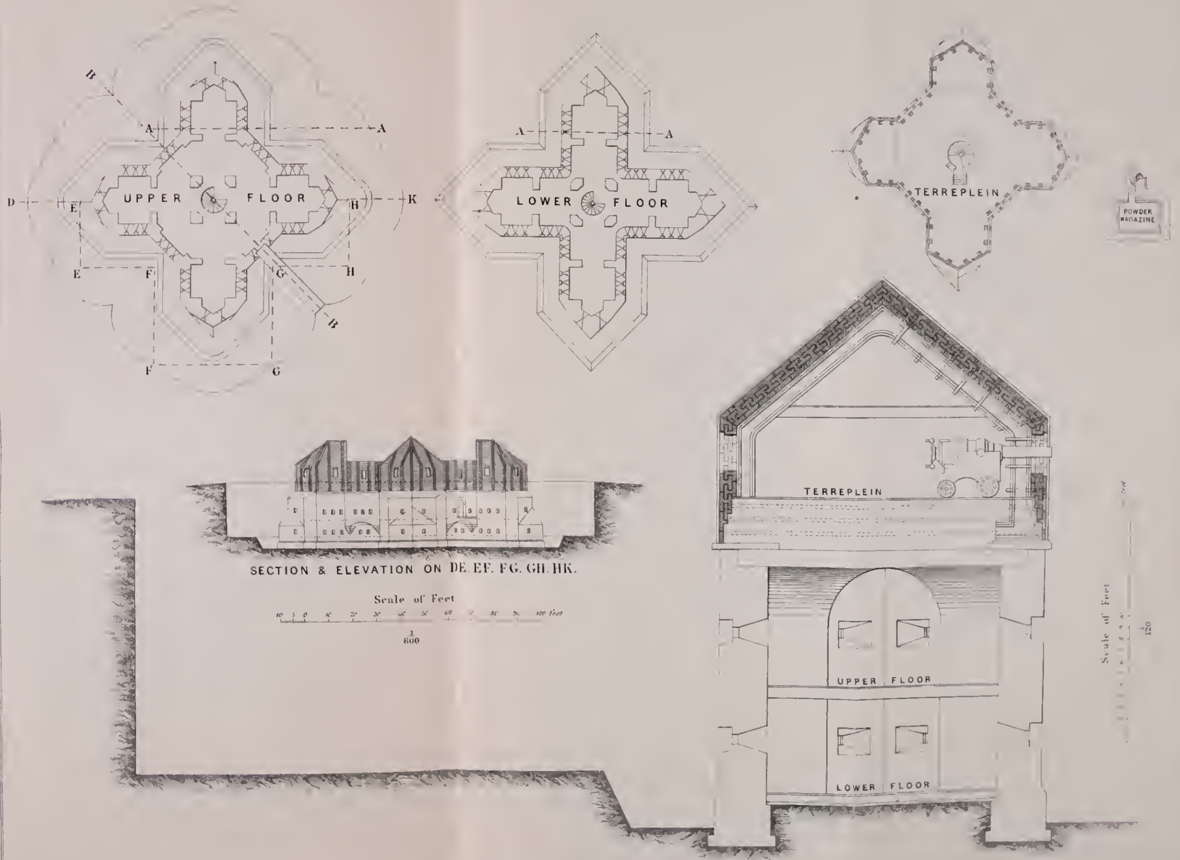
PLAN & SECTION OF THE PROPOSED IRON FORT.



Pl. III.


TERREPLEIN
D
POWDER MAGAZINE
LEIN
PER FLOOR
WER FLOOR
Scale of Feet
1/120
20 feet

SUNKEN TOWER WITH IRON PARAPETS.



SECTION & ELEVATION ON DE. EF. FG. GH. HK.

SECTION ON A. A.

In reply to various comments which were made during a discussion which ensued after the reading of this paper*, Captain Du Cane said he thought that after all the experiments that had been tried on iron shields we might fairly consider that we knew, at all events some of the principal points that were essential to success in constructing them, and some elements of failure which it was desirable, if possible, to avoid. That amongst the latter, the most prominent was the system of bolting the plates to one another, or to the backing, which in every plan that had hitherto been tried had been a very great source of weakness. That he had therefore endeavoured to contrive a plan for forming the facing that would not require the use of a single bolt, and he believed that the plan he proposed had, in addition, the great advantage that the whole mass of the facing was all firmly bonded together, so that the force of the blow was not met solely by the plate struck, but was distributed over the whole shield, and that it was to a very small extent dependent on the ribs for its resistance.

That with respect to the effects of vibration on the fort, he did not think there would be any caused by firing guns from it that the ordinary modes of iron construction would not meet. That an iron steamer at sea, for instance, had to bear much heavier shocks and vibration than the firing of guns would produce. With respect to firing at it, it was of course not possible, without further experiments, to speak with certainty; but targets had been constructed, and fired at, which had not suffered from this cause. That he believed that the greater portion of the effects of a blow would be absorbed by the facing and very little transmitted to the back; but that if any difficulty was found on this ground, it would be very easy to counteract the effect by placing some material, such as lead or vulcanised india-rubber, between the facing and the ribs, to deaden the concussion. That for this reason the upper ends of the sloping ribs had been bedded on wood, which had been found to have great advantage as a backing in the Warrior target. That the floors might also be made of wood, if the brick arches were found objectionable, which, however, he did not anticipate.

That with regard to the necessity for using iron, it could not, he thought, be said that the fact of our having very heavy guns to overpower an enemy's batteries would enable us to dispense with it, because a gun, however heavy, might be silenced by rifles or field pieces unless it was itself well protected.

That cupolas might be a very good form to use the iron in, in some situations, but for general use (speaking of fortification), he thought they had fundamental disadvantages; as it is contrary to the principles which, above all, ought to govern warlike constructions, that you should not be able to manœuvre your weapon without moving a ponderous mass weighing from ten to twenty times the weight of the weapon itself. That the great disadvantages of this must be obvious, and that he did not think there was any advantage that might not *in general* be secured as well with stationary parapets.

* This paper was originally read at one of the Friday Evening Meetings of the Royal Engineer Officers at Chatham.—Ed.

PAPER IV.

ON THE APPLICATION OF RIFLED CANNON
TO THE
OPERATION OF BREACHING UNSEEN DEFENCES BY HIGH ANGLE FIRING.

By COLONEL LEFROY, R.A., F.R.S.

[Extracted, by permission, from the Proceedings of the Royal Artillery Institution.]

1. The present notes have reference to a question which arose on one of the preceding papers, when it was read a few weeks since at this Institution, and which was expressed in the following terms:—"What is the greatest amount of curve that can be given to the Armstrong projectile, still preserving its power of penetration, and limited to what range?" The question had reference to the practibility of breaching masonry concealed by earthwork in front of it: as for example in firing over the crest of a glacis against an escarp unseen; and it is evident that in replying to it we must take the case of some particular projectile, and assume some definite resistance. For reasons which will presently appear, the 12-pr. and 20-pr. guns may be at once given up, as too light for the task. I shall assume therefore that the battering gun is not less in calibre than a 40-pr., and the escarp built of good brickwork.

2. In this form the question is,—What are the smallest 40-pr. charges which will secure a serviceable degree of penetrating power at given distances?

To have a considerable descending angle we must have high angles of elevation. To combine high angles of elevation with a limited range we must use a small charge; the smaller the charge that will do the work, the lower in vertical descent may we go, and the greater the choice of position for the battery. The famous experiments made in this garrison by order of the Duke of Wellington, in 1822 and 1824, furnish the first and most obvious standard of comparison.

The experimental practice of 1822, it will be remembered, was at a screen, and chiefly intended to furnish data for an actual operation of breaching. I extract an account of it from a manuscript in my possession in the handwriting of the late Sir Alexander Dickson, a name never to be mentioned by the artilleryman without honour. It seems to be the draught of a report, but whether of a report actually rendered does not appear. Referring the reader to the Appendix (p. 29,) for this document, it will be sufficient to say that it concludes by stating that the 10-in. howitzer, 8-in. howitzer, and 68-pr. carronade, had proved themselves the most efficient pieces for this description of fire, and by recommending further experiments with them against an actual Carnot's wall. The angle of elevation was to be 15°, and the charges adjusted accordingly; however, as we shall see presently, it was not actually so great. The wall was erected in the summer of 1823. It was 21 ft. high, 7 ft. thick at the bottom, and 6 ft. thick at the top, with a frontage of 30 ft., strengthened at either end by a counterfort 4 ft. square; there was one loop-hole about the centre. It was covered by a counterguard of earth of the same height, the crest of which was 60 ft. distant, as shewn by the annexed section.*

3. In the instructions to the officer commanding the battery, the object of the experiment was stated to be "to determine whether the detached wall, which is covered by a counterguard, and not visible from the batteries, can be breached so as to render an assault practicable." The instructions go on to say, (2) "The ordnance used are 10-in. and 8-in. iron howitzers, firing live shells filled with powder, and 68-pr. carronades firing solid shot. (3) The howitzers and some of the carronades are on garrison carriages placed on raised traversing platforms, solely with the view of raising these pieces to the correct level; the rest of the carronades are merely on garrison carriages placed on common platforms, the difference of level being disregarded. (4) The ordnance are all proposed to be fired at an elevation of 15° above the crest of the counterguard, and the charges, which will not be changed, are regulated accordingly, as the shot and shells are wished just to graze the crest; the elevation will be varied in any trifling degree to accommodate itself to this intention, but when the exact elevation for each battery shall have been determined by careful observation of the first few rounds, this elevation will be steadily adhered to during the whole firing.... (8) The batteries will as much as possible be fired in salvos, this mode of firing being evidently the most favourable for breaching the wall. (9) The fuzes for the shells are intended to be so cut as to ensure that the shells strike the wall before they explode...."

4. The report of the practice has been printed by Sir Howard Douglas in his "Observations on Modern Systems of Fortification" (1859), but as that work may not be at hand, I reproduce it in the Appendix.* The ranges, elevations, and charges, were as follows:—

Three 10-in. iron howitzers at 600 yards; charge 1 lb. 3 oz., elevation $12\frac{1}{4}$°, reduced on the third day of practice to 1 lb. 2 oz., elevation $13\frac{3}{4}$°.

Three 8-in. howitzers at 400 yards; charge 11 oz., elevation $13\frac{1}{2}$°.

Eight 68-pr. carronades, firing shot, at 400 yards; charge 1 lb. the first two days, reduced to 14 oz. the third day; elevation 13° to 14°.

The 10-in. and 8-in. shells were at first fired with their full bursting charges of 5 lbs. and $2\frac{1}{2}$ lbs. respectively; but in consequence of some danger apprehended from the splinters, these were reduced to 2 lbs. 14 oz., or 3 lbs. for the 10-in.; 1 lb. 14 oz. or 2 lbs. for the 8-in. howitzer. The general result was that out of 3436 rounds fired, 202 shells and 289 shot took effect on the wall, being about *one-seventh* (0·146) of the whole; out of the remaining 2945 rounds, 1000 took effect on the counterguard, and 608 on the rampart behind the wall; the

* This Section and the Report of the Practice (Appendix No. 2) are omitted, as they are contained in Vol. II, Corps Papers, Quarto Series, and in the Aide-Mémoire, at the end of the article on Permanent Fortification.—Ed.

breaching effect is entirely due to the 491 rounds which struck the wall itself. Many shots were noted to pass a little to the right or left which would have struck a defence of less limited frontage, and have contributed to the result.

One hundred rounds per piece, 1400 in all, made a practicable breach 14 ft. wide; 50 more rounds per piece, 2100 in all, made the breach complete in every respect. The rubbish was then cleared away both before and behind, when 85 rounds per howitzer, and 100 per carronade (1910 rounds) completed the demolition of the part which remained.

5. Such then having been the effect produced by shot weighing 66·2 lbs., and shells weighing respectively 90 lbs. and 48·5 lbs., fired with low velocities, let us proceed to compare their effective powers with those of our existing rifled cannon projectiles. It is necessary for this purpose to ascertain their initial velocities, which has been done by Lieutenant W. H. Noble, R.A., with Navez' electro-ballistic apparatus, as follows:—

TABLE I.

Nature.	Length of bore and chamber.	Calibre.	Shot or shell.	Charge.	Initial velocity V.
	in.	in.	lbs.	lbs. oz.	ft.
68-pr. carronade	61·7	8·05	66·2	1 0	323
10-in. howitzer	57·2	10·00	90·0	1 3	306
8-in. howitzer	45·7	8·00	48·5	0 11	288

The next table contains the value of $\frac{Wv^2}{2g}$ for each of the above projectiles, and the velocity which will give the same value for the 40-pr., 70-pr., 7-in. howitzer or 110-pr. gun, and 7-in. mortar shells. Here v is the remaining velocity on impact.

TABLE II.

Nature.	Smooth bores.			Equivalent velocity for rifled common shells.			
	W	v	$\frac{Wv^2}{2g}$*	40-pr.	70-pr.	7-in. mortar.	7-in. howitzer or 110-pr. gun.
	lbs.	ft.	tons.	ft.	ft.	ft.	ft.
68-pr. carronade..	66·2	284	36·9	362	278	246	226
10-in. howitzer ..	90·0	253	40·0	377	289	256	236
8-in. howitzer ..	48·5	245	20·3	269	190	182	168

* The unit of weight taken is the ton instead of the pound, to give these relative quantities in terms more easily compared. In the common notation of foot-pounds, we should have for the 68-pr. carronade $\frac{Wv^2}{2g} = 667428$.

6. We see at once that very moderate velocities will give 40-pr. common shells, and still lower velocities give 70-pr. or 110-pr. common shells, breaching powers which measured by equality of Wv^2 shall be on a par with those employed in the experiments of 1824; their relative powers are not in fact expressed by this simple comparison, but the corrections, as we shall see below, are all in favour of the rifled projectiles; it remains to enquire what are the charges which will give these velocities, and to ascertain whether such charges are compatible with high angles of elevation, and high angles of descent, at moderate distances.

The following table contains a number of observations which have been made of the initial velocity of shells fired from rifled ordnance with very small charges. The observations were made and the results calculated by Lieutenant W. H. Noble, R.A.

TABLE III.

Decimal value $\frac{C}{P}$	12-pr. 11·75 lbs.		20-pr. 21·5 lbs.		40-pr. 40·5 lbs.		70-pr. 69·62 lbs.		110-pr. gun, 7-in. howitzer 103·87 lbs.		7-in. mortar. 87·56 lbs.	
	Charge	V	Charge	V	Charge	V	Charge	V	Charge	V	Charge	V
	lbs. oz.	ft.	lbs. oz.	ft.	lbs. oz.	ft.	lbs. oz.	ft.	lbs. oz.	ft.	lbs. oz.	ft.
·0114	..	..	..	..	..	..	..	..	..	..	1 0	287
·0201	..	..	..	..	..	..	..	..	2 0	407*	..	..
·0213	0 4	404	..	..	..	..	..	..	..	..	..	..
·0218	..	..	0 7·5	360	0 14	411	1 7·3	408	2 3·5	397	2 14	395
·0228	..	..	..	..	..	..	..	..	..	..	2 0	406
·0248	..	..	0 8·6	397	1 0	449	1 10·8	440	2 8·5	441	2 1	441
·0318	0 6	500	..	..	..	..	..	..	..	..	..	..
·0342	..	..	..	..	..	..	..	..	..	..	3 0	498
·0385	..	..	..	..	..	..	..	..	4 0	576*	..	..
·0435	..	..	..	..	1 12·5	630	..	..	..	..	..	..
·0456	..	..	..	..	..	..	..	..	..	..	4 0	575
·0570	..	..	..	..	..	..	..	..	..	..	5 0	647
·0638	0 12	796	..	..	..	..	..	..	..	..	..	..
·0648	..	..	..	..	2 10	805	..	..	..	..	..	..
·0684	..	..	..	..	..	..	..	..	..	..	6 0	704
·0851	1 0	962	..	..	..	..	..	..	..	..	..	..

7. It appears that a charge of *one forty-fifth* the shell's weight is sufficient to give an initial velocity of about 400 feet a second to all these projectiles except the 20-pr. shell, which takes rather more; we have seen above that no shell of 40-lbs. and upwards requires so high a velocity as 400 feet to contain a greater amount of *vis viva* than any of the shells employed in 1824. It now remains to be seen whether so small a charge is compatible with uniformity of range and accuracy of direction. The following tables contain the results of actual practice made under the direction of the Ordnance Select Committee to determine the point. Two charges were fixed on for the 40-pr., namely 14 oz., which is rather more than *one-fiftieth* (·0216), and 1 lb. Two charges in the same proportion to their respective shells were fixed on for all the other pieces. The ranges of the different pieces differ perhaps more than might have been expected under such

* The 110-pr. gun is not likely to be put to this service, but I have included with the 7-inch howitzer two determinations with this piece, which is 21 inches longer in the bore than the howitzer, but is in other respects comparable with it.

circumstances, owing no doubt to the unequal capacity of the different chambers, and the differences in the lengths of the guns, but they are far more regular than those of smooth-bored pieces with reduced charges; and they concur with the previous observations given in the Report of the Ordnance Select Committee, which I am permitted to quote in the Appendix, p. 32, in proving the great superiority of rifled ordnance for this as for almost every other service of war. A table will also be found in the Appendix, p. 38, giving the elevations for each 100 yds. deducible from this practice. That the pieces employed are very unnecessarily heavy for the duty, will occur to every one. The same reasons which led to the employment of smooth-bored howitzers, under certain circumstances, instead of guns, will, when rifled gunnery attains its full development, cause rifled howitzers to be added to our material, to throw shells with small charges for high angle firing, and to occupy positions which do not require or cannot take, so large and costly a piece as a rifled gun of the intended calibre.

When we make rifled pieces for charges not exceeding those usual with howitzers, it will scarcely be necessary to make them of wrought-iron, cast-iron will probably be strong enough for such purposes—the questions therefore opened up by this enquiry embrace a wider field than is perceived at first glance.

TABLE IV.

Date.	No. of rounds.	Elevation.	20-pr.							
			Charge.	Mean reduced time of flight.	Ranges.			Mean difference of range.	Mean observed deflection.	Mean reduced deflection.
					Min.	Max.	Mean.			
1863.		°	lbs.	sec.	yds.	yds.	yds.	yds.	yds.	yds.
January 29........	5	8	0 469	3·92	373	451	413	18 4	0·80	0·44
February 5	5	10	,,	4·31	441	486	459	12·0	8·44	0·44
do.	5	12	,,	4 95	459	547	510	30·0	8·76	0·68
February 9	5	15	,,	6.02	507	545	528	12·2	5·06	0 76
January 29	5	8	0·535	4·20	466	519	494	21·2	0·84	0·36
February 5	5	10	,,	5·02	508	601	542	27·6	9·12	0·30
February 9	5	12	,,	6 00	589	696	648	35.5	4·84	1·56
do.	5	15	,,	6·82	647	722	694	21·0	4·38	1·02

TABLE V.

			40-pr.							
1863.										
January 29	5	8	0·875	4.28	514	536	525	7·6	2·04	0·60
February 5	5	10	,,	5·16	560	690	626	45·2	1·72	0·42
do.	5	12	,,	5·69	575	721	653	41·4	2 36	0·68
February 9	5	15	,,	7·11	780	830	799	12 8	0 88	0·90
January 29	5	8	1·000	4·55	576	634	616	18 4	1·80	0·48
February 5	5	10	,,	5·23	680	714	699	7·6	1·68	0·38
February 9	5	12	,,	6·55	813	861	*839	18 0	1 65	1·05
do.	5	15	,,	7·66	965	1002	999	12·2	1·12	1·48

* Mean of four rounds.

TABLE VI.

Date.	No. of rounds.	Elevation.	70-pr.							
			Charge.	Mean reduced time of flight.	Ranges. Min.	Ranges. Max.	Ranges. Mean.	Mean difference of range.	Mean observed deflection.	Mean reduced deflection.
1863.		°	lbs.	sec.	yds.	yds.	yds.	yds.	yds.	yds.
February 9	5	8	1·461	4·06	458	512	481	19·0	1·72	0·14
February 11	5	10	,,	4·70	514	547	537	9·4	1·80	0·24
February 9	5	12	,,	5·56	545	654	616	33·2	1·72	0·10
do.	5	15	,,	7·23	760	905	818	42·6	4·60	0·40
do.	5	8	1·672	4·22	530	578	543	14·0	1·60	0·32
February 11	5	10	,,	5·24	648	698	665	15·6	1·32	0·38
February 9	5	12	,,	6·07	725	835	791	44·0	2·44	0·52
do.	5	15	,,	7·88	948	990	969	9·5	5·80	0·24

TABLE VII.

			7-in. howitzer.							
1863.										
January 28	5	8	2·219	4·16	431	515	486	29·8	3·24	0·12
do.	5	10	,,	5·04	571	611	599	17·2	5·52	0·66
do.	5	12	,,	5·75	588	664	629	28·8	7·80	0·64
do.	5	15	,,	7·46	840	912	877	20·2	13·00	0·48
do.	5	8	2·535	4·42	573	597	581	6·0	3·88	0·62
do.	5	10	,,	5·18	604	670	636	22 2	5·48	1·22
do.	5	12	,,	6 32	728	841	803	30·6	9·56	0·84
do.	5	15	,,	8·08	991	1128	1059	53·2	15·88	0·82

TABLE VIII.

			7-in. mortar.							
1863.										
January 28	5	8	1·879	4·32	485	524	507	12·4	2·92	1·38
do.	5	10	,,	5·23	620	654	636	11·4	3·32	3·18
February 4	5	12	,,	5 94	642	752	696	25·2	5·04	4·66
do.	5	15	,,	7·34	794	874	836	24·2	3·84	2 36
January 28	5	8	2·148	4·60	545	611	592	18·4	3·52	3·44
do.	5	10	,,	5·30	637	712	678	30·2	3·88	3·60
February 4	5	12	,,	6·34	758	832	798	24·4	3·08	2 42
do.	5	15	,,	8·02	938	1022	977	27·6	4·28	4·68

8. The foregoing comparison takes no account of the difference in the velocity of the smooth-bore and rifle shells on striking, of the difference in their diameters, or of the aid to penetration afforded by the rotation of the rifle shell, when it strikes point foremost. According to the French experiments the resistance to an elongated projectile is only *two-thirds* of the resistance to a sphere (Didion, § 177), and the penetration of a round shot and an elongated shot of the same weight, striking with the same velocity, into earth or masonry, will be as $\frac{2}{D^2}$ to $\frac{3}{D^2}$; practically it is hardly worth while to encumber the question with these considerations, for which we have insufficient data; so far as an inference may be drawn from a limited number of good penetrations observed in demolishing the two martello towers at Eastbourne* and Bexhill,† in 1860, rifle shot certainly penetrate in a higher ratio than would be given by the rule—"Directly as *vis viva*, inversely as the square of the diameter;" but those rifle projectiles had a velocity more than double the velocities we are contemplating, and a proportionably more rapid spin. I think it is sufficient therefore to point out that the low velocity shells from rifled guns will, doubtless, on the above grounds have an advantage over spherical projectiles; but to what extent can scarcely be stated in the absence of direct experiment. Their greater capacity for bursting powder is obvious, and greatly augments their relative effect.

9. This superiority does not rest entirely on hypothesis. The Prussian Government two years ago took advantage of the demolition of the Fortress of Julich or Juliers, to make certain experiments bearing upon the present enquiry on a large scale; unfortunately, while it duly occurred to the British Government that this was a very important military operation, and advantage was taken of the friendly permission of the Prussian authorities to send Engineer Officers to witness it, it seems to have been overlooked that it was equally an artillery experiment, and no British Artillery Officer was sent there. We have however a very full account published by Captain Weigelt, Commissioner from the Brandenberg Artillery, and which has been translated by Lieutenant de Cetto, R.H.A., from whose MS. I extract the following particulars:—

EXPERIMENT 1.—17th September, 1860.

Two brass 12-prs. rifled, calibre 4·674 English inches, firing shells of 27 lbs. at 1072 yds., charge about 2·1 lbs., breached a brick wall 2 ft. 9 in. thick in 32 rounds (16 per gun), of which only 8 took effect. The profile of the work is shewn in Fig. 1.‡

The wall was 7 ft. high, and completely covered by a counterscarp 90 ft. distant; but of such trifling relief that the angle of descent did not necessarily exceed 5°; as two feet of the base of the wall were covered by the counterscarp of its own ditch, the space to be breached was reduced to 5 ft. in height.

* Report of Breaching experiments at Eastbourne. (Special Paper, Sept. 8, 1860.)

† Vide Vol. II, page 397.

‡ For Figs. 1, 2, and 3, see Vol. X, Professional Papers, New Series, "Siege Operations at Juliers," Pl. II, Figs. 1, 2, and 3.—ED.

EXPERIMENT 2.—17th September, 1860.

Four iron 12-prs. rifled, with the same charge and projectile, made an opening 10 ft. wide and 6 ft. high in a brick wall 4 ft. thick at 1105 yds. The expenditure of ammunition was 64 rounds (16 per gun), but only 47 shells took effect. The profile of the work is shewn in Fig. 2.

The wall was 11 ft. high, of which $1\frac{1}{2}$ ft. was covered, and the whole was hidden from view by a parapet 13 ft. 6 in. high, at a distance of 105 ft.; requiring slightly larger angles of descent than in the first experiment, but still not exceeding 6°.

EXPERIMENT 3.—17th September, 1860.

The two brass and four iron 12-prs. of the preceding experiments were employed to breach a wall at 694 yds. distance. It was 7 ft. thick and 14 ft. high, supported at intervals by counterforts 4 ft. thick, and covered from view by the crest of a glacis at 135 ft. distance, as shewn in Fig. 3.

In this case it was not even necessary to diminish the service charge, and a complete breach was effected with an expenditure of 132 shells, the descending angle being under 3°.

If we compare the above profiles with the profile of the Carnot wall breached at Woolwich in 1824, it will be seen that they prove but little as to the capabilities of rifled guns for the service under consideration. The walls were slighter than will often be met with, the great distance and the slight relief of the covering works permitted the employment of charges and angles of descent which deprive the problem of all practical difficulty.

So far as they go, however, they concur with what has been advanced above, to show that caponiers and concealed or sunken escarps derive no additional value in fortification from the introduction of rifled guns, which are quite as capable of breaching them as the smooth-bored ordnance employed so successfully for that purpose in 1823, and will do it under great advantages from their greater uniformity of range and the larger bursting charge of the shells.

APPENDIX.—No. 1.

COPY OF A DRAUGHT OF REPORT OF AN EXPERIMENT AGAINST A SCREEN REPRESENTING THE WALL OF A FORTRESS, ACCORDING TO CARNOT'S SYSTEM.—DATED WOOLWICH, OCTOBER 24, 1822.

1. The experiment commenced on the 2nd August, 1822, and continued till the 24th September following, during which period 1167 rounds of ammunition were fired from the following natures of ordnance, viz :—

	Length. ft.	Weight. cwt.	qrs.	lbs.
24-pr., iron	9	48	0	0
8-in. howitzer, iron	4	20	2	2
68-pr. carronade	5	36	0	0
10-in. howitzer, iron	5	39	2	20
8-in. mortar, iron		8	1	0

These pieces were each fired at ranges of 400 and 500 yds. distance from the crest of the counterguard in front of the wall.

2. The following is a statement of effect of the total number of 1167 rounds fired:—

	Rounds.	
Grazed short..	417	
Took effect on wall ..	377	Rather less than one-third.
Went over wall	373	
Total	1167	

Of the number of 377 rounds that took effect on the wall, 116 rounds struck the wall at or below 12 ft. from the top, being only one-tenth of the number of rounds fired; but in stating this unfavourable result, it is necessary to observe that every allowance is to be made for loss of effect, by frequent change of the pieces of ordnance used, as well as alteration in the charges, elevations, and stations they were fired from, particularly in the commencement of a difficult operation, when many of the rounds were thrown away in experiments as to the best charges.

3. For the purpose therefore of forming a just opinion of the effect of this experiment, it is requisite to take it into consideration, in three points of view, as follows:—

(1.) The individual effect of each piece of ordnance.
(2.) A comparison of effect from 400 yds. and from 500 yds.
(3.) With regard to the best angle of elevation to be used.

The following is a statement of the individual effect of each piece of ordnance, in explanation of the first point.

	Rounds fired.	Rounds that took effect.	Proportion.
24-pr..	217	53	— $\frac{1}{4}$
8-in. howitzer ..	270	81	— $\frac{1}{3}$
68-pr. carronade	320	112	+ $\frac{1}{3}$
8-in. mortar ..	180	56	— $\frac{1}{3}$
10-in. howitzer..	180	75	+ $\frac{2}{5}$
	1167	377	

From this it appears that in individual effect, the 68-pr. carronade and 10-in. howitzer have performed best.

The second and third points will be best explained by the table annexed.

4. Abstract of effect against the wall of a fortress according to Carnot's plan, classed to show the practice at different ranges and elevations:—

Ordnance.	At 400 yards.												At 500 yards.												Total number of rounds fired from each gun	Total rounds struck wall 12 feet from top.
	10° or under.						15°						10° or under.						15°							
	No. of rounds.				Struck wall at or below 12 ft. from top.	Proportion that took effect 12 ft. from top.	No. of rounds.				Struck wall at or below 12 ft. from top.	Proportion that took effect 12 ft. from top.	No. of rounds.				Struck wall at or below 12 ft. from top.	Proportion that took effect 12 ft from top.	No. of rounds.				Struck wall at or below 12 ft. from top.	Proportion that took eff. ct 12 ft. from top.		
	Grazed short.	Took effect on wall.	Went over wall.	Total fired.			Grazed short.	Took effect on wall.	Went over wall.	Total fired.			Grazed short.	Took effect on wall.	Went over wall.	Total fired.			Grazed short.	Took effect on wall.	Went over wall.	Total fired.				
24-pr.	33	25	49	107	1	$\frac{1}{107}$	..	..	..	..	..	..	52	28	30	110	4	$\frac{1}{27}$	..	..	..	..	..	..	217	5
8-in. howitzer .	40	42	28	110	11	$\frac{1}{10}$	8	14	8	30	6	$\frac{1}{5}$	36	8	16	60	..	..	24	17	29	70	9	$\frac{1}{8}$	270	26
68-pr. carronade	46	46	48	140	8	$\frac{1}{17}$	15	29	26	70	10	$\frac{1}{7}$	16	16	8	40	2	$\frac{1}{20}$	26	21	23	70	11	$\frac{1}{7}$	320	31
8-in. mortar ..	15	10	15	40	..	..	26	23	11	60	14	$\frac{1}{4}$	14	11	15	40	..	..	16	12	12	40	8	$\frac{1}{5}$	180	22
10-in. howitzer.	14	13	3	30	..	..	14	26	20	60	16	$\frac{1}{4}$	18	22	20	60	6	$\frac{1}{10}$	4	14	12	30	10	$\frac{1}{3}$	180	32
	148	136	143	427	20	$\frac{1}{21}$	63	92	65	220	46	$\frac{1}{5}$	136	85	89	310	12	$\frac{1}{26}$	70	64	76	210	38	$\frac{2}{11}$	1167	116

At 400 yards, 10° or under: Of 427 rounds fired, 136 took effect, being less than $\frac{1}{3}$. Of the same number of rounds (427) fired, only 20 struck the wall 12 feet from top, being less than $\frac{1}{21}$.

At 400 yards, 15°: Of 220 rounds fired, 92 took effect on wall, being more than $\frac{2}{5}$. Of the same number of rounds (220) fired, 46 struck the wall 12 feet from top, being more than $\frac{1}{5}$.

At 500 yards, 10° or under: Of 310 rounds fired, 85 took effect on wall, being rather less than $\frac{2}{7}$ Of the same number of rounds (310) fired, only 12 struck the wall 12 feet from top, being more than $\frac{1}{20}$.

At 500 yards, 15°: Of 210 rounds fired, 64 took effect on wall, being rather more than $\frac{2}{7}$. Of the same number of rounds (210) fired, 38 struck the wall 12 feet from top, being rather less than $\frac{2}{11}$.

5. By the comparison of fire from 400 and from 500 yds. in the foregoing table, it is found that the former range is preferable to the latter, and with regard to the best angle of elevation to be used 15° has greatly the advantage over 10° at 400 yds., and is something better than the smaller angle at 500 yds., but with respect to the number of shot striking 12 ft. from the top, the angle of 15° is at both ranges far superior in effect.

It ought also to be considered with respect to probable penetration with the small charges necessarily used, but as the experiment has only been made on a wall of lightly rammed earth, it is difficult to calculate anything like an effect. It is a fair presumption, however, that the action of such powerful projectiles as 68-pr. shot, assisted by 10-in. shells filled with powder, would very possibly succeed in breaking down the brick wall in question.

6. On the whole, therefore, it appears that 68-pr. carronades and 10-in. howitzers placed in battery at 400 yds. and fired with 15° of elevation, afford the greatest hopes of success, and by the preceding table there is just reason to expect, that from a continuance of fire without change, about half the practice would be successful.

It is in consequence submitted to His Grace the Master-General, whether these results do not merit a more definitive investigation of the experiment, by trying the fire against a real wall, disposed according to the profile of Carnot's sytem.

(The draught is not signed, but is in the handwriting of the late Sir Alexander Dickson, R.A.)

APPENDIX No. 2 omitted; see Note, page 23.

APPENDIX.—No. 3.

REPORT

OF THE

ORDNANCE SELECT COMMITTEE

No. 1988, dated December 2, 1861.

On the Efficiency of Armstrong Guns Employed in Ricochet Fire.

1. The Committee have the honour to submit the following Report of Experiments made under instructions received in June to test the efficiency of Armstrong guns when employed in enfilading a battery, and the distance at which the fire is most destructive and certain. The work in Plumstead Marshes was put in repair for this trial. It consists of a single face about 340 ft. long, with two flanks. It is divided unequally by four traverses, and further derives

essential protection from a screen or bonnette of earth 10 ft. high and 30 ft. long, at the angle of the nearest flank. Ground platforms were laid for four guns, and two mortars (the latter were unoccupied); iron traversing platforms for two guns; wooden traversing platforms for two guns; and there were two guns on naval carriages not on any platforms; in all ten guns mounted. In addition to which, on the last occasion of fire, a second row of three guns was formed 50 ft. in rear of the proper armament, leading up to a small field magazine which it was desired to strike.

2. After some preliminary practice to ascertain the ranges due to reduced charges and high elevations, the Committee proceeded on the 30th October, and 6th November, to ricochet the work; 950 yards from the nearer angle, or 1000 yards from the centre, was fixed on as a proper distance for the battery, being beyond the risk of much annoyance from an enemy's riflemen. The guns in battery were:—

(1) Smooth-bored 32-pr. of 25 cwt.
(2) " 8-in. of 62 cwt.
(3) Armstrong 40-pr.
(4) " 20-pr.
(5) " 12-pr.

The work fired at not being visible from the battery, owing to an intervening parapet, pickets were set up in proper alignment on this parapet at 340 yards in advance, to aid the laying of the guns, and a non-commissioned officer was posted near them, under cover, to signal the apparent result of each shot.

The following is an abstract of the practice:—

Date.	No.	Charge.	Elevation.	Effects.	First Grazes.
1861.		oz.	° ′	§ 3.—Armstrong 40-pr.	yds.
Oct. 30	1	24	8 0	Knocked off about 16 in. of the muzzle of an 18-pr. gun, which had been cracked by a former blow	1002
	2	—	—	Lodged in the parapet	990
	3	—	—	Do. do.	995
	4	—	—	Do. do.	1012
	5	—	—	Slightly grazed the muzzle of a gun, and proceeded over the work	1000
	6	—	—	Lodged in the parapet	990
	7	—	—	In the work; grazed the front of a wooden platform without occasioning serious splinters	1015
	8	—	—	Grazed a traversing platform, and lodged in a traverse	995
	9	—	—	Into the parapet	980
Nov. 6	10	—	8 10	Into the further flank	960
	11	—	8 0	Struck a traverse	1050
	13	—	7 45	Went through the cheeks of a carriage, and struck a wooden platform causing numerous splinters. The carriage was old	1020
	14	—	7 30	In the work	968
	15	—	7 30	Struck the parapet	?
	16	—	7 30	In the work	980
	17	—	7 30	Caught by the bonnette .. .. about	960
	18	—	7 30	Struck outside	930
	19	—	7 30	Struck the parapet	970

Date.	No.	Charge.	Elevation.	Effects.	First Grazes.
1861.		oz.	° ′	ARMSTRONG 40-pr.—*Continued.*	yds.
Nov. 6	20	24	7 30	Struck outside .. .. about	930
	21	—	7 30	Caught by the bonnette	960
	22	—	7 30	Grazed the rear of the bonnette, and skimmed along the whole length of the work without rising more than a foot or two, burying itself at last in the further flank..	960
				§ 4.—ARMSTRONG 20-pr.	
Oct. 30	1	12	8 30	Short..	—
	2	—	8 45	Do.	—
	3	—	9 0	Do.	—
	4	—	9 15	Caught by the bonnette	970
	5	—	9 30	Short..	844
	6	—	9 45	Do.	917
	7	—	9 50	Caught by the bonnette	970
	8	—	9 55	Do. do.	970
	9	—	9 55	Short..	900
	10	—	9 55	Caught by the bonnette	970
Nov. 11	11	14	8 0	Short..	900
	12	—	8 10	Do.	910
	13	—	8 0	Into the nearer flank	940
	14	—	8 0	Struck the top of the bonnette	970
	15	—	8 0	Into the bonnette	960
	16	—	8 0	Short..	—
	17	—	8 0	Rather short	930
	18	—	8 0	Into the bonnette	950
	19	—	8 0	Short..	912
	20	—	8 0	Struck a traverse, and did not rise, but turned over where it fell	965
	21	—	8 0	Struck a traverse	964
	22	—	8 0	Into the bonnette	950
				§ 5.—ARMSTRONG 12-pr.	
Oct. 30	1	7	8 0	Struck short, and ricocheted into the bonnette	850
	2	—	8 15	Struck the parapet near the 1st traverse ..	970
	3	—	8 15	Caught by the bonnette	960
	4	—	8 25	Passed under an iron traversing platform, and was stopped by traverse 2	990
	5	—	8 25	Struck traverse 2	990
	6	—	8 25	Struck traverse 3	1018
	7	—	8 25	Short	900
	8	—	8 25	Caught by the bonnette	960
	9	—	8 25	Rather short	920
	10	—	8 25	Caught by the bonnette..	960
Nov. 6	11	8	7 0	Grazed a gun carriage and the iron traversing platform it was on ; buried in traverse 2 ..	990
	12	—	6 50	Rather short .. .. about	920
	13	—	6 55	Struck short, and ricocheted over..	—
	14	—	7 0	Short..	—
	15	—	7 0	Do.	—
	16	—	7 10	Struck short, and ricocheted into the further flank	990
	17	—	7 10	Rather short .. .. about	930
	18	—	7 10	Struck short, and ricocheted over .. about	843
	19	—	7 10	Caught by the bonnette .. .. .. about	960
	20	—	7 10	Struck short	910
	21	—	7 10	Caught by the bonnette	960
	22	—	7 10	Struck the nearer flank	936

Date.	No.	Charge.	Elevation.	Effects.	First Grazes.
1861.		oz.	° ′	§ 6.—8-in. GUN OF 62 cwt.	yds.
Oct. 30	1-7	20	—	All short	—
	8	—	12¾ 0	Into traverse at	995
	9	24	12¾ 0	Short..	912
	10	—	13 0	Over into the butt beyond	1100
Nov. 6	11	32	7 0	Short.. .. .. about	800
	12	—	7¼ 0	Short; ricocheted into the further flank ..	900
	13	—	7½ 0	Short; the second graze was in the work, and the third into the further flank	906
	14	—	8 0	Rather short, and ricocheted clear over the work into the butt	933
	15	—	9 0	Clear over the work into the butt	1100
	16	—	8½ 0	In the work beyond the further traverse ..	1050
	17	—	8½ 0	Into the further flank	1060
	18	—	8½ 0	Clear over the work..	—
	19	—	8½ 0	Rather short; grazes not recorded	1020
	20	—	8½ 0	Struck the parapet at 1010 yards, then ricocheted against the side of a wooden traversing platform at 1030 yards, and fell beside it making a small indentation only	1030
	21	—	8½ 0	Clear over..	—
	22	—	8½ 0	In the work	940
	23	—	8½ 0	Clear over..	—
	24	—	8½ 0	In the work	1050
	25	—	8½ 0	Near the same place as the last	1050
				§ 7.—32-pr. of 25 cwt.	
Oct. 30	1	22	8 0	Rather short	—
	2	—	8 0	Over	—
	3	—	8 0	Do.	—
	4	—	8 0	Do.	—
	5	—	7½ 0	Rather short	916
	6	22	7¾ 0	Into parapet	1002
	7	—	7¾ 0	Over	—
	8	—	7¾ 0	Into the ditch of the work at about	1000
	9	—	7¾ 0	Struck the bonnette high	960
	10	—	7¾ 0	Into the work	1010
Nov. 6	11	—	7¾ 0	Rather short	910
	12	—	7¾ 0	Struck a wooden platform without causing serious splinters, and into traverse 3.. ..	1015
	13	—	7¾ 0	Short, struck the bonnette on second graze..	—
	14	—	7¾ 0	Into the work	995
	15	—	7¾ 0	Ditto	1008
	16	—	7¾ 0	Went clear over the butt.. .. .. about	1160
	17	—	7¾ 0	Struck the butt high .. .. .. about	1100
	18	—	7¾ 0	Struck the butt.. .. .. about	1055
	19	—	7¾ 0	Passed through an iron gabion and buried itself in the cheek of an embrasure	1025
	20	—	7¾ 0	Into the work behind traverse 3	1010
	21	—	7¾ 0	Grazed the rear of traverse 2, carrying away 2 gabions	990
	22	—	7¾ 0	Into traverse 3..	1020

8. The results of the foregoing practice may be stated generally as follows:—

	Armstrong.				Smooth-Bore.		
	40-pr.	20-pr.	12-pr.	Total.	8-in.	32-pr.	Total.
Shots which fell in the work or on the parapet	17	2	5	24	7	10	17
Shots caught by the bonnette which would have otherwise entered the work	2	8	6	16	0	1	1
Short	2	12	11	25	13	3	16
Over	0	0	0	0	2	8	10

9. It will be seen that very little material was struck, there was consequently little opportunity of judging of the effect of Armstrong projectiles in dismounting ordnance. It has however been ascertained that the initial velocity of the 12-pr. shell is as follows:—

With charge 6 oz., 500 ft. per second.
" 8 oz., 620 ft. "
" 10 oz., 732 ft. "

It is probable that these velocities will be very near the truth for charges of the other natures bearing the same proportion to the weight of the shot, namely, for the 40-pr.—20 oz., 26·6 oz., and 33·8 oz.; for the 20-pr.—10·5 oz., 14·0 oz., and 17·5 oz.; and their mechanical effects can therefore be easily compared with those of smooth bored projectiles if we also ascertain the velocity of the latter. This has not at present been done for the low charges used in ricochet fire*, but by calculation the initial velocity of a 32-pr. shot, with 22 oz. of powder, as fired on this occasion, is about 715 ft. per second; being nearly 100 ft. greater than that of the 12-pr. and 20-pr., and 120 ft. greater than that of the 40-pr. The elongated projectiles preserve their velocity rather better than the round shot; but on the whole, although it appears sufficiently great to produce destructive effect on the artillery material they strike, it must be less than that of the round shot, and consequently their mechanical effect less also: on the other hand the larger bursting charges of elongated shells will make these much more destructive to traverses and solid obstacles, as well as to troops.

10. The present practice has fully satisfied the Committee that Armstrong projectiles may be fired with greatly reduced charges, so as to have a high descending angle, and still retain precision of direction and uniformity of range. This adapts them well for silencing guns covered by traverses, or for breaching capponnières and sunken defences; but they are not so well adapted as round shot for what is commonly intended by ricochet fire, namely, to proceed through a work by short bounds, making more than one graze in it. The second graze is almost invariably too far distant from the first to be in any way relied on; it is however tolerably regular both in direction and distance.

* See Table III for results obtained since the date of this Report.

The following table contains the observed first and second grazes of a part of the practice. In some instances the second graze was not traced.

COMPARISON OF 1st AND 2nd GRAZES OF ARMSTRONG PROJECTILES.

Gun.	Charge.	Elevation.	No. of rounds.	Mean range. 1st graze.	Mean range. 2nd graze.	Diff. 1 — 2	Deflection. 1st graze R	Deflection. 2nd graze R	Soil.
	oz.	°		yds.	yds.	yds.	yds.	yds.	
12-pr.	6	7	2	765	1290	525	—	23	Good turf.
do.	—	10	2	937	1331	394	—	75	do.
do.	8	5	3	729	1513	784	—	63	do.
20-pr.	16	5	3	744	1536	792	—	115	do.
do.	—	7	5	1009	1600	591	—	65	do.
do.	18	5	3	828	1405	577	—	47	do.
do.	—	7	4	1112	1795	683	—	71	do.
do.	20	7	5	1195	2188	993	2·4	50	Wet sand.
do.	—	10	5	1650	2435	785	6·7	61	do.
40-pr.	32	5	5	883	1683	800	1·1	47	do.
do.	—	7	5	1173	2286	1013	2·7	80	do.
do.	36	5	5	1004	2058	1054	1·7	38	do.
do.	—	7	5	1306	2422	1116	2·7	60	do.
do.	40	5	5	1083	1933	850	1·7	86	do.
do.	—	7	5	1448	2626	1178	3·7	166	do.

11. Two exceptional grazes occurred in the practice, both of which would have been very destructive inside a work. A 20-pr. shot fired at 5° with 18 oz. charge, struck the ground at 798 yards, and cut off the top of the long grass in a continuous line for 19 yards, the ground here dipped a little, but the trace was distinguishable further on, showing that it could not have risen so much as a foot for 120 yards. A 40-pr. shot fired at $7\frac{1}{2}$°, charge 24 oz., struck the ground at 980 yards, and skimmed along until stopped by the shoulder of the battery at 1060 yards, not rising above 2 or 3 ft. It will be seen however by the distance of the second graze from the first (as given in column 7), that with these rare exceptions, the effect of each shot will be confined to the portions of the descending and rising branches of the curve comprised between the ordinary height of the parapet and the ground—a distance of 100 to 150 ft., according to the angle. There is scarcely any chance of shot which fall short, getting into the work on second graze, a thing which frequently happens with round shot and shells.

12. The Committee do not consider it necessary to expend more ammunition in endeavouring to strike the half-sunken field magazine, which has not yet been struck, or to obtain more direct evidence of the effect of a blow on guns and gun carriages; they recommend that the use of the 12-pr., 20-pr., and 40-pr. Armstrong guns with reduced charges at high angles, be reduced to practice, and recognized as an occasional employment of those guns, and that the Commanding Officers, Royal Artillery, receive instructions to keep a careful record of the results of all shots which take effect on material as well as of the actual first grazes for given charges and elevations, to verify the annexed table. They would also suggest that orders be given to the P. S. S. to issue fresh (unserviceable) carriages instead of some of those now in the work, which are too much shattered to furnish any longer a fair illustration of the effects of shot.

(Signed) J. ST. GEORGE,
President O. S. C.

TABLE VIII.

Giving the Approximate Elevations necessary to pitch an Armstrong Shot or Shell into a Work at the Distances Specified, and with the Charges given.

Distance of object.	L. S. 12-pr.			L. S. 20-pr.			L. S. 40-pr.			
	Elevation for			Elevation for			Elevation for			
	oz. 6	oz. 8	oz. 10	oz. 14	oz 16	oz. 18	oz. 24	oz. 28	oz. 32	oz. 36
yds.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
500	5 6	..	..	..	..	..	..	..	..	..
600	5 54	..	..	..	..	..	..	..	..	..
700	6 42	4 15	..	6 20	4 50	..	5 30	..	..	..
800	8 0	5 10	..	7 4	5 30	4 50	6 15	5 20	..	..
900	9 30	6 5	4 40	7 46	6 13	5 30	7 8	6 5	5 5	..
1000	..	6 58	5 20	8 30	6 56	6 10	7 55	6 45	5 45	5 0
1100	..	8 6	6 4	9 10	7 40	6 50	8 35	7 30	6 30	54 0
1200	..	9 20	6 46	9 50	8 25	7 40	9 25	8 12	7 10	6 20
1300	..	..	7 40	..	9 10	8 23	..	9 0	8 0	7 0
1400	..	..	8 40	..	10 0	9 10	..	9 46	8 45	7 40
1500	..	..	9 40	..	..	9 55	..	..	9 30	8 25
1600	..	..	..	..	..	..	..	..	..	9 15

TABLE IX.

Approximate Angles of Elevation and Times of Flight due to Short Distances when the Angle of Descent is required to be not less than 10°.

Elevation.	20-pr. 21·5 lbs.		40-pr. 40·5 lbs.		70-pr. 69·62 lbs.		7-in. howitzer or 110-pr. gun. 103·87 lbs.		7-in. mortar. 87·56 lbs.	
°	yds.	sec.	yds.	sec.	yds.	sec.	yds.	sec.	yds.	sec.
	Charges all in the proportion 0·0211 *P*.									
8	410	3·7	520	4·0	445	3·7	490	4·2	520	4·0
9	435	4·1	560	4·5	500	4·3	540	4·6	570	4·7
10	460	4·4	610	5·1	550	4·8	580	4·9	620	5·5
11	480	4·7	640	5·4	600	5·3	630	5·5	660	6·1
12	500	5·1	680	5·9	650	5·7	670	5·9	705	6·8
13	520	5·4	715	6·4	690	6 2	720	6·4	750	7·5
14	535	5·6	750	6·7	740	6·7	760	6·7	790	7·9
15	555	5·9	780	7·1	780	7·1	810	7· 0	830	8·3

TABLE IX.—*Continued.*

Elevation.	20-pr. 21·5 lbs.		40-pr. 40·5 lbs.		70-pr. 69·62 lbs.		7-in. howitzer or 110-pr. gun. 103·87 lbs.		7-in. mortar. 87·56 lbs.	
°	yds.	sec.	yds.	sec.	yds.	sec.	yds.	sec.	yds.	sec.
	Charges all in the proportion 0·0236 *P*.									
8	480	4·2	600	4·4	540	4·2	560	4·4	560	4·3
9	520	4·7	655	4·9	600	4·7	620	4·9	615	4·8
10	560	5·2	710	5 3	660	5·2	680	5·4	690	5·4
11	595	5·6	770	5·9	725	5·7	740	5·9	745	5·9
12	625	5·9	830	6·4	790	6·2	810	6·4	800	6·3
13	660	6 3	890	6·9	850	6·7	870	6·9	860	6·9
14	680	6 6	940	7·2	910	7·3	930	7·4	910	7·4
15	705	7·0	1000	7·7	970	7·9	990	8·0	960	7·9

The above charges are respectively :—

	lbs.	oz.	dr.		lbs.	oz.	dr.
For the 20-pr.	0	7	8	and	0	8	9
,, 40-pr.	0	14	0	,,	1	0	0
,, 70-pr.	1	7	6	,,	1	10	12
,, 7-in. howitzer or 110-pr. gun	2	3	8	,,	2	8	9
,, 7-in. mortar	1	14	1	,,	2	2	6

In practice it will be sufficient to take them to the nearest half-ounce.

NOTE.- In the note on page 24 for 667,428 read 82,910.

PAPER V.

NOTES ON THE CONSTRUCTION OF MAGAZINES.

BY LIEUTENANT HOME, R.E.

In the construction of a magazine it is requisite that damp should be excluded, that there should be free ventilation, that the magazine should be of a convenient shape, the powder bags so arranged as to allow of easy issues or receipts of powder, and that there should be a convenient communication with the shifting room.

These desiderata are usually met by erecting a building with very thick walls, and a passage some 2 feet or 2 feet 6 inches wide through the centre of the wall, and by covering in the building with a coating of asphalte on the top; the results being that, owing to the great quantity of water in the green brickwork, and to the impossibility of the moisture passing through the asphalte, it dries downwards into the chamber of the magazine, rendering it for a long time damp.

The shifting room is generally constructed as a separate building which entails the necessity of carrying the barrels of powder from one building to another, an undesirable arrangement in a fort.

As a remedy for these defects, it is proposed to line all magazines with $4\frac{1}{2}$-inch brickwork with a $4\frac{1}{2}$-inch space between this lining and the main wall, (as shown in Section, Figs. 1, 2, and 5, and on the Projection Fig. 4). Ventilators with splay mouths (B, B, Fig. 3), permit the air to pass into the $4\frac{1}{2}$-inch space, and by building in perforated bricks here and there in the lining, the air is conveyed into the chamber of the magazine itself. This lining is strengthened by occasional headers built into the outer wall.

The first ring of the arch is turned in hollow brick, the end of this ring stopping $4\frac{1}{2}$ inches short of the main wall (as shown in Fig. 5). The hollow bricks form a succession of pipes round the arch, and a current of air passes through them, from the space between the brick lining and the main wall. It is conceived that by this arrangement all the advantages of a double arch are obtained.

The shifting rooms are placed immediately in front of the magazines, and between runs a passage (Fig. 3) by which the magazines are entered. Dumb waiters A.A.A. to contain a barrel of powder communicate with the shifting rooms.

SECTION ON C. D

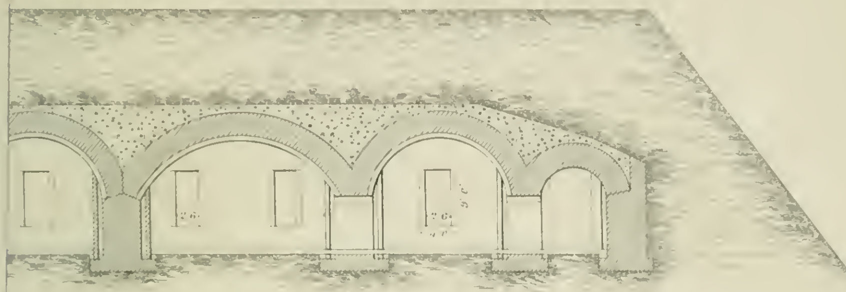


Fig. 2.

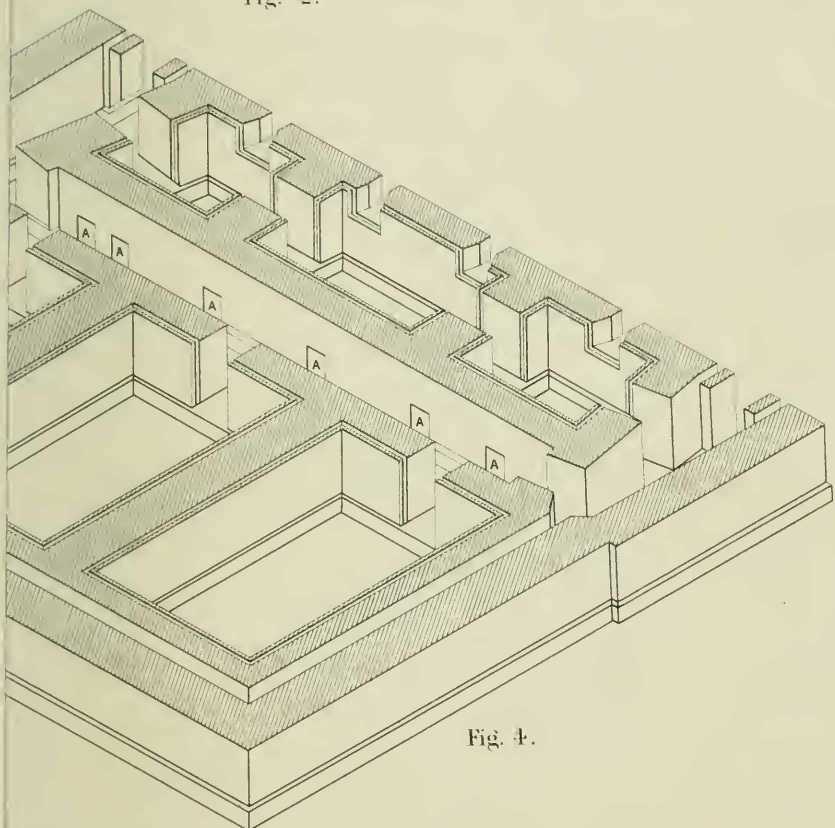


Fig. 4.

ETRICAL PROJECTION OF MAGAZINE WALLS.

SECTION ON G. H.

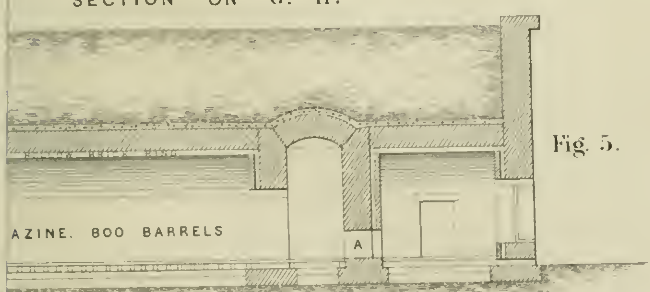


Fig. 5.

POWDER MAGAZINE.

SECTION ON E. F

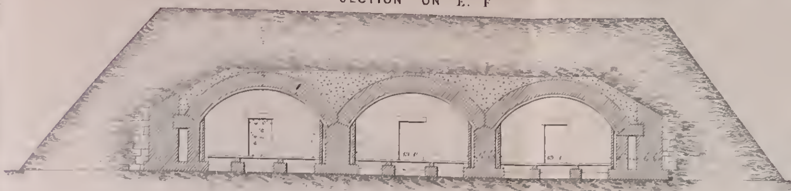


Fig. 1.

SECTION ON C D

Fig. 2.

PLAN.

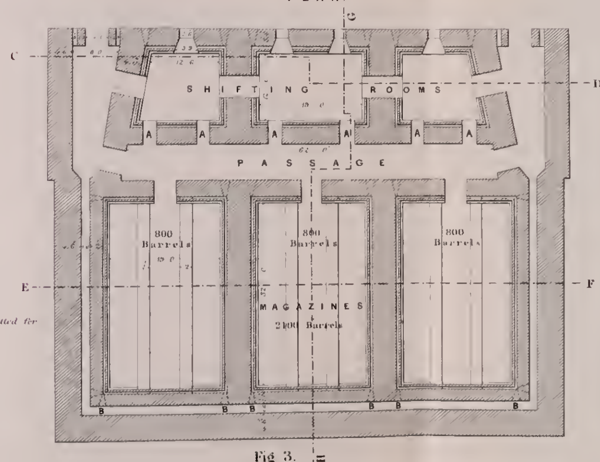


Fig 3.

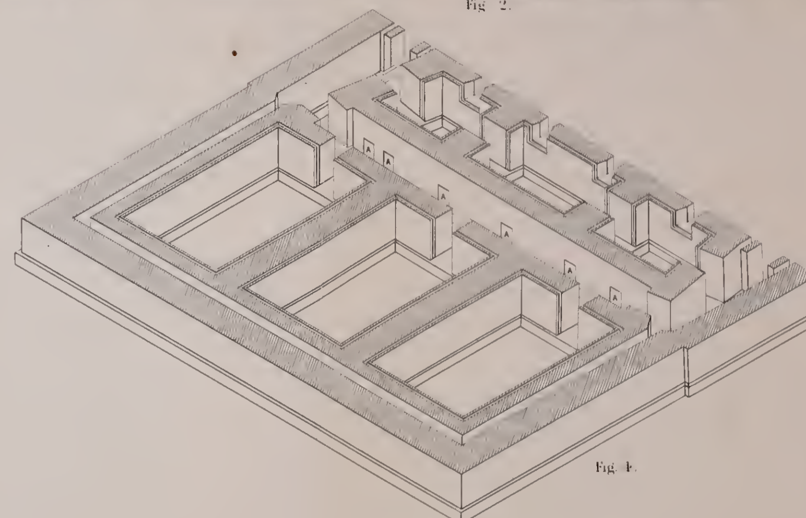


Fig. 4.

ISOMETRICAL PROJECTION OF MAGAZINE WALLS.

SECTION ON G. H.

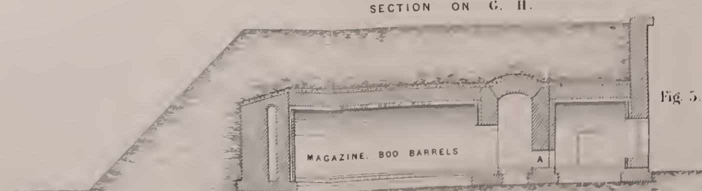
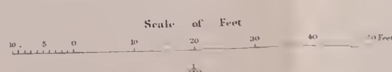


Fig. 5.



The magazine man hands the powder to a man stationed in the passage who receives it, places it in the dumb waiter, and turns it round; it is then lifted out in the shifting room. The cartridges when made up can be passed out at the windows shown in Section, Fig. 5. Thus none of the magazine doors need be opened during the time the men are at work.

Since mortar or concrete, made of Scott's cement, becomes very rapidly dry from the great affinity of that substance for water, it is proposed to use it for all magazines. The cost of the magazine shown in the Plate, built in Scott's cement, would be about £4100, or £1 14s. 6d. per barrel.

As powder is always issued in lots of 100 barrels at a time, it is proposed to make each bay contain either 100 barrels or some multiple of that number. If it be really requisite that the doors of a magazine should be covered with metal, it is suggested that muntz metal, being quite as good as copper and about half the price, be used.

In very large magazines, where the span is great, and consequently the abutments have to be thickened, it is suggested that the latter should be counter-arched, thus gaining room for stowage and economising material.

R. HOME, Lieutenant,
Royal Engineers.

Portland, May 7, 1863.

PAPER VI.

SUGGESTED IRON PROTECTION FOR CASEMATE EMBRAZURES.

By MAJOR GENERAL SANDHAM, R.E.

No very satisfactory decision has yet been arrived at as to the impregnability of iron plates—the protection afforded by wrought iron plates of very considerable thickness is only partial—and cast-iron plates have failed altogether.

A succession of shot striking any iron plate à plein fouet, taking into account the weight of metal projected against it, (which has hitherto been increased, and, is increasing, as plates, capable of greater resistance, have been produced,) must by their repeated force eventually break up or displace the heaviest and the strongest; if however the impact of the shot can be received by a plate at an acute angle to its plane, the effect upon it is but trifling, the shot glances from it, and is broken into small pieces that can have but little effect on any other plates that may be so placed as to receive them, and it is under these considerations that the iron-cased embrazures shown in the accompanying drawing are suggested. The opening of the mouth of the embrazure is reduced to a minimum through which a direct shot only could enter the casemate. It has been proved by experiments that shot will deflect and break from $\frac{5}{8}$-in. boiler plate iron backed by granite, at angles of impact or incidence from 10° to 30°, beyond which the experiments alluded to were not carried on; up to what angle shot would deflect and break from the heavier plates now in use, if they should be backed by lead-concrete, or even by granite, can only be satisfactorily ascertained by experiment. It was found that the fragments of shot above referred to deflected at an angle equal to that at which the shot struck the plate, and that, at the distance of 10 feet from the point of impact, the pieces spread into a circle of from $4\frac{1}{2}$ to 5 feet in diameter; this constant effect has led to the idea of rounding the plates at the mouth, of indenting the cheeks and of covering the throat of the embrazure by a shield having a slot in it merely large enough to admit of the gun being traversed, elevated, or depressed.

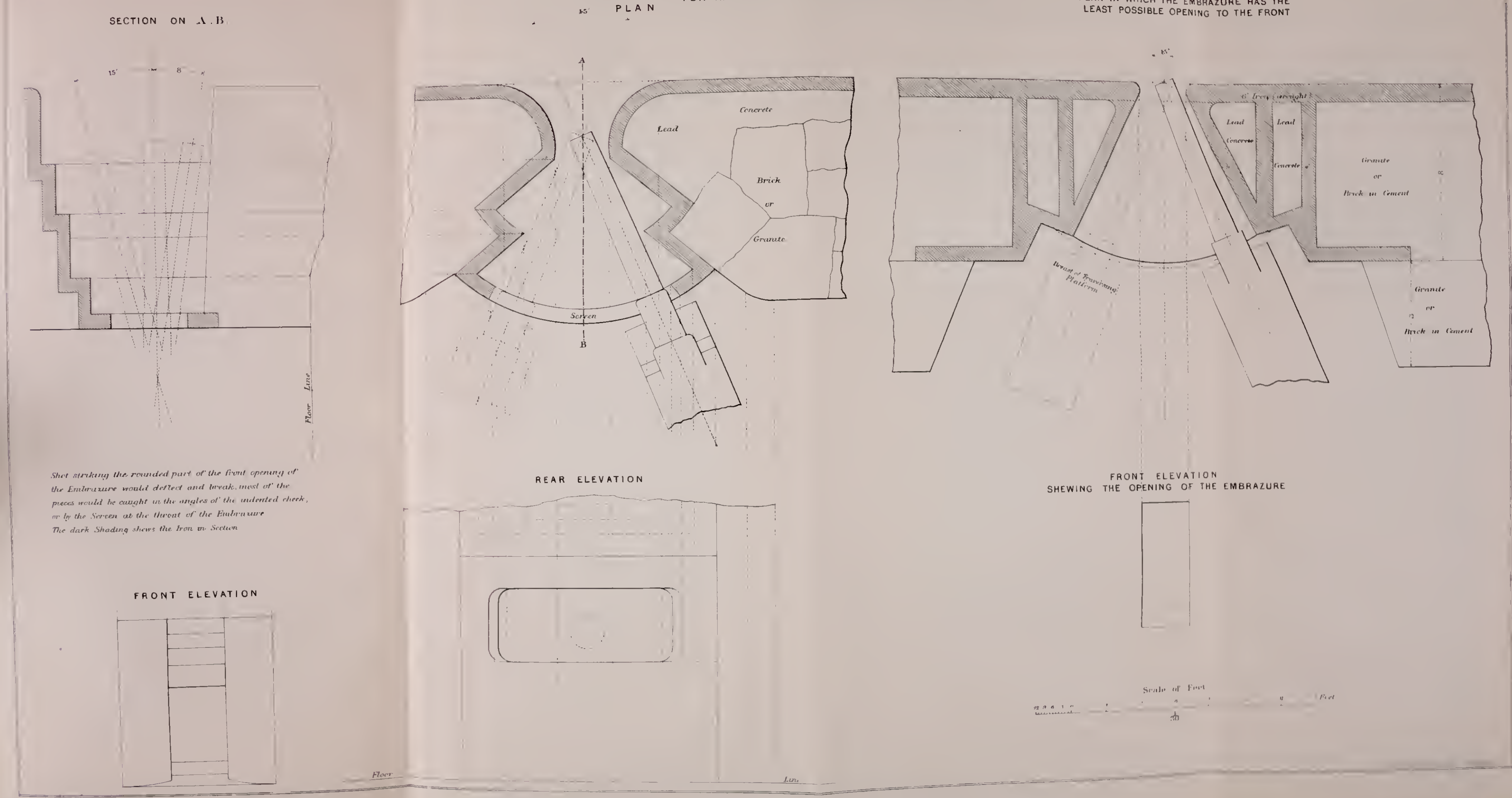
It has been found that the effect of shot upon iron plates covering masonry or brickwork imparts a motion to the whole mass, so that the masonry is dislocated often to a considerable distance beyond the protecting plate struck; to modify this effect it is proposed to back the plates immediately about the opening of the embrazure with lead-concrete, which, from its gravity and tenacity, is not so liable to be dislocated or broken up as granite, which in block even is extremely friable under the effect of shot. The granite blocks which supported the $\frac{5}{8}$-in. boiler plate iron in the experiments above referred to were found to be pulverized to the extent of a foot and 18 inches, and to the depth of 2 or 3 inches about the point of impact of the shot, although in most instances the grazing shot did not actually cut through the plate.

Should the progressing experiments on iron plates lead to their application for the protection of scarps, that protection should not be confined to the immediate neighbourhood of the embrazure of a casemate, it must be extended beyond the walls that support the arches, or they would be breached and the arches would fall.

H. SANDHAM.

IRON CLAD CASEMATE EMBRAZURES

FOR ARMSTRONG 40 P^R GUNS.



PAPER VII.

ON THE DEFENCE OF THE MAIN DITCHES OF FORTRESSES BY COUNTERSCARP CASEMATES.

By CAPTAIN WEBBER, R.E.

In reading a short paper on this subject before Colonel Harness and the Officers of Royal Engineers, at the Chatham Establishment, in February, 1863, I thought it necessary to explain my reasons for bringing it forward; but since hearing my proposition discussed by several of my brother officers, I have had less hesitation in bringing the paper in a modified form to the notice of the corps generally, and have therefore omitted to enter into those reasons.

The proposition is, that, in all works constructed on the bastioned system, the adoption of casemates in the salients of the counterscarp, for the defence of the main ditch of a fortress, will have the effect of prolonging the defence.

It has been always admitted that the defence of a ditch by counterscarp galleries or casemates was in itself faulty, owing to the facility with which an attacking force could destroy them by mining. In consequence, most military engineers have avoided placing guns in the counterscarps, and when galleries for musquetry did exist, they were more intended as a communication with a system of countermines, than as an assistant of any importance in the defence of the ditch. And, it is asserted that the communication with these galleries across or under the ditch is so intricate as to make them difficult of access, and deter their defenders making such a good stand as they would otherwise do, were there no apparent chance of their retreat being cut off.

Where the length of tenure of any fortified place depends mainly on the time during which the defenders can keep efficient the arms flanking the ditch, it is generally considered that the capture of that place is only a matter of time. And though there are means by which the progress of a siege may be accelerated on the one hand, or retarded on the other, the chief attention of either party is directed to the ultimate attack and defence of the main rampart of the place by the passage of the ditch. And it is almost certain that no general will storm a breach unless the guns flanking it are either partially or wholly silenced. Therefore, if we are to judge of the destructive effects of rifled ordnance by what experiment has demonstrated up to this time, we must more than ever direct attention to the scientific defence of the ditch; for even if that portion of a fortress which is above the level of the ground be pounded into a chaotic mass, and all cover but bomb-proofs destroyed, the besieger is still far from his object, if the means of defending the ditches remain efficient.

As in most cases, ditches have been hitherto flanked by guns on the terrepleins of the bastions, owing to the objection to casemates generally conceived in the beginning of the 18th century, so now, as these objections are considered to be done away with, casemated means of flanking are being adopted, but with one or two exceptions invariably in the escarp or in the caponiers connected with it.

By experiments fully described in Vol. X, Corps Papers, it has been shown that unseen walls can be breached with rifle projectiles. I believe I am not wrong in stating that the power of rifled guns to discharge a projectile with equal effect in a curved flight, is not limited as to range; so that the prolongation of a ditch, the flanking fire of which must be destroyed, can be more easily taken up, now that the range of our guns allow of more choice of position. Indeed, as far as experiment goes, it has been ascertained roughly, that a projectile from a 40-pr. Armstrong gun, at ranges varying from 700 to 1,600 yards, with about seven or eight degrees elevation, will have an angle of descent giving a fall of about one in thirty. In the modern system, then, where a considerable distance intervenes between the crest of the glacis which conceals the flank and the flank itself, it is possible to strike the revetting wall, and if the tenaille was shortened to admit of casemated guns in the flank, the guns would soon be disabled, or such a mass of debris would be brought down as at length to mask them. Without therefore taking into consideration the advantage attainable by the possibility of placing the besieger's guns on an elevation (and such is also likely to arise), we may now safely conclude, that in all cases where the prolongation of a ditch can be taken up, the flank which enfilades it is liable to be struck from a distance. Such being the case, we may believe that a besieger will endeavour to destroy it and cross the ditch by escalade, rather than be obliged to crown the glacis by the slow approach of a siege.

The next point to consider is, the probability that in future sieges the besieged will be able to retard the near approach of the besieger for a much longer period than heretofore: but to enlarge on all the speculations on this subject, would require much knowledge and experience, and more than the mere theoretical data now in our possession. Should such be the case, however, the besieger will be retarded in achieving what is all important to him, viz: the coming within mining distance of the counterscarp casemates which it is indispensable for him to destroy. While on the other hand, should the ditches of the fortress be flanked by escarp casemates, his whole object will be directed to breaching them from a distance. Having accomplished which, it is open to him to cross the ditch by escalade with comparative impunity, as regards such an attempt in the other case.

My chief reason for supposing that the besieger's near approach will be a much longer matter than heretofore, is founded on the supposition that iron cupolas or turrets will be erected in fortified places. A few of them in slightly commanding positions, would give the besieged such a superiority as almost to prevent the besieger getting a gun in position and working it; for what earthen embrasure will not be destroyed by an elongated shell projected by a rifle gun? And although something has been mooted about a means of plating the embrasures of field batteries, the practical difficulties in the way are very great, both as regards application and transport. At any rate, it will be conceded that if batteries are raised or half sunken, the parapets must be considerably thickened; data for which will probably be arrived at in forthcoming experiments. To thicken parapets earth must be excavated, and without mechanical aid more time will be required. Trenches must be opened at a greater distance and embrace a wider extent, and approaches will be lengthened. Every yard of distance and every obstacle to rate of progress will increase the time of execution.

The question of time will not be influenced, even if the means of attack and defence were to resolve themselves into the same relations that they have hitherto held to one another. Before fire-arms were in use, the fortified place was much oftener impregnable than was the case after their introduction; not that the defenders could keep the besieger at a distance, but through the difficulty and length of time required, to destroy the ramparts and means of offence and defence of the besieged. The case has in some respects returned to its original circumstances, except that the near approach of the besieger is prevented, and he must now destroy these means of offence and defence from a distance. And if the ditches are flanked by counterscarp casemates, the destruction of the upper defences, and consequent approach by sap, is only the signal for a description of warfare where his preponderance of metal gives him very little advantage.

The only means of destroying or seriously injuring casemates or galleries in the counterscarp, is by mining, and to do this the besieger must have approached the point within a short distance, say 50 yards. Should he, at length, be in such a position, the possible existence of rocky ground would be a serious impediment; and the knowledge of the direction of his attack on the side of the besieged, raises the countermine nearly to an equality with his mine. Although victory is generally the reward of the besieger in a subterranean war, yet we have only to read the opinion of most writers of experience to find that they deprecate its adoption whenever he can avoid it. The siege of Bergen op Zoom, in 1747, illustrates the delay attending the necessity of adopting this means of attack, when the besiegers were delayed forty days in prosecuting the destruction of the counterscarp defended by countermines, during which time about sixty mines were exploded on either side. Also the siege of Schweidnitz, in 1762, when after fifty-three days of attack, twelve of which were occupied in mining, the destruction of the counterscarp succeeded thus early only through the desire of the besieged to avoid sacrificing their principal gallery. And in our own time, I may quote the defence of Lucknow, when skill and energy enabled the defenders to destroy nearly every mine, constructed by men whom they had themselves trained in mining, but who lacked the leadership necessary for the carrying out of such a mode of attack.

As regards the next objection to counterscarp casemates, viz., the difficulty of their communication with the interior, I can only point out that in practice it does not exist; and that the many cases lately where galleries have been constructed under dry ditches, the ascent and descent of the stairs and passages has been found safe and easy. The engineering difficulty in constructing a gallery under a wet ditch can be overcome by laying one thickness of bricks in asphalte. Gunners will work their guns well, as long as they know that their retreat is not cut off; and in some respects, should the enceinte be captured, their position is a better one than that of the defenders of the breach, who would receive no quarter; whereas, men shut up in a casemate, which could not easily be forced or destroyed, might make terms for their lives. However, this is presupposing that the besieger would breach and storm the escarp without having previously destroyed the enfilade fire of the ditch.

In the third place, objection has been made to placing counterscarp casemates in the salient of the bastion on account of the guns firing across one another; but in the case of either one or both the faces of the bastion being assaulted, it is evident that after the first discharge the gunners would only have to fire straight to their front, the nature of gun and projectile being short 8-inch with grape or canister.

Fourthly.—The fact of the guns firing towards the place would prevent the flanks being manned; but will not the fire from uninjured casemates completely raking the ditch make up for the want of it from an exposed and probably injured flank?

Fifthly.—It is said that an enemy, previous to an assault, might render these casemates useless by hanging obstacles over the ditch or rolling powder barrels down in their front; but if considered for a moment, it will be very plain that such a mode of attack could be frustrated by the most ordinary precautions.

Lastly.—It may be said that their ventilation is difficult; but it appears that owing to their unexposed situation, openings under the arch may be much larger and more numerous than usual; so that, though smoke will not quickly rise out of the ditch, sufficient air, which is all that is necessary, will be supplied.

In the foregoing remarks, it has been not only claimed for counterscarp casemates, that they have the advantage of being well protected from direct or curved fire, but that their adoption is the least expensive mode of giving a work the additional defence of countermines, compelling the besieger to attack with mines within a limited area, under disadvantages which will be evident from an inspection of any of the bastioned systems. The casemates themselves may be cheaply constructed, the piers and arches alone requiring any great strength. In new works, obtuse lunette bastions may be substituted for the existing form, the fire of the casemates from their counterscarp salients meeting in front of the curtain, or a tenaille wall, and leaving no dead space; the ravelin remaining as it is; giving a much simpler form to the existing systems, and allowing of the main escarp revetment being considerably lowered. Thus we have—the direct fire, the well flanked ditch, and less expensive construction of the German system, together with that power of checking the advance of the sap, due to the salients of the bastioned system. In old works the counterscarp casemates, together with their communications, will not cost much more than casemates in the flanks of the bastion, and certainly much less if either of the following means of protecting the latter were resorted to.

Firstly.—By plating with iron or using it in such a way in the construction as to make a wall which will resist any projectile that could strike it. Where casemates in flanks already existed, iron plating them would probably be preferred to constructing new casemates in the counterscarp salient, but even if such a decision were come to, it might be fairly asked, what mode of combining iron with brick and stone masonry, in a substantial, permanent, and economic way, applicable to casemates, has as yet been discovered? And should casemates in the flank not already exist, what objections to having them in the counterscarp overweigh the advantage of getting over the necessity of using iron?

Secondly.—By adopting the plan proposed by Mons. Piron, of the Belgian Engineers, in his Essay on Fortification, published in 1859, and one long since suggested by Marshal Saxe and others of his time; which is, to protect the face of a casemate by the erection in front of it of a detached "couvre face," something in the form of a bridge, the piers and arches of which coincide with those of the casemates. Though not coming up to what is claimed for tunnel embrazures by their inventor, it is evident that while they stood they would protect the casemate from the curved fire of the besieger, except perhaps in the case of a shot grazing the bottom of the ditch at a very low angle, to which rifled projectiles have a known tendency. It would however be possible to achieve their demolition by elongated shells, the destructive qualities of which are not taken into account in Mons. Piron's calculations; resulting in the exposure of the casemates, or their guns being more or less masked by the debris. In itself the "couvre face" may be objectionable. First, owing to the difficulty of adapting it to many old works, without a most costly reconstruction of the orillons of the bastion. Secondly, that although giving a very perfect system of ditch defence as applied by Mons. Piron to the German system, and illustrated in his "Decagone à caponnières," it entails a large amount of ditch excavation and revetment. To those who would enter more fully into the study of this subject, I recommend his most interesting essay.

Other modes of protecting a flank from curved fire, such as deepening the ditch, or erecting bonnettes on the glacis, might be suggested; but these again, while they correct one evil create another.

In concluding, I have to apologise for occupying so much space in trying to prove the advantage of a system of ditch defence, the existence of which already in a few situations shows that it has been previously adopted. So I must again remind my readers that the argument is based on certain presumed changes in the mode of attack and defence of fortified places, due to the introduction of rifled arms; and that the desire of the Inspector General of Fortifications, expressed in a circular to the Corps in 1857, binds every officer to make the results likely to arise from these changes a matter for thought and examination.

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Woolwich, 28th May, 1863.

PAPER VIII.

ON PONTOONS.

By LIEUT. COLONEL J. W. LOVELL, C.B., R.E.

Without entering into the question of the precise meaning of the word pontoon, I propose to use it in this paper simply as the name now generally given to those vessels which form part of portable bridge equipments, and which are used as the supports of the roadway where a floating bridge is required. It must be borne in mind, however, that the bridges so formed are purely for temporary purposes, and should always be replaced as soon as possible by others made of stronger and more durable material, whenever it is necessary that communication across a river should be of permanent character.

These floating vessels have been made of many different forms and sizes, and of almost every description of material which could be made available for their construction. The great objects sought for in all the various changes being the efficiency of the bridge in respect to mobility and power of support. However, as great difficulty has been experienced in the combination of these two essential qualities, we find that in most systems one or the other has been sacrificed according as the minds of the inventors have been biassed by what they have read or seen of the causes of failure of bridge equipments; and while history records many failures of bridges through the latter, which is the most important quality, having been neglected to insure the former, it also presents several instances where skilful combinations of strategical operations have been frustrated in consequence of the tardiness of movement of the bridge equipments.

The onus of these failures is generally laid upon the pontooners, and most probably the same would be the case in any future similar occasions, and it is, therefore, incumbent upon the Royal Engineers, who are the pontooners of the British Army, as they value the credit of the Corps, to make themselves acquainted with the requirements of bridge equipments, and to ascertain how far these would be met by the material with which they would be furnished for the formation of military bridges in time of war.

In studying the pontoon equipment of bye-gone days and those of the present time, every person must be struck by the great differences which have existed, and which do exist, not only in the floating power or buoyancy of each vessel of the different equipments, but also in the total power of support given to the roadway of the bridge.

At the first glance it is evident that within certain limits it matters but little whether the total buoyancy required to support the roadway is made up by a large number of small, or a small number of large vessels, provided that the aggregate is equal to the load which can be brought on the bridge. This, of course, refers merely to the question of buoyancy, as other considerations do exist which would lead to the preference of either large or small vessels, but at present these will not be taken into account. Now, the load which a military bridge is required to support is only that of the various component parts of an army under the several conditions in which they may be met in war; and we all know sufficient of the organization of the armies of the principal nations in the world to be aware that the load to be expected must be the same for every bridge equipment, and, therefore, the power of the bridges need not vary on this account. Again, although the rivers in various countries differ very much in their width, depth, and in the strength of the current, &c., yet bridge equipments should be constructed quite as much with the view to their employment in our neighbour's as in our own country, and here, therefore, we can discover no good reason for the difference of power which I have noticed.

In order to facilitate the consideration of the power of a bridge to support a load, which is the quality of primary importance in all equipments, I have prepared a table showing what is the actual power of several equipments of which I can find authentic accounts. That power has been calculated as follows:— From the total displacement of the pontoon has been deducted its own weight with that of its fitments, together with that of one bay of the superstructure, and the remainder is the entire power of support of the pontoon. In the case of open pontoons, one-fourth of this remainder, and in closed vessels one-tenth, has been deducted as surplus buoyancy, and this second remainder being divided by the interval at which the pontoons are placed in bridge has been taken as the power of the bridge per lineal foot of roadway, which is shown at column 11 of the table. In the next column is shown the greatest weight which can be brought on the bridge, calculating at 110 lbs. per superficial foot of the roadway, and as the width of the roadway varies in many systems, you will notice that the maximum load also varies very considerably. In the next column is shown the greatest ordinary load, which is about 560 lbs. per lineal foot of the roadway, and is, therefore, the same for all equipments of which the roadway has a width sufficient for infantry marching in fours.

The first pontoon on the table is that proposed by General Gribeauval, and which was always found to be of sufficient power to allow the usual loads to pass over it, but I cannot trace any record of its having been very severely tried at any time. The pontoon of this equipment was carried on one waggon, and the superstructure on another, but even then the waggons were so heavy that it was found impossible for them to accompany the army in rapid movements.

The second pontoon is that constructed by the French upon the model of the Austrian pontoon, which was in very general use on the continent of Europe about the end of the eighteenth century. It is recorded of this pontoon that bridges formed with it failed three times on account of insufficient buoyancy, and the great obstruction caused to the flow of the current in the streams in which it was used; and in the retreat of the French army from Russia, the equipment, of which this pontoon was the basis, was so unwieldly, that to prevent its falling into the hands of the Russians it was burnt, although at the time the French pontooners well knew that in a few days they would be called upon to form a bridge for the passage of the French army over the river Beresina. The pontoon and the material for one bay was carried on one waggon, which, when loaded, weighed 5,800 lbs. These pontoons have been introduced chiefly as standards to which to compare those of other systems.

The third and fourth pontoons are those which were in use in the French army until 1853. The former was carried with the rear guard of the army. The latter accompanied the advanced guard, and was introduced because the reserve equipment had not sufficient mobility. Finding that the plan of keeping up two different equipments was attended with many inconveniences, besides being very uneconomical, the French, in 1853, abandoned these two equipments and adopted that which stands fifth on the list, and of which the pontoons are of similar dimensions to those of the former reserve equipments, but the material of which they are constructed is of a lighter description, the bottom and sides being of fir planks about 1 inch thick, nailed to a framework of wooden ribs 3 inches by $2\frac{1}{4}$ inches. The bateaux are quite open and have a flare bow and stern, the latter being rather shorter than the former. As ordinarily arranged in bridges, these bateaux are placed at intervals of 19 feet 8 inches, when, as is seen by the table, the bridge has a power of 644 lbs. per lineal foot, and is quite equal to any ordinary load. When required for extraordinary loads, the necessary power is obtained by diminishing the intervals between the pontoons. In order to support 110 lbs. per superficial foot of a roadway 10 feet wide, they would require to be placed at intervals of 11·9 feet, and the obstruction to the passage of the water which would then be offered by the bridge would be so great that in a rapid river the bridge would be liable to be swept away; comparing this equipment with the two proposed as standards, it will be seen that it has only about three-fourths of the power of that which has failed, and about one-half of that which has been found efficient. For transport, two pontoons and the material for the superstructure of two bays of the roadway are subdivided between three waggons, each drawn by six horses, and weighing about 4,670 lbs. (778 lbs. per horse). The anchors, of which one is allowed to each of these bateaux, weigh about 145 lbs. Finding that these bateaux, in consequence of their great length, are very unwieldly when loaded on their waggons, the French pontooners have lately proposed and made an equipment of demi-bateaux, each of which is just half the size of those which they at present employ and with the buoyancy of which they express themselves as being perfectly satisfied. This step, however, is merely the same as the first of those taken by Birago and Cavalli; and, as the latter found that the demi-bateaux were not convenient for bridge making, and, therefore, gradually increased their length until they again became simply long bateaux with square sterns; while the former found that the two demi-bateaux, when joined together, were inadequate to the support of the bridge, and, therefore, introduced a middle piece; we naturally conclude that the French, also, will be led on to something of the same kind. The great defect of the French bateaux appears to be their want of buoyancy, and the impossibility of forming a bridge capable of supporting the maximum load which may be brought upon it, without at the same time increasing to a dangerous extent the obstruction offered to the current, and it should be borne in mind that pontoon bridges fail quite as frequently from being washed away by the current as from insufficient buoyancy. The French have discovered the inconvenience of the great length of their pontoons, and this they are now attempting to remedy.

The baulks of this equipment are laid with double bearings; that is, they extend across both the bateaux on which they rest, and must, necessarily, be very long (26 feet 3 inches) and unwieldly for transport; with the idea of making them pack in a smaller space, it is now proposed by the French to make them in three pieces, that part which extends between the bateaux being in one piece, and those which lie across the bateaux being attached to it by hinges so that they can be folded together, and thus lie more compactly for transport.

The French have made many experiments as to the material which is best adapted for covering their pontoons, and have decided that wood is preferable to all others as yet brought to their notice. The sheet iron corrugated according to Mr. Francis's pattern they condemn, on account of its being so difficult to repair when injured; and flat sheet iron they disapprove of for the same reason, and they also say that it is found by experiment that the injury caused by a blow of a rifle bullet is much less in a pontoon covered with wood than in one covered with flat iron of strength equal to the wood of their present pontoons. Copper and tin, as well as canvass, they have also tried, but have found cause not to adopt them.

Omitting the English pontoons, the next which we come to, at line 16 of the table, is that of the Austrian, or Birago pattern, which is now so generally employed by continental armies. I have made an abstract of the original pontoons of this pattern, and of those which are now adopted in Austria, in order that the two may be compared. The original pattern was of fir planking nailed to a wooden framework, and the pontoon was formed of several pieces of two different forms, one called the bow piece, the other the prism or middle piece. These are provided in the bridge equipment in the proportion of 8 of the former to 7 of the latter. When used to form a bridge, each supporting body is made by coupling together two bow pieces, or a bow and middle piece, or by fixing a bow piece to each end of the middle piece, the latter method being adopted only when great power of support is required. The interval in bridge is always the same, being determined by the length of the baulks, each end of which is provided with a cleat having a notch cut in it to clasp a strong beam or transom, which lies over the axis of the pontoon, and is supported at its centre by a block resting on the connection of the two pieces of the pontoons, and at its ends by two transoms laid across from gunwale to gunwale. The baulks are not lashed to the pontoons, and the transom is only secured at its middle to a crutch which turns upon a pivot, by which means, in a river where the current is oblique to the direction of the bridge, the pontoons may be moored so that they may place themselves parallel to the direction of the current without disturbing the alignment of the roadway. This is supposed to be a great advantage, but in the war of 1859 in Italy, the Italian pontooners found that this freedom of motion was attended with such danger to the bridge that they adopted a plan for securing the transom firmly to the pontoon. The baulks rest entirely on the transom, and do not bear in any way on the sides of the pontoon, which therefore, has nothing to keep it level in the water, and should the transom not be exactly over the axis of the pontoon, that side to which it is nearest bears most of the weight, and is, of course, most deeply depressed; the pontoon, under these circumstances, appears liable to be filled by the waves when the bridge is under any heavy load. The middle piece has the form of a truncated prism, being 11 feet 4 inches long, 6 feet $1\frac{1}{2}$ inches wide at the top, and 4 feet 6 inches wide at the bottom, and 2 feet 5 inches deep in the original pattern, and 11 feet 4 inches long, 6 feet $2\frac{1}{2}$ inches wide at the top, and 5 feet $8\frac{1}{2}$ inches wide at the bottom, and 2 feet 7 inches deep in the new pattern; the additional width in the bottom having been added in consequence of experience having shown that the original pattern was not sufficiently buoyant, and the additional height or depth was added with a view to obviate the necessity of making use of a canvass wash streak, which was placed on the gunwale in windy weather to prevent the waves from washing into the original pontoon. The prow, or bow piece, of both patterns has a square stern, at which point, and for a distance of 8 feet, the transverse section is the same as that of the middle piece, the prow piece is 14 feet long, and has a flare bow, and the sides gradually curve in, so that at the bow the distance between the gunwales is 3 feet 10 inches. The object of this sub-division of the pontoon appears to be to make the equipment more mobile, and at the same time to make provision for adding to the power of the bridge, when necessary, without increasing the obstruction opposed to the flow of the current. The pontoons—when the bridge is prepared for ordinary loads—are formed of one bow and a middle piece, or two bow pieces; and when prepared for extraordinary loads of two bow pieces and one middle piece. In the original equipment two kinds of anchors were used, one weighing 148 lbs, and the other 99 lbs.; in the new equipment the large anchor only is employed, the other having been found to be inefficient. With regard to the power of the bridges formed with the pontoons of the original pattern, which were made of wood, it will be seen that when they consisted of two pieces coupled together, it was about five-eighths of that which failed (No. 2 on the table), and about five-twelfths of that which was efficient (No. 1). When the pontoons were made of three pieces, the power was raised to about the same as that of No. 2, and about two-thirds of No. 1. In neither case was the bridge equal to the theoretical load. As might naturally be supposed, these original bridges were found to have insufficient buoyancy, and others of the new pattern were constructed which gave to the bridge, when prepared for ordinary loads, a greater power than is theoretically necessary, and when prepared for extraordinary loads a power nearly equal to the maximum weight which can be brought upon it. It appears doubtful, however, whether even these large pontoons have sufficient power; the roadway is narrow, 9 feet 4 inches, as is seen by column 14. The Austrians now make their pontoons of flat sheet iron, which they prefer very much to wood, or to corrugated iron. The different parts of the pontoons are coupled together by hooks at the bottom, on the plan proposed by the Belgians, and by screw bolts at the top. Some of the Austrian pontooners complain that their bridge material is not sufficiently simple, but it is almost universally employed, wholly, or in part, by the nations of Europe, and, therefore, must be supposed to have some good qualities.

Combined with this pontoon equipment is an arrangement of trestles which can be used in the water, or on the pontoons resting either on planks on the bottom, or on baulks laid over the axis of the pontoon. These trestles stand on only one leg at each end; the stability of the bridge, therefore, depends entirely on the continuity and strength of the connection between its several parts and the banks at each end. When used in the water these trestles offer but little obstruction to the flow of the current, and as they are easily manipulated are very useful in rivers not liable to sudden floods, but as the height of the transom cannot be quickly altered to suit the varying level of the water, they are not adapted to rivers affected by tides or other causes of rapid rise and fall. The baulks used with the Austrian pontoons are 21 feet 8 inches long, and as they are transported on the same waggons as the pieces of the pontoon, it does not appear that any advantage with respect to turning the carriages in narrow roads is gained by the latter being made so very short.

The Prussian pontoon is the next on the table, and here again I have abstracted the dimensions, &c., of the pattern which has been lately abandoned, and of that which has taken its place. The former was made entirely of wood, the latter is entirely of iron, with the exception of the gunwale and the fenders which are placed on the outside of the bateaux. As in the Blanshard system, the Prussian bridges are formed with the pontoons placed at intervals which vary according to the nature of the load for which they are intended; the pontoons of the original pattern, *vide* lines 22, 23, 24, and column 11 of the table, are not equal to the greatest of the ordinary loads, even when they are placed at the close order intervals. The bridges formed of the new pattern are all equal to the greatest ordinary load, but when the pontoons are at close order the bridge has not more than three-quarters of the power required to support the greatest load which can be brought upon it. There can be but little doubt that the Prussian bridge equipment would fail if brought to a really severe test; and I understand, now, that it is not yet decided to adopt the pattern of which I have last spoken. The Prussians make use of two kinds of anchors, one weighing 150 lbs., and the other, which is more generally employed, about 100 lbs. Experiments have been tried by the Prussians with a view to ascertain whether corrugated iron would answer as a covering for the pontoons, but they have rejected it on account of the difficulty of repair.

The next pontoons on the table are those of the Italian army, invented or proposed by General Cavalli. His original pontoon was formed of two pieces, each of which had a buoyancy equal to about that of one of Birago's prows, and half of one of his middle pieces; and Cavalli's idea was to use these demi-bateaux singly for ordinary loads, and to couple two together when the bridge was required for extraordinary weights. As will be seen by reference to columns 11 and 12 of the table, they were not equal to the loads; the power of the bridge when they were used singly being only 402 lbs., and when used in twos, coupled together, 878 lbs. per lineal foot of bridge, while the weights to be borne were respectively 560 and 1,082 lbs. The power of the demi-bateaux was then increased by adding 5 feet to their length, making them 24 ft. 6 in. long, 5 ft. 9 in. wide at top, and 4 ft. 4 in. at the bottom, the depth being 2 ft. 10 in. With these dimensions the power of the bridges was increased to 551 and 1,178 lbs. respectively, which is sufficient to satisfy the requirements of an army. However, owing to the great length of the demi-bateaux, the strain upon the junction of the sterns becomes so great that, without special means are taken to strengthen the bateaux, the bridge is not safe. The anchors employed weigh about 132 lbs.

Cavalli's original baulks were made with a large hinge in the centre, so that they folded to half their length for transport. It was, however, found to be so difficult to make these hinges exactly similar, so that each baulk might take an equal share of the load, that they have been abandoned, and baulks in one piece have been adopted instead of them. These baulks do not cross on the bateaux, but their ends abut against a raised rib in the middle of a long plank which is supported over the axis of the boat on bearers laid from gunwale to gunwale. Close to the ends of the baulks a hole is bored, which being passed over a pin in the longitudinal plank on which they rest, prevents the bateaux from parting asunder. Were it not for the weakness of the juncture of these bateaux, and their great length for transport, they would appear to be very well suited for bridge purposes generally.

The Russian canvass pontoon is the next of which I have to speak, and its dimensions, &c., as shewn at lines 36, 37, 38, of the table, are length 21 feet, width over all 5 feet 3 inches, and depth 2 feet 4 inches, the bow and stern sloping at an angle of 45°. They consist of two side frames, which are kept asunder by cross bars at the top and bottom, and the whole is bound closely together by means of ropes which are twisted taut as with a tourniquet, a canvass cover is then stretched over all, and secured to the framework by nails. The pontoon is very quickly put together, and, with one bay of its superstructure, is carried on a waggon. On account of the small amount of buoyancy in these pontoons they are placed very close together, and the flow of the current is very much obstructed; the power of the bridge thus formed is equal, and indeed rather exceeds the greatest ordinary load on the bridge, but is far below the greatest extraordinary load. The displacement given in the table is that due to the form of the pontoon without any deduction for the loss of buoyancy, caused by the bending in of the canvass when the bridge is heavily loaded. The frames of these pontoons will last about 14 years, and the canvass about 7 or 8 with care; but I do not think they are very efficient, and as the Russians make use very much of Birago pontoons, I believe they do not quite approve of their own, and in a few years they will probably be given up.

The Dutch pontoon—lines 39, 40, 41, of the table, is of wood, and is much of the same form as the Prussian pontoon. It is, however, divided into two pieces for the convenience of carriage; its absolute buoyancy is rather more than that of the Prussian pontoons; but from the intervals at which they are placed, these bridges have less power than those of the Prussians, and it may be expected that they would be found inadequate to the purposes of war.

The Belgian iron pontoon is the last of which I have to speak—lines 42, and 43 on the table. These pontoons are in the form of an open demi-bateau, with a square stern, and a boat-shaped bow; their dimensions are nearly the same as those of the last pattern of the Cavalli pontoon, and they are proposed to be used in the same manner; that is, the bridge when intended for ordinary loads is formed with single demi-bateaux, and when for extraordinary loads, with two bateaux coupled together by the stern; the bridges so formed have ample buoyancy for the loads which may be brought upon them; being of iron, the connections are more secure than in the wooden bateaux of the Italians. This pontoon, however, is peculiarly liable to the objections urged against all open vessels, which is their liability to be filled and swamped by the waves. The greatest width of the bateaux is about 4 or 5 inches above the water line when the bridge is not loaded, and the sides fall inwards towards the top about 6 inches, thus forming as it were an inclined plane up which the waves can easily pass. The bows of the pontoons are of the boat shape for some distance above the water line, and then spread out until at the gunwale the bow is about 2 feet wide; the bateau, thus, not only has a good cut water, but is protected against the wash of the water which curls up in front when a heavy load is crossing over a bridge formed in a strong stream. The construction of the bateaux is simple, and they are very durable; some which had been in constant use for 14 years showing no sign of decay.

The Belgian equipment is also provided with trestles of a very ingenious construction. They consist of a strong beam or transom, on which rest the baulks of the roadway, and which is supported at each end by a sliding bar or yoke moving up and down two of the legs of a tripod, and capable of being adjusted and secured at any height by pins passing through the legs. These trestles can be used either in the water, or supported on the demi-bateaux, and as the sliding bars can very easily be raised or lowered, they are peculiarly suitable for employment in tidal rivers. One great objection to the Belgian equipment is, that the pontoons are heavy, and the loaded waggons are long, and not easy to turn in narrow roads; the baulks are 26 feet 3 inches in length, and the waggons weigh when loaded 4,410 lbs., requiring 4 horses to draw them. Taking the equipment altogether I have no hesitation in saying, that it appears to be the simplest and most efficient yet produced.

Having now described, in a very general manner, some of the pontoons employed by the nations on the continent of Europe, I purpose to notice the most important of those which have been tried in England, confining my observations chiefly to those matters which have reference to the question of buoyancy, and I would call particular attention to the very small capacity which the inventors of these systems appear to have considered necessary for each of the floating supports of the bridge, and also the great want of power in the various bridges formed with them.

It must be borne in mind also that none of these equipments have been brought to the test of actual warfare in a campaign where their merits could be fully proved. Some of them, I believe, were used in India, but I have not been able to obtain any impartial account of the experience of the officers who had charge of them.

The old English pontoon which was used by the British Army in the Peninsular War was of almost the same pattern as those which had been employed by the continental nations in the middle of the eighteenth century, and having been found inefficient had been abandoned and replaced by others of nearly double, and in some cases, of more than double their capacity. According to Sir Howard Douglas, these pontoons or bateaux were made of a wooden framework covered on the outside, and lined on the inside with tin, the sides, bottom, and ends being double, with a view to security against leakage, and forming also a water-tight chamber to prevent the pontoon from sinking in case of being filled with water. In plan the pontoon was rectangular, the bottom was flat, and the sides rose perpendicularly from it, the ends having an inclination of 45°. The length was 21 ft., the breadth 4 ft. 10 in., and the depth 2 ft. $10\frac{1}{2}$ in., the weight 1,050 lbs., and the buoyancy 13,092 lbs. These pontoons were given up on account of their unwieldiness, their liability to be submerged, and the great obstruction which was opposed to the current by the bridges formed with them. On the continent they were succeeded by others of the open or bateau form; but in the English Army, in 1814, Sir James Colleton, of the Royal Staff Corps, who witnessed several of the failures with the old English pontoon, conceived the idea of using closed vessels of a very ingenious design, which had the advantages of being cheap and light, and at the same time of such simple construction that they could be made in a very short time by moderately skilled workmen. Using his own words:—"The general idea was a buoy of a figure between that of a cylinder and one formed by the junction of two cones at the bases, the diameters of which are 4 ft., and the length 21 ft., which figure (supported at the centre by a slight wheel with another 6 ft. at each side of it drawn together by hoops of iron, or copper, keyed on both sides, and coated with mineral tar) is intended to stand in the place of the common pontoon both in the water and on the carriage ... the packing of the buoys might be rendered much easier than that of the common pontoons by taking off the hoops, and packing up the staves in a small compass." These buoys were proposed to be employed in pairs yoked together with an interval between them so as to form small rafts which could be used in the place of one of the old pontoons, and for the transport of heavy artillery several were connected together to form a large raft.

Sir James Colleton also proposed smaller buoys 20 ft. long, and 2 ft. 4 in. in diameter, two of which were to be carried on one waggon; and he also proposed that a vessel of tin or copper should be used inside the staves. In 1819, these small buoys were divided into two parts, and an increase of power and stability obtained by the addition of a cylinder 4 ft. in length which was introduced between the two end pieces. One of these buoys was made in 22 hours by 10 artificers, and cost £10. The staves were 1 in. thick, and 6 in. wide, the bows were made of various forms, some were conical, and some were in the form of a semi-spindle, the apex being in some cases in line with the axis, and in others with the circumference of the pontoon. This mode of construction, if not exactly suitable for a permanently organised bridge equipment, might be very useful for temporary purposes where small means only are available.

The late General Sir Charles Pasley, to whom the Corps of Royal Engineers owes so much, was early in the field with various projects for the improvement of the British pontoons, and after many years of study and practice he produced the system which I have included in the table, and upon which he was engaged at the time of his death. Each of the supporting bodies of his equipment consists of two demi-bateaux coupled together by the stern; they are made of copper sheathing on a framework of wood or copper, and are closed above by a wooden deck, the transverse section being a rectangle 2 ft. 9 in. wide, and 2 ft. 5 in. deep, the lower angles being rounded off by quadrants described with a radius of 13 in.; the bow is similar to that of a boat, with a small cut-water which is continued into a keel along the bottom; these demi-bateaux are connected below by a rope lashing which is rove through holes in the ends of the keels, and above by other lashings which are secured to ring bolts fastened into the decks. The baulks rest on, and are pinned to, gunwale pieces which lie on the deck, and are secured to it by rope lashings. These gunwales consist of two beams of wood connected together by a pair of long hinges in such a manner that they fold close together for transport, and open out to such a width that the bearers rest over the gunwales of the pontoons. As these gunwales have not sufficient stiffness to support the weight of the loads passing over the bridge, the strain upon the keel lashings is so great that they break, and thus endanger the load.

Sir C. Pasley increased the thickness of the chesses from 1½ in. to 2½ in., but does not give any reason for so doing. The interval at which these pontoons were supposed to be placed in bridge was 12 ft. 6 in., and the bridge then had a power equal to 481 lbs. per lineal foot of roadway, and when arranged for the standard loads of 560 lbs. and 1,100 lbs., the intervals would require to be made 10·95 ft. and 5·86 ft. Each pair of demi-bateaux and the superstructure of one bay was intended to be carried on one two-wheeled cart, which, when loaded, weighed 3,110 lbs., and was proposed to be drawn by two horses; the length, including the horses, being 26 ft. 6 in., which is about the diameter of the space in which the cart could be reversed. This equipment, or rather one very similar, was tried on the Medway against that proposed by the late General Blanshard, of the Royal Engineers, which then gained the palm, and still continues the established pontoon of the British Army.

General Blanshard's pontoons consist of a cylinder of tin with hemispherical ends, the length being 22 ft. 4 in., and the diameter 2 ft. 8 in. The weight of one cylinder is 464 lbs., and the displacement is equal to a buoyancy of 6,785 lbs.

Before the cylinders can be used for the supports of the bridge, a saddle weighing about 90 lbs. must be lashed to them for the support of the baulks, which are secured to the saddles by horizontal pins. The interval in bridge varies according to the nature of the load which is expected, the greatest being 12 ft. 6 in., the least 8 ft. 4 in., and the intermediate 10 ft. 5 in., the powers of the bridges so formed being 373, 581, and 476 lbs., and in order to support the standard loads of 560 and 1,100 lbs. it is necessary to make the intervals 8·64 ft. and 4·55 ft. This equipment is supposed to possess great mobility, the two cylinders and two sets of superstructure being carried on one waggon, which, when loaded, weighs 4,800 lbs., and is intended to be drawn by four horses; never having been tried on service, there is no sure record of this quality of the equipment, but from what has been said of the results of experiments in peace time, there is little doubt in my mind that the equipment will break down under the test of actual warfare.

Bridges formed with these pontoons having proved very unstable and lively under a passing load, Mr. Forbes, who was for many years a sergeant-major in the Corps of Royal Sappers and Miners, proposed to remedy these defects by giving to the pontoons a triangular section, the sides of the triangle being arcs of circles, of which the chords were 2 ft. 8 in., and the versed sine ⅛th of the chord, the ends being pyramids of which the altitude was 2 ft. 8 in. This section increased the weight of the pontoon, but gave a continually increasing area of bearing surface up to nearly the total immersion of the pontoon, thus increasing the stability of the bridge. It was also considered that this peculiar form would give increased facility for the pontoon to pass through the water, or which is the same thing, would reduce very much the pressure of the current upon the bridge. On trial it was found that the angles were so liable to injury as to counterbalance any advantages which this pontoon might be supposed to possess.

Captain Fowke, of the Royal Engineers, is the next who appears as an inventor. His pontoons when complete are 24 ft. long, and have a flat bottom 2 ft. 8 in. wide, with curved sides inclining outwards until at a height of 1 ft. 9 in., the width is 5 ft. 3 in., whence they fall in again until the top is 2 ft. wide. The bow and stern have an inclination of 35°, and are covered in for a length of about 4 ft., the remainder of the pontoon being open. The covering is waterproof canvass attached to a number of distinct ribs, so that for transport it can be collapsed like the bellows of an accordion, and when required for a bridge it can be extended by two stretchers, which pass through the stern transom and through a number of loops of iron on the top of the ribs, and fit into sockets in the bow transom, the stretching being effected by means of screw caps, which are applied at the stern end of the stretchers. On the outside of the canvass at all the frames are ash hoops, which are intended to form a case for the canvass when folded up, and to protect it from injury against stones, &c., when extended and used as a pontoon. The weight of a pontoon and its stretchers is 403 lbs., and the buoyancy due to the outline form is 13,594 lbs., but is reduced to 8,456 lbs. in consequence of the concavities formed in the canvass between the ribs by the pressure of the water on the outside. These pontoons are proposed to be placed in bridge at intervals of 10 ft., the power of the bridge being then 541 lbs., and in order to support the standard loads of 560 and 1,100 lbs., the intervals would require to be made 9·702 ft. and 5·07 ft. By experiment it has been found that the pressure exerted by a current upon a bridge formed with these vessels is about three times as much as that upon a bridge of equal power formed of Blanshard's or Pasley's pontoons, in consequence of the inequalities of the surface; and until this defect is remedied, the risk of the bridge being carried away by a strong current would prevent the adoption of these pontoons for the general use of an army, although there can be but little doubt that they might be most useful in desultory operations.

Many trials have been made in England and in some of her foreign possessions with the American pontoons, which, as is well known, are air-tight bags made of canvass prepared with india-rubber, and which can be inflated by means of bellows, and then form cylinders 22 ft. long and 1 ft. 8 in. in diameter. Any number of these cylinders can be connected to form a pontoon, but the normal number is three, the weight of which is 420 lbs., and the buoyancy, when completely inflated, 8,125 lbs. According to the load which is expected, the intervals at which the pontoons are placed in bridge vary from 18 ft. to 14 ft. 8 in., the power of the bridges being then 307 and 393 lbs., and in order to support the standard loads of 1,100 and 560 lbs., the intervals would require to be reduced to 5 ft. 7 in. and 10 ft. 9 in. The great objection to these pontoons is, that the buoyancy depends on the material being perfectly air-tight, a condition which practically it is almost impossible to maintain during the vicissitudes of war.

In the foregoing summary I have purposely abstained as much as possible from noticing any qualities of the pontoons except those which relate to their buoyancy. On reference to the table which is attached to this paper, it will be seen that pontoons have varied in dimensions from those which weigh 4,500 and 5,000 lbs., have a buoyancy of 45,000 lbs. and require one waggon and 12 horses for their transport, without any superstructure, to others which weigh 403 lbs., have a buoyancy of 8,400 lbs., and of which three, with the superstructure of three bays of the roadway are intended to be carried on one waggon drawn by four horses. In the powers of the bridges a remarkable difference will also be perceived, extending from 1,215 lbs. to 393 lbs. per lineal foot of roadway, in bridges arranged for the same description of load.

In most of the accounts which have been written by the inventors of different systems of pontoons, the comparisons, into which they enter, appear to be made almost entirely with those of other inventors, rather than with the actual requirements of service, and I have not been able to trace any clear chain of reasoning which has been followed in the arrangement of any equipment, although there is something to be learned from almost all who have written upon the subject.

Birago and Cavalli give more information than any other writers with whom I have met; and Captain Thierry, of the Belgian Army, must have well understood his subject when he developed his system, which in all its details bears the impress of having been well thought out by a clear practical head with good powers of invention. Unfortunately, I have not been able to find any of his memoirs.

Without wishing to be at all dogmatical, and with every desire to learn rather than to appear as a teacher of this very difficult subject, I will now state my own views of the manner in which the details of an equipment should be worked out.

A pontoon equipment consists of a certain number of waggons which accompany an army in the field, and are loaded with the material required to form temporary bridges for the passage of the army over the rivers which may impede its movements. These bridges usually consist of a platform of planks resting on a chain of beams supported at their junctions by floating vessels. There are many minor details, as cables, anchors, oars, &c., but the foregoing are those which are most important, and which must always be the chief consideration in a bridge equipment. It is evident that each of the floating bodies must have sufficient buoyancy to support its own weight; that of the baulks, which extend from it to one of the adjacent pontoons; that of the chesses which lie upon them; together with so much of the passing load as can be placed upon the roadway between the axis of the two pontoons: and as the risk of submergence of open pontoons by the wash of the waves, the drag upon the cable, and the lateral oscillations of the bridge is very great, a certain amount of surplus power must be allowed, which is usually effected by giving an extra buoyancy of $\frac{1}{4}$ of the power of support, or, which is the same thing, $\frac{1}{3}$ of the passing load. In open pontoons it is usually considered that the total buoyancy is available, but as the stability of the bridge would be destroyed, when it is loaded to the extent of its ultimate buoyancy, a certain surplus is necessary, which I have taken at $\frac{1}{10}$ of the power of support, or $\frac{1}{9}$ of the passing load. All the materials of the equipment must be transported with the army, and one of the first things to be considered in an equipment is how it is to be carried.

Captain Fowke allots three pontoons and three bays of superstructure to one waggon; General Blanshard two; the French and Sardinians two pontoons and two bays of superstructure to three waggons; the Belgians, Prussians, and Russians, one to a waggon; General Pasley one to a wheeled cart. The Austrians employ 15 waggons, which are of four different kinds, to carry $7\frac{1}{2}$ pontoons, eight trestles, and eight bays of superstructure with all the necessary tools and stores for their repair; but there is such variety in the method of packing, that confusion might probably occur were that operation performed hastily, and the loads of the different waggons, not being aliquot parts of the bridge, cannot easily be detached. The weight which is allotted to each horse which draws the waggons or carts also varies considerably; Pasley allows two horses to 3,100 lbs., or 1,550 lbs. per horse; the Russians give 6 horses to 3,780 lbs., or 630 lbs. per horse. These are two points which are open to discussion, but without waiting for that I will pass on to other matters, and return to these afterwards, supposing in the mean time that we have decided upon the weight to be drawn by each horse, the number of horses to which, for the sake of mobility, the team for each cart or waggon should be limited, and the number of waggons which should be allotted to the transport of each unit of the equipment which may be considered as consisting of one pontoon and its fitments, and one bay of the superstructure, for I do not think it would be advisable to entertain the complicated plan adopted by the Austrians. The above having been decided, as well as the particular description of pontoon which is to be adopted, the weight of the oars, cables, and minor fitments, together with that of the waggon and its appurtenances must be deducted from the total amount of draught allowed for each unit, and the remainder will be that which is available for the transport of the pontoon, baulks, chesses, and anchors, and we have to arrange the portions which should be allotted to each of these articles. For this purpose we have first to consider the weight which can be taken over the bridge, and to reduce it to the lineal foot of roadway, the surplus buoyancy being then taken at $\frac{1}{3}$ of that weight. The weight of the chesses must also be reduced to the lineal foot of roadway as well as that of the baulks; the latter is difficult on account of their scantlings varying in proportion to the interval in bridge, and the length varying according as they are laid with central or double bearings, &c.; but having decided which of these methods should be adopted, the weight per lineal foot of roadway can be obtained approximately with sufficient accuracy for practical purposes. Now knowing the weight of the pontoon per cubic foot of its displacement, which varies according to its peculiar construction, we can ascertain from it and the above weights the amount of cubic capacity which is required in the pontoon for each lineal foot of the roadway.

Let x be the	capacity of the pontoon per lineal foot of roadway in feet.			
l	,, load	do.,	do.,	in lbs.
$\frac{1}{3}l$	,, surplus buoyancy		do.,	,,
c	,, weight of the chesses		do.,	,,
b	,, weight of the baulks		do.,	,,
a	,, weight of the pontoon per cubic foot of capacity			,,

$$\text{then } x = \frac{l + \frac{1}{3}l + c + b + a x}{62.5}$$

From x by multiplying by a we can get the weight of the pontoon per lineal foot of roadway. The weight of the anchor should vary in proportion to the size of the pontoons, and must be included in the calculations; and a convenient method of effecting this is to allow a certain weight of anchor for each cubic foot of capacity in the pontoon, so that if we multiply x by this weight we shall obtain the weight of anchor required for each lineal foot of roadway. Now, if we divide the weight allowed on each waggon for the transport of these articles, (chesses, baulks, pontoon, and anchor), by their weight per lineal foot of bridge, we shall obtain the number of lineal feet of bridge which can be so carried, and multiplying this again by the number of cubic feet required for the support of each lineal foot of roadway, we shall find the total displacement which should be allotted to the pontoon.

I now propose to examine into the various points which have been referred to before. The first is the weight of load which should be allowed for each horse, and here we are met at once by the question as to the degree of mobility which the bridge equipment should possess.

In earlier times campaigns were generally decided by the fate of actions fought on well chosen ground, and the success of these actions depended more or less on the tactical movements on the field of battle. Armies manœuvred but slowly, and their bridge equipments were not required to move more quickly than the army. Rapidity in the execution of strategical movements, was next found to have a marked influence on the success of a general, and the bridge equipments were, therefore, made lighter, so that they might take their part. This rapidity of movement is now still more developed, and is developing more and more each day, while the experience of late wars has shown that armies of great numerical strength are coming into play; so that taking into account the extended range of the modern rifled arms, and the increased celerity of movement in the units of these large masses, it may be expected that battle fields will extend over a much larger area than hitherto, and that the tactical movements of the troops will be so extended as to be almost of a strategical character, in which pontoon bridges will most surely be called upon to bear a part, and for this purpose it will be necessary that the equipments should possess a great degree of mobility, and that the personel and material should be so organized that the formation of the bridges should proceed with the utmost regularity and rapidity.

Not having had any practical experience in matters connected with draught in the field, I can merely offer an opinion that waggons suitable for four horses would be more advantageous than those for six; not only because the actual work done by each horse is greater, but, because if at any time it is necessary to give increased mobility to the waggons, it can be effected without increasing the length of the team beyond what may be considered a good working length. Bridge equipments are not often required to do so, but it might be necessary that they should move as quickly as any other branch of the army.

The weight which a horse should draw is a subject upon which there has been much controversy, and on which I cannot obtain any trustworthy opinion. The French allow from 550 to 660 lbs., besides the weight of the waggon. The *Artillerist's Manual* lays down that

4 horses should be allowed to	24 cwt.	Including the carriage.
6 do.	30 ,,	
8 do.	36 ,,	
12 do.	48 ,,	

The *Hand-book for Field Service* says the same, but also that in practice 12 horses only are employed for the heaviest load in the service (24-pounder weighing 88 cwt.), and that a greater number cannot be employed with advantage. The old brass 9-pounder gun complete weighed 38 cwt. 1 qr. and was drawn by eight horses, and the present 9-pounder Armstrong gun weighs 35 cwt. 16 lbs., and the waggon 38 cwt. 3 qrs., the former is drawn by six, and the latter by four horses. The French pontoon waggon loaded weighed 6,760 lbs., and was drawn by six horses. My own opinion, from what I have read, is, that a total weight of 9 cwt. is not too much to allow for each of the horses which would be employed in the draught of the pontoon train on ordinary occasions, and if the waggons are calculated for four horses, the addition of an extra pair would reduce the load per horse to 6 cwt., and make the equipment sufficiently mobile for any purpose.

I now pass to the consideration of the bridge material; and first, as to the chesses, one limit to the length of which is the width of roadway necessary for the troops crossing the bridge. Infantry in fours occupy 7 ft. 4 in., and with the supernumerary rank 9 ft. 2 in.; artillery and waggons require 6 ft. 6 in.; and cavalry in two ranks about the same. The roadways of the early equipments were 15 ft. 6 in. wide, but this has been reduced gradually until at present very few are more than 10 ft. wide, and in the Sardinian service the roadway has been reduced to 8 ft. 6 in., in consequence of the experience of the war of 1859. The Belgian roadway is 9 ft. 10 in. wide. It is necessary that the width of the roadway should be a *minimum*, in order that the pontoons and other parts should be as small and light as possible, for as the greatest weight, which it may be expected that a pontoon bridge will be called upon to support, is that of a crowd of unarmed men, if the roadway be wider than is absolutely required for the passage of troops, it merely allows so much extra space on which the above-mentioned load could be placed, for the support of which, of course, additional buoyancy must be provided in the pontoons to prevent their submergence. Speaking, then, from theory alone, 9 ft. 6 in. would be ample for the roadway, and as the latest experience has induced the Italians to make their roadway only 8 ft. 6 in. wide, I believe that between 9 ft. and 9 ft. 6 in. would be found sufficient in practice, and I would propose to adopt 9 ft.

The thickness or strength of the chesses depends upon the load which they may have to support, and the intervals between the baulks or beams on which they rest. The greatest weight would be about half that which is supported on the hind wheels of a 24-pounder gun, or 40-pounder Armstrong, which is about 60 cwt., the half of which is 30 cwt. Taking the bearing at 1 ft. 6 in., the chesses would require to be $1\frac{1}{3}$ in. thick. Most nations have fixed upon $1\frac{1}{2}$ in. as the proper thickness, if the planks and chesses are made of fir; the Sardinians however make theirs nearly 2 in.; as, however, the wear of the chesses need not be taken into account, $1\frac{1}{2}$ in. may, perhaps, be considered sufficient. In all equipments the chesses are made of such a length as will not only give room for the roadway and the ribands which are employed to secure the ends of the planks, but will also allow the planks to project considerably beyond those ribands; this has always appeared to me to be of no service either to the bridge or to the troops using it, and at the same time to add considerably to the length and weight of the chesses, and I would, therefore, reduce the length of the planks, so as to allow space merely for the roadway and the ribands. Rope lashings, which are made taut by means of a short stick (called a rack), are usually employed for securing the ends of the planks to the baulks, and I have no hesitation in saying that I have never seen these rack lashings so securely made as to stand the strain caused by the oscillations of the bridge, and it is very desirable that some better plan should be devised for this purpose. In all foreign equipments a hand rope, called a "garde fou," is arranged along the sides of the bridge, and is considered to be very necessary; in most instances where I have seen it prepared the supports have been so weak that the rope, instead of being a safeguard, has been rather a trap to deceive those who trusted to it; this is another point which requires improvement.

The baulks are the next subject, and here we must bear in mind the question of stowage for transport. Baulks are laid in three different ways—with double bearings, that is, with the baulk resting on both gunwales of the pontoons which it connects; with alternate double bearings, that is, with every other baulk resting on the two gunwales of one and one gunwale of the other pontoon; and with central bearings, that is, when the baulks are supported over the axis of the pontoons. The first method is said to give the greatest stability to the bridge, but it also requires the baulks to be much longer than is necessary with the two other methods; and it is supposed, also, that if the baulks are secured firmly to the pontoons, the swell which may always be expected to arise during the passage of an army over a bridge is likely to strain the various parts of the bridge. I do not believe that there is much foundation for this supposition, and mention it only because it is met with in the writings of many authors upon this subject, but always as a supposition. Another disadvantage of the double bearing is, that twice as large a section of timber is employed to carry the roadway over the short bearing from gunwale to gunwale of a pontoon, as is required to support it over the long bearing between two pontoons, which is not an economical measure. Laying the baulks with alternate bearings reduces their length, but is supposed not to give so much stability to the bridge, there is still too much timber across the pontoons, and the bridge is nearly as rigid as in the former case. When laid with central bearings, the baulks must be at least as long as in the last case, and as the length of the bearing is greater, the scantling, and therefore the weight of the baulks must be increased, the bridge is, however, more flexible, and therefore is supposed to be less liable to be strained. The Italians lay their baulks from centre to centre of the pontoons, but they are also supported at the gunwales, and the deflection of the middle of the baulk under a load causes their ends to spring, and thus unsettle the planks and strain the rack lashings, &c. The baulks appear to me to require some new arrangement in open pontoons, so that the parts which extend between and across the pontoons may have the proper proportion of strength without weakening the bridge, and at the same time the length for packing may be diminished. The French pontooners have endeavoured to accomplish the latter purpose by making their baulks in three pieces, that part which extends between the two pontoons being in one length, and those which lie across the pontoons being connected to it by hinges. The weight of the baulks (and also that of the chesses), might be reduced by diminishing their scantlings towards the ends, and I believe this might be effected without any disadvantage. It appears to be a question whether iron might not be used in the construction of baulks.

I will now take up the subject of the pontoons, and omitting, for the present, any reference to the size of the vessels, consider in the first place the general form. Pontoons have hitherto been made of two forms, open or closed, and I understand that at the present time Captain Fowke is engaged in the construction of vessels which will combine the advantages of both ; if successful, this may be an important step gained. All the earlier pontoons or bateaux were open, but we read that, from time to time, attempts were made to introduce closed vessels, from which we may deduce that grave objections must very early have been found to exist against open bateaux. On the continent it is considered imperative that pontoons should be so constructed that they can be used as rowboats, and the importance of this qualification is acknowledged by the supporters of the closed vessels, inasmuch as one of the chief points studied in the exercise with these vessels has always been their formation into rafts, which no doubt might be employed with advantage on many occasions, but at the same time there are circumstances under which rowboats only could be employed, more particularly in very strong currents. It must be borne in mind that the open bateaux offer still greater facilities for the formation of rafts than closed vessels. Although the experience of the British in the war in the Peninsular was very much against the open pontoons, which were frequently submerged, it must be remembered that those which were then used were of a very rude form, and did not possess the proper amount of buoyancy, and their floors were very short. They were moored by cables attached to rings on the outside of a projecting bow, a combination of extremely adverse conditions, so that the experience thus gained must be considered as operating rather against the individual pontoon concerned, than the form of vessel which it represented. The advantage which the closed vessel is considered to possess is simply that it cannot be submerged, and that, therefore, a smaller and lighter vessel will be as efficient as one much larger and heavier, if it be open. This I do not quite agree with ; for if we take the case of a cylinder 1 foot in diameter, the quantity of material employed in its construction would make a semi-cylinder of double the diameter, and of a capacity, and therefore buoyancy, equal to twice that of the cylinder, and when immersed to an extent equal to the displacement of the smaller cylinder, the gunwales would still remain 5 inches out of the water. The disadvantages of the closed vessels are, the difficulties of making and keeping them water-tight, of discovering and repairing a leak, and of clearing them of water when a leak is once established—in addition to these they cannot be used without some arrangement for the support of the baulks, the interior space is not available for stowage of material, either on the waggons or on board ship, and they cannot be used singly in the water. Open vessels have the one disadvantage, that they have hitherto proved liable to submersion. Experiments, which can alone decide the question of the superiority of one form over the other, are very much needed, but whatever the result may be, I believe that it would be a great advantage if a vessel could be devised capable of being used as a rowboat, and also of being decked over, when employed in bridge in windy weather.

From this we will pass on to the consideration of the material of which pontoons should be constructed. The early pontoons, or vessels employed as the supports of portable military bridges, were formed of basket-work covered with leather, and the same idea has been revived in later days, but without success; these were succeeded by large bateaux formed of oak, which being too heavy were succeeded by others of copper, tin, iron, and various other materials, which, with addition of canvass, are in use at the present day. If we examine closely into the accounts received of these various materials, we shall find that tin has never been employed for any long period as a covering for pontoons in war time, on account of its want of strength, and the corrosion to which it is extremely liable. It certainly has been employed for exercise in England, but I believe that all who have been much engaged in the practice will acknowledge that the decay of the metal has been so rapid, that the cylinders would have been useless at the close of a season's wear and tear on actual service. Copper does not corrode, but from its non-elasticity and want of toughness, the pontoons very soon become indented to such an extent as would cause a great loss in the buoyancy of the vessels, and a great increase to the obstruction of the current, while at the same time the projecting folds of the metal are very liable to injury from blows or abrasions against stones, &c. At present it appears to be undecided whether sheet iron is to be preferred to wood of equal strength; the French have made experiments, and say that the result has been that the iron is more liable to injury and more difficult to repair than wood; all the other continental pontooners are of the opposite opinion, and all, including the French, unite in condemning corrugated iron. Besides the injuries caused by blows, the destruction of the pontoons by regular decay of the material has to be considered, and the advantage here is incontestably on the part of the iron; I myself have seen an iron pontoon which, after 14 years of constant use, was to all appearance as serviceable as the day it was made, the only repairs which it had undergone being renewing each year the mineral tar which was used to protect the metal from corrosion. Diagonal planking has not yet been employed for the construction of pontoons, for which I believe it to be particularly applicable, and should it be decided that closed vessels are to be preferred, this material appears to be well worthy of trial.* For open pontoons flat sheet iron will most probably be chosen. Waterproof canvass has also been employed for many years as a covering of pontoons by the Russians, who still make use of it, and have many trains, three-quarters of each of which consist of these. Their great disadvantage appears to be the obstruction which they offer to the currents: they are also somewhat difficult to manœuvre in rapid streams. The canvass is merely stretched by hand over the framework, so that it is not much strained, and therefore is more likely to last for a considerable time.

Captain Fowke's system brings a great strain upon the canvass, particularly at the part near the bow, where the whole of the straining power is applied in an oblique direction, so that while the canvass at the bottom is not stretched sufficiently to give it rigidity, that at the bow is uselessly submitted to an undue strain. Many minor points might also be adverted to, but as the inventor is now said to be re-modelling his pontoons, it may not be advisable to submit them to further criticism. Two great advantages of Captain Fowke's pontoons are that they pack into an extremely small compass, and that their weight per cubic foot

* Since this was written I have been informed that diagonal planking has been proposed for the construction of pontoons.—J. W. L.

of displacement is very small; and so important are these two qualities that if the other defects can be overcome there appears to be little doubt that they would stand a fair chance of superseding most others. In the meantime I am much in favour of vessels covered with flat sheet iron.

We have next to consider the amount of buoyancy or dimensions most advantageous for pontoons, and, at present, I would omit all considerations as to dimensions for packing, supposing only that the weight of all the parts of the material is to be within the limit of waggon transport. Pontoons may be either small or large, and may be either long or short, and broad or narrow, the depth, of course, varying with the other two dimensions. To guide us in this subject we have to consider the stability of the roadway, the rapidity of formation of the bridge, the comparative weights of small and large pontoons of similar construction, and the relative obstructions which they cause to a current, &c. There are special considerations which fix an absolute limit to the minimum length of the pontoon, but without entering upon these, I purpose to consider the abstract question as to the preference which should be given to large or small pontoons. The loads which can be distributed uniformly over the roadway are the same in both cases, and the total power of the bridges must therefore be equal, whether the supporting bodies are few and large, or many and small; but besides the action of a uniform load we must consider that of a load such as that of a gun carriage &c., which bears unevenly on different parts of a bridge, and during the passage of which the pontoons are influenced in succession by heavy and light weights, and are thus alternately depressed and elevated; now, whatever be the size of the pontoon, as it derives no assistance in buoyancy from those adjacent to it, the displacement due to the loads must be equal in all cases, and as this displacement is a function of the length and breadth of the pontoon, and the depth of the immersion, it follows, that in order that this latter should be a minimum, the other two dimensions should be as large as possible; that is, with large pontoons the undulating motion would be less than with those of smaller dimensions. The roadways of floating bridges are also subject to a transverse oscillating motion, due to the passing loads acting alternately with greater or less power on the opposite sides of the centre of floatation of the pontoons. As the roadways should be of equal width whether the pontoons are large or small, the action which causes the oscillations is the same, and with pontoons of similar construction the forces which tend to counteract the motions in the bridges are on one side the weight, and on the other the displacement of the disturbed portions of the pontoons, &c., each acting at their respective centres of gravity, the centre of motion being about midway between them; and it is evident that the longer the pontoons the greater will be the distance from the centre of motion to that of gravity, and the less will be the powers, that is the weight and displacement, required to act at those centres; now as the powers of these forces are functions of the length and width of the pontoon, and the depth of the depression, it follows that in order that this latter may be a minimum, the other two dimensions should be as large as possible; length, however, is the more important quality in this respect, as the resistance to oscillation is proportional to the area of the pontoon at the water line multiplied by its length at the same point. The resistance to the mere depression, or to the undulating motion, is simply proportional to the area of the pontoon at the water line.

I will now pass to the question of the influence which the size of the pontoon may be expected to have on the time required for the formation of the bridge, and it must be borne in mind that these comparisons are supposed to be made between equipments of similar construction. As regards loading and unloading the waggons, if the length and construction of the pontoons are such as to admit of the convenient application of the power of an adequate number of men, there appears to be no good reason why, if the operations be well arranged, the facility of loading and unloading, and carrying pontoons to the water should be much affected by their size or weight, provided they are within the limits suited for waggon transport in the field. As respects the baulks, which are the chief part of the material affected by any variation of the size of the pontoons, when they are short and light it is the practice that each should be carried by one man, who must of necessity balance it by the middle, in which position, in consequence of the impetus acquired when the unsupported ends are once set in motion, he has not much power to direct the baulk steadily in any required direction, and, consequently, finds a difficulty in adjusting it. Should two men be employed, which they can be quite as easily as one, although they might actually handle a short and light baulk with more facility and rapidity, yet the actual value of the work done as respects the formation and dismantling of the bridge is not so great as if they had carried a longer baulk, provided its weight did not seriously interfere with the freedom of their movements. The planking would be the same in both cases, and the operations, in which time may be gained or lost in the actual formation of the bridge when the pontoons are once in the water, are casting the anchors, bringing the pontoon into position, and booming out to the extent of the bay (I allude here to the method of forming bridge by adding successive pontoons to the ends, which is the method almost universally adopted on the continent in preference to booming out the whole bridge). As a sufficient number of men can always be placed in the pontoon to row or pole it to the place where the anchor is to be cast, the time occupied in this part of the work would be about the same in both cases in slow currents, but would be in favour of the large pontoons in rapid streams with which the smaller vessels have not sufficient power to contend. The anchors of large pontoons would, of course, be heavier, but as the vessels are steadier on the water, and allow more space for the pontooneers to exert themselves, I am of opinion that the anchors could be cast with as much rapidity and with more regularity from large than from small pontoons. When the anchors are cast the pontoons are allowed to drift down opposite to the end of the bridge, where they lie until required, when by a simple shifting of the cable they are sheered in by the current quite as quickly if large as if small; when alongside, the baulks are adjusted, the pontoon boomed out to the extent of the bay, and the bridge end of the baulks secured to the bridge pontoon; now in this movement the operations which occupy the principal part of the time are the adjustments and securing of the baulks, which would be the same in both cases, booming out being very quickly performed. It thus appears that with active men thoroughly practised in a well arranged exercise there is no good reason why each of the several operations before mentioned should not be performed in the same time with large as with small pontoons, provided the two equipments are upon the same system; and, therefore, that a bridge would be formed in less time with large than with small vessels, because those operations, which are the same for each pontoon, are less frequently repeated. As to the comparative weight of large and small pontoons of similar construction, whatever the material of which the covering is formed, it must always have sufficient strength to resist the blows and shocks to which the vessels are liable, and which are nearly the same whether large or small, and, therefore, the additional strength required in the former would be obtained principally by increasing the dimensions of the members of the frame upon which the covering material is placed, and as this increase would not be proportionate to that of the buoyancy, the comparative weight of large pontoons would not be so great as that of those of smaller dimensions.

The obstruction offered by a bridge to a current may be divided into four parts, which are respectively due to the impact of the water on the bow, the friction on the surface of the body of the pontoon, and the resistance due to the action of the water on the stern, and that offered by the cables. The first and third of these are functions of the greatest immersed transverse sections of the pontoons and factors which vary according as the entrance and run of the pontoon are more or less free. With a definite load upon a bridge of a given length, the aggregate volume of those portions of the pontoons of which the submergence is due to that load must be the same, whatever be the length of the pontoons, and it may be assumed that the volume due to the weight of the bridge material is also the same, and as these volumes are the product of the length and mean area of the submerged portions of the pontoons, it is evident that the shorter the pontoons the greater will be the area of the immersed section, and if the same factors be supposed to be applicable in each case, the greater will be the resistances due to the action of the water on the bows and sterns of the pontoons. With respect to the second, as the bodies are similar, the frictional surface varies simply as the squares, while the capacity or buoyancy varies as the cubes of the like dimensions, and, therefore, in a given length of bridge, as the number of the pontoons vary as their capacity, the frictional area must be greater with small than with large pontoons. The total strength required in the cables depends on the above resistances, and, consequently, less power would secure a given length of bridge formed with large pontoons than would be necessary if supported on others of smaller dimensions; this total strength is besides divided between a smaller number of cables, the strength of which is proportional to the square of the circumference, while the surface which they expose to the current is in direct proportion to the circumference; so that in all four of the sub-divisions of the obstruction to the current, the advantage is decidedly in favour of large pontoons.

From the foregoing remarks it would, therefore, appear that theoretically in every respect, with the single exception of transportability on waggons, &c., the advantage is on the part of bridge equipments based on large pontoons.

The points which appear to be open to discussion without entering into any details with regard to particular systems of equipment are—

1.—The degree of mobility which the equipment should possess.

2.—The weight which should be allotted to each horse in draught.

3.—The number of horses, or rather the weight which should be allowed to each waggon.

4.—The load for which the bridge should be prepared.

5.—The width of roadway which is desirable.

6.—The great question of the relative superiority of open or closed pontoons.

7.—Whether the same equipment, which will satisfy the requirements of an army engaged in scientific warfare, may be expected to be also applicable to desultory operations against undisciplined troops, in which our forces are so often engaged in our foreign possessions.

J. W. LOVELL,

Capt. R.E., and Lieut. Col.

osed by the inventors of tho various systems.

[illegible] total lbs.	Do. do. for load; three-fourths for open pontoon, nine-tenths for close do.	Interval in Bridge.	Power per lineal foot of roadway.	Greatest possible load at 110 lbs. per foot (superficial).	Greatest ordinary load, 560 lbs. per foot (lineal).	Width of roadway.	Weight of Pontoon and Fitments per cubic foot of displacement.	Area of greatest immersed transverse section of Pontoons per lineal foot of Bridge, when arranged to support, on each foot of a roadway 10 feet wide, a load of	
								1,100 lbs.	560 lbs.
8	9	10	11	12	13	14	15	16	17
lbs.	lbs.	Feet.	lbs.	lbs.	lbs.	Feet.			
,000	27,750	22·8	1,215	1,716	560	15·6	6·70		
,791	14,093	16·6	849	1,254	560	11·41	4·35	·968	·510
,678	12,509	19·69	635	1,159	560	10·54	5·09	·923	·487
,228	6,171	16·41	376	1,026	560	9·33	4·17		
,912	12,684	19·69	644	1,082	560	9·84	4·12	·898	·472
),718	8,039	16·83	477	1,100	560	10·0	5·03	1·176	·62
,866	4,400	14·0	314	990	560	9·0	6·41	1·571	·823
..	..	..	..	..	..	..	3·43		
,678	6,010	12·5	481	1,100	560	10·0	5 83	·956	·513
,185	4,667	12·5	373	1,100	560	10·0	5·43	1·026	·541
,280	4,752	10·42	456	1,100	560	10·0	5·43		
,377	4,839	8·33	581	1,100	560	10·0	5·43		
,300	1,170	5·33	220	..	..	7·0	5 33		
,214	5,411	10·0	541	1,100	560	10·0	3·55	1·615	·846
,288	5,659	11·0	514	1,100	560	10·0	5·26		
,658	11,744	21·67	542	1,026	560	9·33	5·00	·938	·494
,092	11,319	21·67	522	1,026	560	9·33	5·15	·981	·517
3,907	17,930	21·67	827	1,026	560	9·33	5·16	·613	·323
8,392	13,794	21·67	636	1,026	560	9 33	5·55	·943	·497
3,454	13,841	21·67	639	1,026	560	9·33	5·38	·945	·498
8,634	21,476	21·67	991	1,026	560	9·33	5·49	·615	·322
7,833	5,875	15·30	384	1,093	560	9·94	6·93	1·191	·627
7,923	5,943	13·26	448	1,093	560	9·94	6·93		
8,013	6,010	11·22	535	1,093	560	9·94	6·93		
1,176	8,382	15·30	561	1,093	560	9·94	4·47	1·05	·554
1,266	8,450	13·26	637	1,093	560	9·94	4·47		
1,356	8,517	11·22	759	1,093	560	9·94	4·47		
4,078	10,559	26·25	402	1,082	560	9·84	3 91	1·369	·721
0,748	23,061	26·25	878	1,082	560	9·84	3·71	1·294	·688
0,748	23,061	26·25	878	1,082	560	9·84	3·71	·647	·344
6,889	12,669	22·97	551	1,082	560	9·84	4·01	1·001	·528
6,091	27,068	22·97	1,178	1,082	560	9·84	3·84	·982	·518
6,091	27,068	22·97	1,178	1,082	560	9·84	3·84	·496	·259
6,141	5,530	18·0	307	1,210	560	11·0	2·00		
6,401	5,761	16·66	393	1,210	560	11·0	2·00		
0,687	8,015	16·625	493						
0,823	8,117	14·15	573	1,140	560	10·371	..	1·172	·611
0,950	8,219	11·66	705						
0,780	8,085	21·33	379	1,082	560	9·84			
0,546	7,910	26·25	301	1,082	560	9·84	6·02		
1,170	8,378	13·13	637	1,082	560	9·84	..	1·164	·591
5,248	11,436	19·69	580	1,045	560	9·5	4 09	·964	·508
2,620	24,465	19·69	1,244	1,045	560	9·5	4·09	·462	·242

of a bridge. The small figures shew the weights of the pontoons alone.

TABLE showing the power per lineal foot of roadway, &c., &c., of Pontoon Bridges, formed according to the plan proposed by the inventors of the various systems.

	Total length of pontoon over all.	Width of do. greatest section.	Depth of do. midships.	Displacement do.	Do. do.	Weight of pontoon.	Do. of one bay of superstructure.	Power of support; total lbs.	Do. do. for load; three-fourths for open pontoon, nine-tenths for close do.	Interval in Bridge.	Power per lineal foot of roadway.	Greatest possible load at 110 lbs. per foot (superficial).	Greatest ordinary load, 560 lbs. per foot (lineal).	Width of roadway.	Weight of Pontoon and Fitments per cubic foot of displacement.	Area of greatest immersed transverse section of Pontoons per lineal foot of Bridge, when arranged to support, on each foot of a roadway 10 feet wide, a load of 1,100 lbs.	560 lbs.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Feet.	Feet.	Feet.	Cubic ft.	lbs.	lbs.	lbs.	lbs.	lbs.	Feet.	lbs.	lbs.	lbs.	Feet.			
1. Gribeauval, open bateau oak; found efficient, but too heavy for transport	36·29	6·74	3·81	592·7	45,044	4,075	3,969	37,000	27,750	22·8	1,215	1,716	560	15·6	6·70		
2. Austrian model, open wood; in general use 1799; failed three times, from want of power; burnt in retreat from Russia	26·97	6·23	2·59	353·97	22,123	1,540	1,792	18,791	14,093	16·6	849	1,254	560	11·41	4·35	·968	·510
3. French, reserve pattern, until 1853; open wooden bateau; fir	30·93	5·06	2·58	324·58	20,286	1,654	1,934	16,678	12,509	19·69	635	1,159	560	10·54	5·09	·923	·487
4. ,, advance guard pattern, until 1853; open wooden bateau	19·69	4·59	2·30	155·74	9,734	650	856	8,228	6,171	16·41	376	1,026	560	9·33	4·17		
5. ,, present general pattern, open wooden bateau	30·93	5·06	2·58	321·04	20,065	1,323	1,830	16,912	12,684	19·69	644	1,082	560	9·84	4·12	·898	·472
6. English, Peninsular reserve equipment; open tin bateau, double sides and bottom ..	21·08 16·67	4·83	2·29	209·47	13,092	1,050	1,324	10,718	8,039	16·83	477	1,100	560	10·0	5·03	1·176	·62
7. ,, ,, advanced guard equipment; open tin bateau, double sides and bottom	16·83 13·33	4·0	2·0	120·33	7,520	772	882	5,866	4,400	14·0	314	990	560	9·0	6·41	1·571	·823
8. ,, Colleton, buoy pontoon; cylindrical, with conical ends; made like a cask; wood ..	..	..	..	173	..	594	..	..	..	..	..	..	..	..	3·43		
9. ,, Pasley, copper; demi-canoes, with wood deck	25·0	2·75	2·58	140·5	8,781	818 / 778	1,325	6,678	6,010	12·5	481	1,100	560	10·0	5 83	·956	·513
10. ,, Blanshard, cylinder, tin; hemispherical ends; open order..	22·5	2·66 Diam.	Diam.	108·56	6,785	590 / 482	1,120	5,185	4,667	12·5	373	1,100	560	10·0	5·43	1·026	·541
11. ,, ,, ,, ,, intermediate order	22·5	2·66 Diam.	Diam.	108·56	6,785	482	1,023	5,280	4,752	10·42	456	1,100	560	10·0	5·43		
12. ,, ,, ,, ,, close order..	22·5	2·66 Diam.	Diam.	108·56	6,785	482	926	5,377	4,839	8·33	581	1,100	560	10·0	5·43		
13. ,, ,, ,, conical ends; infantry pattern	15·5	1·58 Diam.	Diam.	26·25	1,640	140	200	1,300	1,170	5·33	220	..	..	7·0	5 33		
14. ,, Fowke's pattern; collapsible, canvass, open	22·0	5·25	2·66	133·60	8,460	496	750	7,214	5,411	10·0	541	1,100	560	10·0	3·55	1·615	·846
15. ,, Forbes, spherangular; tin, closed	24·166	2·77	2·84	127·6	7,977	665	1,024	6,288	5,659	11·0	514	1,100	560	10·0	5·26		
16. ,, Birago, original pattern, open wood bateau; two bow pieces	28·00	6·14	2·42	302·51	18,907	1,515 / 1,280	1,969	15,658	11,744	21·67	542	1,026	560	9·33	5·00	·938	·494
17. ,, ,, ,, ,, ,, one bow and one middle piece	25·4	6·14	2·42	293·41	18,338	1,512 / 1,277	1,969	15,092	11,319	21·67	522	1,026	560	9·33	5·15	·981	·517
18. ,, ,, ,, ,, ,, two bows and one middle piece	39·4	6·14	2·42	444·66	27,791	2,295 / 1,915	1,969	23,907	17,930	21·67	827	1,026	560	9·33	5·16	·613	·323
19. ,, ,, present pattern, iron; open bateau; two bow pieces	28·00	6·22	2·59	353·44	22,090	1,964 / 1,729	1,969	18,392	13,794	21·67	636	1,026	560	9 33	5·55	·913	·497
20. ,, ,, ,, ,, ,, ,, one bow and one middle piece	25·41	6·22	2·59	353·44	22,090	1,902 / 1,667	1,969	18,454	13,841	21·67	639	1,026	560	9·33	5·38	·945	·498
21. ,, ,, ,, ,, ,, ,, ,, two bows and one middle piece	39·41	6·22	2·59	530·16	33,135	2,912 / 2,532	1,969	28,634	21,476	21·67	991	1,026	560	9·33	5·49	·615	·322
22. Prussian, old pattern, wood; open boat, both ends boat shaped; open order	23·69	5·06	2·49	163·62	10,226	1,134	1,259	7,833	5,875	15·30	384	1,093	560	9·94	6·93	1·191	·627
23. ,, ,, ,, ,, intermediate order	23·69	5·06	2·49	163·62	10,226	1,134	1,169	7,923	5,943	13·26	448	1,093	560	9·94	6·93		
24. ,, ,, ,, ,, close order	23·69	5·06	2·49	163·62	10,226	1,134	1,079	8,013	6,010	11·22	535	1,093	560	9·94	6·93		
25. ,, new pattern, iron, ,, ,, open order	24·71	5·15	2·75	214 16	13,385	959	1,250	11,176	8,382	15·30	561	1,093	560	9·94	4·47	1·05	·554
26. ,, ,, ,, ,, intermediate order	24·71	5·15	2·75	214·16	13,385	959	1,160	11,266	8,450	13·26	637	1,093	560	9·94	4·47		
27. ,, ,, ,, ,, close order	24·71	5·15	2·75	214·16	13,385	959	1,070	11,356	8,517	11·22	759	1,093	560	9·94	4·47		
28. Italian, Cavalli's original pattern, open wood bateau; stern square, bow boat shaped; one piece..	19·6	5·77	2·95	282·56	17,660	1,107 / 990	2,592	14,078	10,559	26·25	402	1,082	560	9·84	3 91	1·369	·721
29. ,, ,, ,, ,, ,, ,, two pieces (side by side)..	19·6	11·54	2 95	565·12	35,320	1 980	2,592	30,748	23,061	26·25	878	1,082	560	9·84	3·71	1·294	·688
30. ,, ,, ,, ,, ,, two pieces (end to end)..	39·2	5·77	2·95	565·12	35,320	2,091 / 1,980	2,592	30,748	23,061	26·25	878	1,082	560	9·84	3·71	·647	·344
31. ,, ,, modified pattern, ,, ,, one piece..	24·6	5·77	2·82	324·64	20,290	2,097 / 1,188	2,133	16,889	12,669	22·97	551	1,082	560	9·84	4·01	1·001	·528
32. ,, ,, ,, ,, ,, two pieces (side by side)..	24·6	11·54	2·82	649·28	40,580	1.305 / 2,376	2,133	36,091	27,068	22·97	1,178	1,082	560	9·84	3·84	·982	·518
33. ,, ,, ,, ,, ,, ,, two pieces (end to end)..	49·2	5·77	2·82	649·28	40,580	2,493 / 2,376	2,133	36,091	27,068	22·97	1,178	1,082	560	9·84	3·84	·496	·259
34. American, inflated india-rubber; three cylinders connected; open order	20·0	5·0	1·66	130	8,125	420	1,560	6,141	5,530	18·0	307	1,210	560	11·0	2·00		
35. ,, ,, ,, close order	20·0	5·0	1·66	130	8,125	470	1,404	6,401	5,761	16·66	393	1,210	560	11·0	2·00		
36. Russian, open, canvass on wooden framework, which can be taken to pieces — open order ..	..	..	..	..	..	..	1,640	10,687	8,015	16·625	493						
37. ,, ,, common order ..	21·0	5·25	2·33	208·66	13,042	715	1,504	10,823	8,117	14·15	573	1,140	560	10·371	..	1·172	·611
38. ,, ,, close order ..	..	..	..	..	..	..	1,368	10,950	8,219	11·66	705						
39. Dutch, open boat, in two pieces, wood; common order..	26·25	5·25	2·33	225·79	14,112	1,363	1,969	10,780	8,085	21·33	379	1,082	560	9·84			
40. ,, ,, ,, ,, open order	26·25	5·25	2·63	225·79	14,112	1,363	2,203	10,546	7,910	26·25	301	1,082	560	9·84	6·02		
41. ,, ,, ,, ,, close order	26·25	5·25	2·63	225·79	14,112	1,363	1,579	11,170	8,378	13·13	637	1,082	560	9·84	..	1·164	·591
42. Belgian, open iron boat, square stern, boat-shaped bow; one piece	24·8	5·75	2·56	297·35	18,584	1,212	2,124	15,248	11,436	19·69	580	1,045	560	9·5	4 09	·964	·508
43. ,, ,, ,, ,, two pieces (stern to stern)	49·2	5·75	2·56	594·70	37,168	2,424	2,124	32,620	24,465	19·69	1,244	1,045	560	9·5	4·09	·462	·242

The large figures, in column 6, show the weights of the pontoons, together with those fitments without which they cannot be employed as the supports of a bridge. The small figures shew the weights of the pontoons alone.

PAPER IX.

DESCRIPTION OF A TEMPORARY DAM APPLICABLE TO FIELD OPERATIONS.

By CAPTAIN FIFE, Royal Engineers.

In executing canal works in Sind a few years back, it became necessary to close a canal with all possible despatch, on account of a breach having taken place in one of its banks, which permitted the whole of the water to escape into the excavations of the new works.

The canal which had to be closed was one of the ordinary irrigation canals of the country, filled by the rising of the inundation of the Indus and destitute of any means of regulating its supply. During the inundation period it exactly resembled a natural stream. It was 30 feet wide at the water line, 9 feet deep, and the stream had a velocity of about 3 miles per hour. The bed and banks consisted of alluvial soil, which had become firm by age. To effect the closing of the canal there were no materials ready. Trees and brushwood had to be cut down and collected, and soil had to be stored on each bank of the canal, such as would very likely happen in effecting a similar operation in the field.

Five date trees, 40 feet in length and about 1 foot in diameter, were procured and laid across the canal, two in one place, and three in another, the interval being about 8 feet. Strong stakes were driven into the banks to prevent the date trees from moving. Three boughs, forked at one end, were then added as struts on the down-stream side, one end of each strut resting on the canal bed, while the forked end abutted against the date trees. The down-stream date trees were then loaded with a layer of brushwood and about 2 feet of soil. Up to this time, beyond the fixing of the three struts, the passage of the water had not been interfered with, and there was no injurious action on the banks or bed.

Two rows of saplings of from 2 to 4 inches in diameter and of from 4 to 12 feet in length, according to the position they were intended to occupy, were next driven into the bed of the canal, with their heads resting against the date trees, and at intervals of about 6 inches. Directly the rows of saplings were completed, fascines of about 3 feet in diameter, consisting of thin twigs with the leaves on, were rolled into the stream above the dam site, dropped down with the current and jammed against the up-stream row of saplings. The first fascine was placed on the bed of the canal and corresponded in length with the bottom width. The second fascine was placed upon the first, and in length corresponded with the width of the canal at that height above its bed. The third fascine was similarly placed over the second. As soon as the fascines had been jammed into their places every hole that remained for the stream to rush through was stopped with small fascines, brushwood in any shape, and grass matting. Two or three thicknesses of grass matting were also placed against the down-stream row of saplings.

The fixing of the saplings occupied some hours and was done without hurry, and as long as the operation lasted those first fixed were frequently examined, to see whether the stream was eating away the soil at their footings, and when necessary they were driven down further with a mallet. The staunching of the water by means of the fascines and matting was effected with all possible despatch and occupied about an hour. The effect was great. Below the dam the stream of water was now reduced to three feet. Above the dam there was an afflux of about 1 foot, and the surplus water was forced back to the Indus again. There was then a head of 7 feet of water against the dam, and all possible vigilance had to be used to prevent the forming of large leaks.

Not a moment was now to be lost in pushing on the earthwork and rendering the whole secure. Two large mounds of earth had been prepared, one on each bank, and 100 men with native hoes were placed on each to pass the material down with all possible expedition. To prevent the soil from melting into pap, and from being carried away by the leaking water, five men went into the canal on each side, and placed their backs against the advancing earthwork. They thus formed a support to the face of the earthwork, and prevented it from sinking and melting away, and thus delaying the completion of the work. Indeed, it may be said that they prevented the failure of the work, for with such material success depends entirely upon the rapidity with which the operations are carried on, after interference with the stream has once been commenced. As the earthwork advanced towards the centre of the canal, the men were forced forward till they met. They did not get out of the water, however, as long as there was standing room. Wherever a gap had to be filled, a man inserted himself till the earth gradually forced him out. Even with this precaution, a great deal of soil melted away, and when the two parties of men met in the centre of the canal, there was a depth of about four feet of mud below their feet. The earthwork was commenced at 7 p.m., and was completed across the canal by 1 a.m., the following morning. As soon as the earthwork had been completed across between the two barriers, the dam was thickened, and made perfectly watertight and secure by adding earth to its up-stream slope, and raising it.

During the progress of the earthwork, the strain which was at first borne by the up-stream row of saplings, was transferred to the down-stream row and the struts. Every shovelful of earth which was thrown into the canal had a tendancy to jam against the lower barrier, all the leakage and pressure being from the up-stream side. In fact, each shovelful of earth acted like an additional blow to a wedge, and the down-stream barrier was only maintained by means of the struts and the loading placed upon it at the commencement of the operations.

The temporary dam above described is, in all its details, in common use in one part of Sind, where the natives sometimes close a canal to raise its level and inundate their fields. Constant practice at such works has taught them what danger to guard against, and the skill in the design and the adaptation of means cannot but be admired.

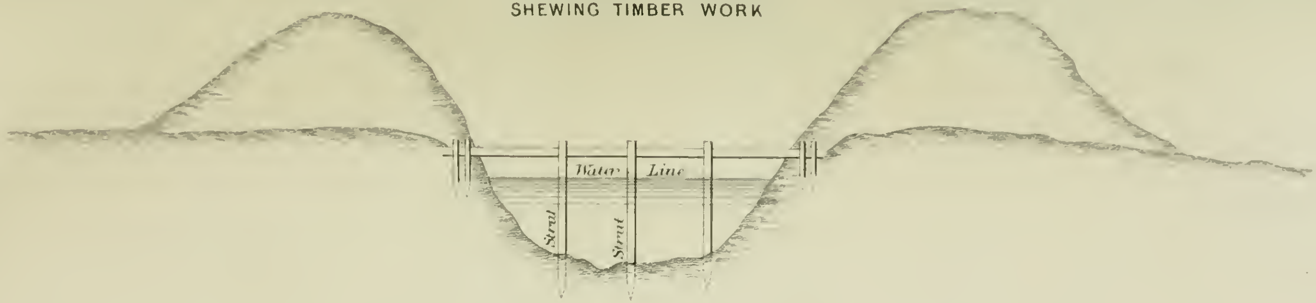
It may be remarked that the green wood which was used for the dam is much better than dry wood, because it has no tendency to float, and is, therefore, more manageable in the water. It is also tougher and, therefore, less likely to give way than dry wood when applied to such a rough purpose.

The collection of the materials and the construction of the dam occupied about 48 hours. In military operations, where there is perfect organization, the whole of the operations might be effected in 24 hours, supposing the materials to be readily procurable. The collecting of the earth on the banks should be commenced by strong parties simultaneously with the cutting and collecting of the trees and brushwood.

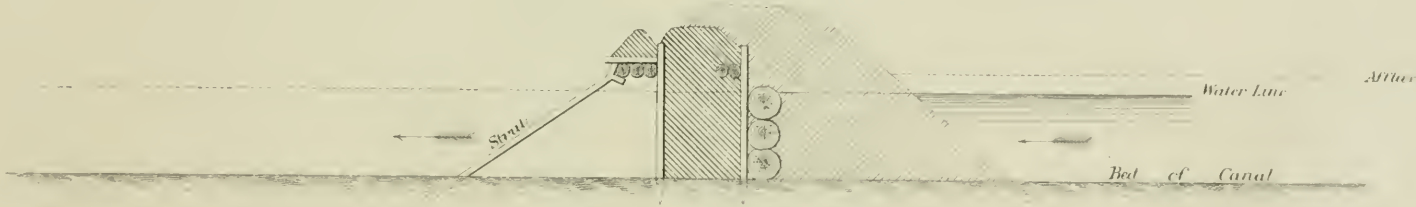
J. G. FIFE, Captain, Royal Engineers.

TEMPORARY DAM

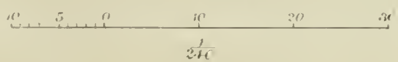
LONGITUDINAL SECTION
SHEWING TIMBER WORK



CROSS SECTION
SHEWING BOTH TIMBER AND EARTH WORK.



Scale of Feet



REMARKS.

The dark shade shews the earth work first executed
The light shade shews what was afterwards added

PAPER X.

ON THE USES OF BALLOONS IN MILITARY OPERATIONS.*

By LIEUTENANT G. E. GROVER, R.E.

The following paper, as its title implies, has for its object the consideration of the different uses to which balloons can be advantageously applied in warfare. The main question to be decided appears to be—are balloons capable of rendering sufficient service to an army engaged in active operations to make it worth while to authorise their employment as one of the resources of modern warfare? This question, however, involves another, viz.—Whether the advantages obtained from the employment of balloons are commensurate with the time, trouble, expense, and ordinary difficulties necessarily attendant upon their use? To investigate these questions I propose—

1stly. To inquire into the apparent practicability of the different purposes for which it has been hitherto proposed to use balloons in war.

2ndly. To examine the results of the experience afforded by previous occasions on which balloons have been actually employed for military purposes.

3rdly. To consider the objections usually raised against them; and

4thly. (On the supposition that their use would be beneficial in a military point of view) to consider the best method of organizing the service, and working out the practical details necessary for its execution.

But first of all, to prevent any mistake, I would point out that the word "balloon" is used in this paper, in accordance with the ordinary popular acceptation of the term, to signify the machine complete with all its accessories of car, netting &c., though strictly speaking it applies only to the bag enclosing the gas, whose low specific gravity constitutes the motive power of the machine.

Balloon ascents (as every one knows) are now very frequent and common as popular spectacles, but with the exception of the small message-dropping balloons used in the Arctic Regions by the searchers after Sir John Franklin, no practical application seems to have been ever devised for them except in connection with military operations. Their probable use in this capacity was pointed out by the very earliest projectors of schemes for aërial locomotion, almost indeed before balloons were invented; but the means proposed to attain this end are for the most part amusing in their absurdity, in consequence of the projectors' ignorance of the common laws of nature. Though I have no intention of detailing the history of the art of ballooning, I propose to touch briefly upon

* This Paper was originally read at Chatham, on 23rd April, 1862.

those early aëronautic projects which relate to the present question of the use of balloons for military purposes.

The first of these was put forward by an Italian Jesuit, Francis Lana, who, in a book published at Brescia in 1670, proposes to construct four hollow copper spheres, each 25 feet in diameter, and $\frac{1}{225}$ inch thick, and he calculates (being ignorant of the pressure of the surrounding atmosphere) that if a vacuum were procured in them they would rise from the ground with a total force of 1,120 lbs. This idea of rising into the air by means of hollow copper spheres was, however, originally conceived some 400 years previously by our countryman Roger Bacon, who states that the secret was known at the time to but one person besides himself. Lana's pamphlet inferentially points out the practical advantages that would arise from the power of thus moving through the air at will, for he earnestly prays God to avert the danger that would result from the successful practice of the art of aëronautics to the existence of civil government and of all human institutions. "No walls or fortifications," he says, "could then protect cities, which might be completely subdued or destroyed, without having the power to make any sort of resistance, by a mere handful of daring assailants, who shall rain down upon them fire and conflagration from the region of the clouds."

Another scheme of similar object was devised about 100 years later by a Dominican Friar, Joseph Galien, Professor of Philosophy and Theology at the papal university of Avignon. His pamphlet published in 1775 (not very long before the final invention of balloons) proposes to collect the fine rarefied air of the upper regions, far above the loftiest mountains, and to enclose it in a huge cubical bag constructed of stout sail cloth, the side of the cube being upwards of a mile in length. With such a vast machine it would be possible (he thought) to transport a whole army and all their munitions of war from place to place as desired. It is astonishing, indeed, that such a visionary scheme could have been seriously entertained scarcely ninety years ago by the Professor of Philosophy at a Continental University.

In 1780 (only five years after Galien's project) the Montgolfiers made a variety of experiments which resulted in the construction of their smoke balloons, thus laying the foundation stone, as it may be called, of the balloons of the present day. Their machine was composed of coarse linen, with a paper lining; it was pear-shaped, 75 feet high, and with a transverse diameter of 43 feet. The smoke of 50 lbs. of dry straw in small bundles, joined to that of 12 lbs. of wool, was found sufficient to fill it in 10 minutes, the white smoke produced from this combustion having a specific gravity of ·7 that of atmospheric air.

As instances of the practical uses that the Montgolfiers proposed to derive from their invention, they suggested that "large balloons might be employed for victualling a besieged town, for raising wrecked vessels, perhaps even for making voyages, and certainly in particular cases for observations of different kinds, such as reconnoitering the position of an army, or the course of vessels at 25 or even 30 leagues distance."

This leads us at once into one of the divisions of the present paper—viz., the consideration of the respective values of the different military purposes to which it has been proposed to apply balloons. The foregoing suggestion enumerates three—viz., throwing supplies into a besieged town, the conveyance of messengers on journeys, and the general purposes of reconnoissance. It has been also proposed to employ large balloons for aërial batteries, and small ones as the carriers of single shells for vertical fire.

With reference to the first proposition—that of relieving a besieged town—many objections at once present themselves. To support in the air any quantity of provisions or munitions of war, a very considerable buoyant power would be necessary, requiring either an immense balloon, if one only were employed, or a great number of smaller ones, either case involving the production of gas on a very large scale, which (difficult enough during peace, with ample time and convenience) would be doubtless quite impracticable to the relieving force in actual war. Besides, as past experience shews that balloons in the air are entirely at the mercy of the wind, and no attempt at steering them has ever yet proved successful, it would be necessary (for a balloon to move directly between two given points) to wait until the wind happened to blow *exactly* in the required direction. Practically, this would be almost impossible, and of course time would be an object; but even supposing the balloon to ascend and proceed on its journey with the favourable condition specified, there still remain the chances of the wind shifting whilst it is on its way, the possibility of its coming within range of the enemy's fire, and the difficulties of making a descent exactly upon the required spot. As an instance of the difficulty of ascertaining one's exact whereabouts after a long aërial journey, I would mention that when Green's large balloon (after its long voyage from England) descended in Nassau, the aëronauts were at first actually in doubt whether they had alighted in Poland or Sweden. The idea is, in fact, quite impracticable, and too much time perhaps has been already occupied in seriously discussing it.

Almost identically the same objections apply to the proposed conveyance of troops or messengers on long journeys; but the idea of using balloons for aërial batteries has been so frequently started and worked out as a feasible project, that its alleged merits and defects would seem to deserve a more careful investigation on the present occasion.

I have already mentioned Lana's proposition, "to rain down fire and conflagration from the clouds" upon the devoted cities and lines of fortification beneath; and during the Crimean war it was similarly proposed to drop combustibles into Cronstadt from an elevation attained by means of a large balloon. During the Indian mutiny in 1857, a Scotch gentleman, Mr. Gillespie, took a great deal of trouble to convince the Government that aërial batteries were quite practicable, and were very much wanted in the British service. As his project is a fair specimen of most schemes of the kind, the following brief description of it may prove interesting. He proposed to raise, by means of a balloon, a square wooden platform, large enough to contain a dozen men and an unlimited number of loaded shells. This platform having been carefully adjusted by means of three guy ropes over the required spot, at a height above it of two miles (so as to be out of range of the enemy's projectiles), the twelve men could, according to Mr. Gillespie, effectually destroy the town or works beneath by dropping their shells upon them. When their ammunition was all expended it was proposed to use a small traveller balloon attached by a ring to one of the guy ropes, which could thus ascend to the platform with a fresh supply.

The main balloon for this purpose was to be 40 feet in diameter, according to the following calculations prepared for Mr. Gillespie by Professor Sang, F.R.S.E.

Weight of platform and party (at 13 stone per man)	2184 lbs.
Silk balloon, varnish, and network	160 -
Weight of hydrogen (with S. G. of $\frac{1}{16}$)	261 -
	2605 -
Weight of displaced air	2613 -
Excess of buoyancy	8 -

(But no account, it will be noticed, has been taken in these calculations of the weight of the shells upon the platform.)

The guy ropes were to be $1\frac{1}{2}$ inches in circumference, to resist a strain of 484 lbs. on the balloon, exerted by a wind blowing at the rate of 15 miles an hour, and additional balloons would of course be necessary to support these ropes. This scheme was reported upon by an officer of our corps, Lieutenant Locock, R.E., and very successfully demolished by him. It was shown in the first place that the scheme held out no peculiar advantages, even allowing its feasibility. The mere power of pouring shells promiscuously into a place is no gain, and they can be already thrown in with as much certainty and a great deal faster from shell guns and mortars. If, however, an accurate adjustment over an enemy's magazines or the works to be attacked were possible, an object would be certainly gained; but at the elevation of two miles above the earth a perfectly calm day hardly, if ever, occurs, and the slightest wind would disarrange the adjustment. The guns of a ground battery can rectify their aim by observing the effect of their last shot, and they can, without altering their position, direct their fire on several different works. Not so the balloon battery, and even with the aid of instruments, it would be almost impossible for the aëronauts to ascertain the precise spot over which they were hovering. Each shell, before being launched from the swaying platform, would have acquired an initial velocity in a horizontal direction, and it would consequently fall, not vertically, but in the direction of a resultant between this force and that of gravity, supposing the pressure of the wind upon it during its fall to be disregarded. It would be impossible therefore to judge precisely how to correct the aim, *i.e.* the position of the platform, and the shell-dropping would be perfectly promiscuous.

These objections have been made to the scheme on the supposition that it is practicable; this has now to be considered. The $1\frac{1}{2}$-inch rope proposed to retain the balloon to the earth has a safe working power of 484 lbs. But each guy rope was to be $2\frac{1}{2}$ miles in length, which would weigh $957\frac{1}{2}$ lbs., and it would consequently be torn asunder by its own weight, unless supported by auxiliary balloons at intervals along its entire length, the objections to which are sufficiently obvious. Taking *one* balloon, therefore, as the sole supporting power, it was calculated that, in order to sustain guy ropes of sufficient strength to resist a pressure of wind blowing upon it at the rate of 15 miles per hour, it should have a diameter of 386 feet. This result was arrived at on the assumption, by Lieut. Locock, of several very favourable conditions to the scheme, viz., a neglect of the curve of the guy ropes, of the pressure of the wind upon them, and of the weight of the balloon, party, platform, shells, &c. I have omitted to enumerate all the objections that might be fairly urged against the scheme; but it is considered that the above result is quite a sufficient answer to such propositions for the employment of balloons as aërial batteries.

Another use for them has been suggested by a Mr. Green, the son of the well-known aëronaut. He proposes to employ small balloons, each large enough to sustain one loaded shell, and to send them up during a favourable wind, so that they might be wafted over towards the enemy's position. When they had arrived over the spot determined upon, the action of a previously lighted slow match would simultaneously liberate the shell and destroy the balloon (the last operation being performed in order to preclude the possibility of its ever falling into the enemy's hands, and being afterwards used by him in a similar manner). It is however evident that, in order to ensure the success of this scheme, an accurate knowledge would be necessary—1stly, of the precise distance of one's own position from the enemy's works or magazines to be shelled in this manner; 2ndly, of the exact velocity of the wind at the moment, this velocity being assumed to remain uniform; and 3rdly, of the exact altitude at which the balloon would be, and the velocity it would have acquired at the moment of letting fall the shell, which would not drop vertically downwards, in consequence of its previous motion. These appear insuperable obstacles in the way of the scheme's success; but Mr. Green said, when I mentioned them to him, that he had no doubt that at a siege the scientific attainments of the corps of Royal Engineers could easily overcome such slight difficulties as these. The scheme may notwithstanding (like the others) be set aside, as impracticable, from further consideration in this paper.

There appears no reason however why balloons should not be used at moderate elevations to assist reconnoitring officers (by virtually extending their horizon) in obtaining the required information concerning the nature of the surrounding country and the movements of the enemy. They need not necessarily be within range of the enemy's projectiles, and a slight elevation would probably be found sufficient, when it is remembered that at the altitude of about 500 feet objects may be plainly distinguished on a clear day at a distance of twenty miles. This is particularly pointed out by Sir William Reid, who, when Governor of Malta in 1855, forwarded to the War Office a proposal from a Dr. Collings, to use "spy balloons" (as he called them) in the Crimea. This gentleman proposed to attain an elevation of 9,000 feet, and though only *one* retaining rope was allowed for, the buoyancy required for this purpose would necessitate the use of a balloon 70 feet in diameter, if inflated with hydrogen gas having a specific gravity $\frac{1}{8}$th that of atmospheric air.

Sir William Reid writes, "as balloons were successfully used more than sixty years back by a French army, they may perhaps be made of some use in the Crimea just now. To raise an observer even 200 or 300 feet above a fortified position might enable assailants to form more correct ideas on inner intrenchments than when only viewing such a position from a height of equal altitude."*

* Major General Money, in a pamphlet addressed to the Right Honourable Charles Yorke, London, 1803, says:—"There are few men, Sir, in this country who know better than myself what use can be made of balloons in military operations, having been three times up with one, and expressly for that purpose; there never was a doubt in my mind on the subject; you see from them everything you wish to see."

On the same day that the above letter was written by Sir William Reid, a similar proposition was made to the War Department by Mr. Shepherd, C.E., who designed the balloons and their inflating apparatus used during the search for Sir John Franklin's expedition. He states that he "can fit up a portable apparatus which will fill a balloon in about an hour, capable of taking up one man to a height of 600 or 700 feet, with rope to pull him down again."

Though the *principle* of these schemes was highly approved of by the officers to whom they were referred, and though similar propositions have been repeatedly made since that time, it is hardly necessary to mention that balloons have hitherto never been used for military purposes in the British service. Their absence from our field equipment is probably more attributable to an over-estimate of their defects, than to a non-appreciation of their advantages in military operations. That these defects are less serious than is generally supposed, I trust to be able to demonstrate in a future portion of this paper; but it is first proposed to examine the experience afforded from past tests of the use of balloons in actual warfare, so as to ascertain whether failure of precedents can be assigned as the reason for their not having been hitherto adopted in the British service.

The French, by whom the actual idea of balloons was originally conceived and carried into effect, were also the first to discover the adaptability of their invention to practical purposes. At the commencement of the Revolutionary War, about ten years after the production of the Montgolfier balloons, an Aërostatic Institute was formed by command of the French Directory (at the suggestion of Guyton de Morveau) in the Ecole Polytechnique, and under its superintendence reconnoitring war balloons were constructed by a M. Couté, and supplied to each republican army in the field. The army of the Rhine and Moselle was provided with two—viz., the "Hercule" and "Intrépide;" another named the "Céleste" was prepared for the use of the army of the Sambre and Meuse; the "Entreprenant" for the army of the North; and a fifth was destined for the army of Italy. That attached to the army of the Sambre and Meuse, under General Jourdan, was first used May, 1794, by Colonel Coutelle,* at Maubeuge, before Mayence, in reconnoitring the enemy's works. This balloon, which was 27 feet in diameter, and took at first 50 hours to inflate, was retained to the earth by two ropes, and the aëronauts communicated their observations by throwing out weighted letters to the General beneath. After this method of reconnoitring had been successfully practised four or five days, a 17-pounder gun was brought down to a neighbouring ravine, and (being thus masked) suddenly opened fire upon the balloon. Several shots were fired without effect, and the machine was then hauled down; but the next day the gun was forced to retire, and the reconnoissances were then carried on as before. After two or three weeks, the balloon was moved to Charleroi, distant from Maubeuge about 36 miles. To save the expense and trouble of another inflation, it accompanied

* According to the report of this officer (quoted by Mr. Coxwell): "The Aërostatic Institute was established in 1793, and abandoned on Bonaparte's return from Egypt, in 1802. M. Couté, the director, had followed Bonaparte in this latter expedition, but the English having seized the vessel in which the apparatus for generating hydrogen had been embarked, the balloon was not employed in Egypt. In addition to other places, balloons were used at Andernach, Bonne, Chartreuse, Liége, Coq-Rouge, at the siege of Coblentz, at Kiel, Strasbourg, and Fleurus."

the troops at a sufficient height to allow the cavalry and baggage waggons to pass beneath, 10 men marching on either side of the road, and each man holding a separate rope attached to the balloon, which was thus retained at its proper elevation. After making one observation on the way, the balloon arrived before Charleroi at sunset, and the Captain had time before close of day, to reconnoitre the place with a General Officer. Next day they made a second observation in the plain of Tumet, and at the battle of Fleurus, which took place on the following day, June 17th, 1794, the balloon was employed for about eight hours, hovering in rear of the army at an altitude of 1,300 feet.

The Austrians after some time discovered it, and a battery was opened against the aëronauts, but they soon gained an elevation out of the range of the enemy's fire, and the information concerning the Austrians' movements (which they were enabled in this manner to supply to General Jourdan) contributed mainly, it is said, to the success of the day,* the result of which was the loss to the Prince of Coburg and the allied armies of all Flanders, Brabant†, &c.

This notable instance of the successful employment of a reconnoitring balloon is thus commented upon in the French history, "La Guerre de la Révolution de France :"—"Ce fut à cette bataille, (Fleurus) que l'on fit, pour la première fois, l'essai d'un arëostat, avec le secours duquel le Général Jourdan put être parfaitement instruit des dispositions et des mouvemens d'ennemi ; ainsi, cette découverte, regardée jusqu' alors comme un objet de pure curiosité, dut être, dès cet instant, rangé parmi les inventions utiles."

The next battle that the French gained through the assistance of a balloon was near Liège, on the Ourte river. As the Austrian officers afterwards said, "one would have supposed the French General's eyes were in our camp," for they were attacked at the critical moment of sending off their guns and baggage by the rear, the French (though occupying much lower ground than the Austrians) having been intimately acquainted with all their movements, by means of their balloon. The result of this battle was of very considerable importance to the French, as it gave them all the country between Liège and the Rhine.

* A Dr. Miers, of Hamburgh, in his journal that he published on his excursion to Paris, tells us that :—"J'ai vu à Paris et à Meudon le Capitaine Coutelle, le même qui le 17 Juin, 1794, montoit le ballon qui dirigeoit la merveilleuse et importante reconnoissance de l'armée ennemie à la bataille de Fleurus, accompagné d'un Adjutant Général. J'ai lui ai parlé de son voyage aërien, pendant cette bataille, si décisive par suites, dont le succès est du en partie à cette expédition aërostatique d'après le jugement unanime des personnes impartiales. Coutelle correspondit avec le Général Jourdan, Commandant de l'armée Française, par les signaux de pavillon convenus."—*From Major General Money's Pamphlet.*

† After Fleurus, Kléber and other generals reported against "inflated taffeta." Some prisoners taken and questioned after the battle, admitted that even the garrison at Charleroi had been frightened out of its life at the apparition. Many soldiers seeing a machine hovering over their heads, said, "How can we fight against these republicans who, out of reach, see all that passes beneath?" Carlyle has given a most humourous description of this scene :—"Hangs there not in heaven's vault some prodigy seen by Austrian eyes and Austrian spy-glasses, in the similitude of an enormous wind bag? . . . By heaven! answer spy-glasses, it is a Montgolfier, a balloon, and they are making signals! Austrian cannon battery barks at this Montgolfier; harmless as dog at the moon. What will not these devils incarnate contrive!"—*Paris Correspondent of "Army and Navy Gazette."—January 17th*, 1863.

They afterwards used reconnoitring balloons at the sieges of Mentz and Ehrenbreitstein, 1799. A balloon was also attached to the army sent on the memorable expedition to Egypt. What service it rendered there we are not informed* ; but after the capitulation of Cairo it was brought back with the remains of the army to France, and was afterwards used by MM. Biot and Gay Lussac, in their celebrated ascent for philosophical investigations.

These French war balloons were inflated in the field by hydrogen gas obtained on passing steam through red hot cylinders charged with iron turnings. The gas thus evolved was then made to pass over lime, and in this manner freed from any heavy carbonic acid gas that might adhere to it. By this method there was procured at a very moderate expense, and in the space of about four hours, a quantity of hydrogen gas sufficient to inflate a balloon 30 feet in diameter; though at first as much as fifty hours was required to produce the necessary quantity of gas.

To each war balloon there was attached a company of 30 men under the charge of a captain, according to the report by General Baron Pelet, French Minister of War in the reign of Louis Philippe, who says also that "after 5 or 6 years' existence the Aërostation Corps was suppressed, since which time no sufficient inducement has occurred to cause that service to be re-organised in France, or to be established in foreign armies, because the perfection of balloons and the irapplication in war render many more experiments necessary, for which the intervention of a government is necessary." An attempt was, however, made to revive them in the African campaign of 1830, but there was no opportunity for making use of them. The Austrians are said to have employed reconnoitring balloons before Venice in 1849, and the Russians in observing from Sebastopol. The French again made use of them in the late Italian campaign of 1859, but this time the service was in charge of civilian aëronauts, the MM. Godard. Ascents were made from Milan, Gargonzola, Castenedolo, and the Castiglione Hills; and, according to the *Times*' Paris correspondent (in letter dated 11th January, 1862), they proved great failures, as judged from a military point of view. However the *Times*' special correspondent in Italy, Carlo Bossoli, thus writes concerning the balloon reconnoissance of the Austrian position at Solferino:—"On the day before the battle of Solferino, 23rd June, 1859, even with the best glass, nothing was seen at Solferino, which is ordinarily visible from the hills near Castiglione. In the afternoon, however, the brothers Godard tried from these hills a balloon ascent on a larger scale than some days before from Castenedolo. And on the Austrian side, where this ascent was seen, it is supposed that their plans were discovered by the Messrs. Godard."

The expenses of the general balloon service in Italy amounted to about £2,000, of which only a part was paid by the French Government, and, consequently, a lawsuit was recently brought by the MM. Godard to recover the remainder of the sum. This action gave rise to some comments in the *Times*' correspondent's letter previously alluded to, which were very prejudical to the idea of war balloons. But an attentive consideration of the subject only shows that the matter rests precisely where it did before. For the service is still in its infancy, and though the employment of balloons in war need not of necessity be invariably attended by the same anticipated beneficial results, yet it is an indis-

* Vide note page 76.

putable fact that there have been many occasions on which they have been successfully so employed, and these are considered sufficient to justify the expectation that the use of reconnoitring balloons in military operations may be attended in general by the most advantageous results. The most recent instance of a successful balloon ascent for the purposes of military reconnoissance (conducted by the Federal Americans at Island No. 10) is thus noted by the *Times* of April 14, 1862 :—"A balloon reconnoissance was made on the 27th March by Professor Steiner, accompanied by Colonel Buford and Captain Maynardier, which established the fact that shells had been thrown at too great a range to be sufficiently effective against the Confederate batteries. This defect in mortar practice has since been remedied." According to a subsequent account, this balloon was filled on a flat-bottomed boat and confined by a single rope. It attained an elevation of about 600 feet, and the reconnoissance is described as having been "eminently satisfactory." I think it may be deduced then from the foregoing historical account, that a very fair average of success has attended the use of reconnoitring balloons by different armies during the last 70 years.

The following are some of the objections most frequently urged against such a practical application of them :—

1st. The chance of their being struck by the enemy's projectiles, and caused to fall suddenly in consequence of the escape of gas through the holes thus formed in the silk bag.

2nd. The size, weight, and consequent difficulty of transport, attendant upon balloons with sufficient buoyant power to admit of their being attached to the earth by guy ropes.

3rd. The difficulty of providing gas for their inflation when in the field.

4th. The difficulty of attaching to the army experienced aëronauts for the purpose of inflating the balloon, regulating its ascents and movements in the air, and taking general charge of it on service.

5th. The danger incidental to balloon ascents in general, even when undertaken by experienced and professional aëronauts.

1. In answer to the first of these objections it may be stated that, even supposing the balloon to come within range of the enemy's fire, its descent upon being struck would not be effected so instantaneously or completely as is generally imagined. When the great Nassau balloon fell into the sea near Sheerness, in 1850, 60 rounds of ball cartridge had to be fired into it before any perceptible effect was produced in its size by the escape of gas; each bullet passing right through the balloon and thus forming two holes in the bag. If it were struck by shot below the level of the gas, (and balloons are seldom perfectly full) of course not the slightest effect would be produced; and anyhow it is apprehended that wherever the hole be formed, the balloon would retain sufficient buoyant power to admit of an easy and safe descent to the ground. In addition, it should be borne in mind that the aëronauts, if exposed to fire, could at pleasure descend to the earth, or ascend until out of range (as at Fleurus), provided that the length of guy rope were sufficient for this purpose, and in all probability there would be few occasions in a campaign when it would be necessary to reconnoitre in this manner in exposed positions.

2. The size of the balloon depends of course upon two conditions—the nature of the gas with which it is inflated, and the weight it has to lift. A scheme

has been already alluded to in this paper, which proposed to employ a balloon to elevate reconnoitring officers to a height of 9,000 feet. To support one retaining rope of this length, a balloon 70 feet in diameter would be requisite; but if (as is proposed in this paper) an elevation of merely 600—700 feet be considered sufficient—a balloon with diameter of about 28 feet will be found large enough for the required purpose, if filled with hydrogen gas having S.G. ·166. The exact manner in which this dimension is calculated for the proper ascending power will be described afterwards; but with reference to the portability of the machine it may be remarked that the whole apparatus, together with that for the generation of gas, could be easily conveyed in a single Field Train waggon.

3. A specific gravity one-sixth that of atmospheric air, has been allowed for the hydrogen to inflate the balloon (its S.G., when perfectly pure, being about one-fourteenth). That of coal gas, which is usually employed in ordinary balloon ascents, is ·4; but notwithstanding, its superior merits for the purpose are strongly advocated by the amateur aëronaut, Mr. Monck Mason, in his "Aëronautica," in consequence of "the greater subtilty of the particles of hydrogen, and the stronger affinity which they exhibit for those of the surrounding atmosphere*." Its greater lightness renders it, however, preferable in the present case, and the method of producing the gas in the field has now to be considered. Undoubtedly, the quickest manner of doing so would be to obtain it by the action of dilute sulphuric acid upon zinc or iron, but the danger of carrying about large quantities of sulphuric acid is so great, that another method is preferable. The French evolved hydrogen for their war balloons by passing steam over red hot iron turnings, but probably an improvement would be effected in this process by the substitution of charcoal, at a very low degree of red heat, for the iron turnings,† the interior of the tubes having been previously well oxidised by a current of steam; the charcoal presents several advantages, being easy to obtain in well-wooded countries, and requiring a lower degree of heat in order to prevent the formation of carbonic oxide. After

* For, since the rates of diffusion of gases vary inversely as the square roots of their densities—

Diffusive power of coal gas : diffusive power of pure hydrogen

$$:: \sqrt{\cdot 069} : \sqrt{\cdot 45}$$
$$:: \cdot 255 : \cdot 67$$
$$:: 1 : 2\cdot 627$$

† The production of hydrogen in large quantities by this process is described by the French chemist, M. Deville, in the "Annales de Chimie et de Physique," for January, 1861, but his gas contained H 53·2 vols.

Co 40·3 -

Co_2 6·5 -

Mr. Bloxam, of King's College, informs me that by passing steam over red hot coke in an iron tube (whose interior had been previously oxidised by a current of steam) he obtained a gas composed of H 81·6 vols.

Co 8·4 -

Co_2 10·0 -

but even this gas (before being purified) would have a S.G. almost double that required for the present purpose.

the production of the gas, it would have to be purified by lime from any taint of carbonic acid gas, and it must be properly cooled before entering the balloon. Without experiment, it is almost impossible to form any definite idea of the time which would be occupied by this process in the production of gas in sufficient quantities, but it is probable that two or three hours would be found enough, and it is certainly preferable to the zinc and sulphuric acid method,* being safer both in use and transport, and requiring far less weight both of apparatus and materials.

4. For the management of the balloon about five or six Sappers would probably be sufficient, having been previously instructed in all the practical details necessary for the service, such as the method of putting together the gas-supplying apparatus and inflating the balloon, the management of the guy ropes, repairing the balloon (in case of accident), &c. They should also make a few ascents with some experienced aëronaut to be taught the method of using the valve, ballast, grappling anchor, &c., in case they had ever to make an independent voyage ; but all this practical knowledge might be easily acquired in two or three weeks, and the balloon service would then be solely in military charge.

5. The accidents that occasionally happen in balloon ascents are attributable mainly to the negligence and folly of the owners. The envelope or bag is often, for the sake of economy, constructed of cotton instead of silk, and this material, (not being very durable in the first instance, and still more weakened afterwards by the action of the varnish and gas) wears out after a few seasons' use, and the slightest strain on the balloon tears open the stuff. The ropes too are frequently used in wet weather, packed up carelessly and consequently rot, the result being that the netting or grappling ropes, though sound in appearance and sufficient for moderate purposes, give way on any extraordinary tension, and the machine is no longer under the aëronaut's control. To some of these causes may be generally traced the occasional accidents that occur in balloon voyages ; and as the ascents are generally advertised several weeks beforehand, in order that the spectators may not be disappointed, the aëronaut has to ascend at the fixed hour, frequently in a hurricane of wind or under adverse circumstances which would deter him from the attempt if he were in an independent position.

However, the percentage of accidents is excessively low in proportion to the number of balloon ascents made. It is conceived, therefore, that careful superintendence and examination should entirely preclude the possibility of any

* In 1855, Mr. Abel, Chemist to the War Department, designed and constructed such an apparatus to generate hydrogen for balloons from zinc and oil of vitriol. He writes :—"Possibly the so-called water gas process, of American origin, might be modified so as to yield a gas sufficiently light for inflating balloons without the necessity of very extensive arrangements" In a later memorandum (extracts from which Sir John Burgoyne was good enough to communicate to me) Mr. Abel says :—"Portable apparatus have been constructed within the last few years for the production of oil or resin gas for illuminating purposes, and I have little doubt that some similar and efficient arrangement could be contrived for generating gas suitable for balloon inflation." He also alludes to the perfection of Wheatstone's method of magnetic telegraphy as being applicable to the communication of information from war balloons.

accident in the use of military balloons; and as an instance of what proper care and attention will effect, it may be mentioned that the two aëronauts, Messrs. Green (father and son), have made between them some 930 ascents, in none of which have they met with any serious accident or failure.

In the consideration of the proper size, nature, &c., of a balloon fit for reconnoitring purposes, the wind may be assumed to exert the same pressure upon the balloon as it would upon a circle of similar diameter; for though theoretically a solid sphere presents only $\frac{4}{7}$ths of the resistance to the air opposed by its generating circle, yet practically, in the case of a balloon, there would not be much difference, since it often collapses under the force of the wind and presents a flattened surface, and at the same time the network of cordage in which it is encased catches the wind and increases the resistance very considerably.

Balloons also are usually constructed of a pear shape (having the longitudinal axis about $\frac{1}{6}$th greater than the transverse) so that the network may be properly adjusted upon it, and consequently the surface presented to the action of the wind is somewhat larger than a hemisphere. Taking these points into consideration, the resistance of a plane circle 28 feet in diameter may be allowed for, as sufficiently accurate for all practical purposes, this dimension having been stated in a former portion of this paper as being sufficient for a balloon to fulfil all the required conditions.

The area of this circle being 615$\frac{3}{4}$ square feet, the following table shows the pressure it would have to sustain from different winds :—

	Velocity per hour.	Perpendicular force on 1 sq. ft.	Pressure on a balloon 28 ft. in diameter.
Gentle, pleasant, wind	5 miles	·123 lbs. av.	75·73 lbs. av.
Brisk gale..	10 -	·492 -	302·95 -
Very brisk..	20 -	1·968 -	1211·80 -
High wind..	30 -	4·429 -	2727·117 -
Very high wind..	40 -	7·873 -	4847·82 -

1-inch round wire ropes might be employed with advantage as guy ropes to retain the balloon to the earth, since they correspond in strength to the 2$\frac{3}{4}$-inch hemp ropes and weigh exactly half as much. The breaking strain of this rope being 2 tons, its safe working power may be taken at half this weight, or 1 ton.*

Consequently, supposing there to be 2 guy ropes, each 550 feet long (to allow for the curve and inclination caused by the buoyancy of the balloon elevated between the two), as the weight of each rope would be about 92 lbs., we have 4,296 lbs. as the total available resisting force† against the pressure of the wind upon both balloon and guy ropes, a degree of strength sufficient to resist even a

* It has been objected that this is too liberal an estimate of the safe working load of an iron wire rope, in proportion to its breaking strain. It is the usual allowance to make for hempen ropes, but Messrs. Newall and Co., the patentees of the iron wire ropes, allow only $\frac{1}{6}$th in consequence of the uncertainty attached to the working of iron, which cannot be relied upon, being seldom perfectly homogeneous. Fairbairn, however, in treating of iron girders, allows as a safe load $\frac{2}{3}$rds of the ultimate breaking weight.

† Since force $= 2$ (1 ton$-$92 lbs.)
$= 2$ (2240 lbs.$-$92 lbs.)
$= 4296$ lbs.

wind blowing at the rate of 30 miles an hour. As this is considered the maximum velocity of wind in which a captive balloon can be safely used for observation (in consequence of the violent rocking and swaying of the car) there can be little doubt but that these guy ropes would be sufficiently strong for their purpose. The following table then details the weights to be lifted:—

2 Guy ropes (of 1-inch wire rope) each 550 feet long	184 lbs.
2 Men (at 11 st.)	308 -
Silk bag of balloon	40 -
Car, Network, &c..	150 -
Instruments, &c.	18 -
Total weight..	700 -

And as the 28 feet balloon may be considered as a sphere, for the gas seldom fills the lower portion, its cubical contents may be taken at 11,494 cubic feet; and if inflated with hydrogen $\frac{1}{6}$th the weight of the surrounding air, the ascensional force will be $11{\cdot}494 \times 62{\cdot}5 = 718$ lbs. (as 1,000 cubic feet of air weigh about 75 lbs.), and consequently the balloon would rise with an ascending power of 18 lbs.*

The above calculation of the suitable size for a reconnoitring balloon has of course been made upon the supposition that hydrogen is obtainable from the proposed gas apparatus with a degree of purity equal to a specific gravity $\frac{1}{6}$. This could be only definitely determined by experiments, whose results might possibly modify the above figures, though not, it is anticipated, to any very considerable extent.

The balloon itself should be constructed of silk, and payed over with an elastic varnish. Cotton is sometimes used instead of silk, being less expensive,† but it is not so durable and soon wears out from the action of the gas and varnish. It entails also a considerable loss of ascending power, being in itself heavier than silk and requiring about double the quantity of varnish, which increases its weight; besides, the subtle nature of hydrogen gas renders it advisable to use a material of a closer texture than cotton.

As the balloon is to be used for reconnoitring, the colour of the silk should be such as to render it invisible at a distance. Grey is the best for this purpose,

* This ascending power would be sufficient for calm weather, but must evidently be increased (by diminishing the weight or other means) in proportion to the strength of the wind. For the pressure of a strong wind upon the balloon would obviously force the rope so much out of the perpendicular, that the balloon would attain a very slight elevation without considerable buoyant power and a great length of rope. Supposing 45° to be the maximum angle to be safely allowed for the rope's deflection from the perpendicular, in this case ascending power must = force of wind, and $(\text{strain on rope})^2 = 2\,(\text{force of wind})^2$. The guy ropes previously described are of considerable strength, chiefly in order to resist the violent jerks on the rope caused by sudden gusts of wind. Since the above was written, an account has appeared in the *Times* (of April 29th) of an accident happening to an American reconnoitring balloon, at Yorktown, in consequence of the breaking of the retaining rope. This shows the advantage of providing guy ropes of even an excessive strength.

† A silk balloon of the above dimensions, with all its accessories complete, would cost about £250. A cotton one would probably not cost one-third this sum.

but as the varnish would turn it almost black, it would be advisable to employ a white silk, and the varnish would then render it of a light brown colour. Experiment alone can, however, determine upon many important points connected with the balloon service, such as—

1stly. The most desirable arrangement of the gas generating apparatus, and the quality as well as the quantity of gas which it would evolve in a given time.

2ndly. The best way of attaching a balloon to the earth, and of managing the guy ropes.

3rdly. The resistance offered to the wind by the captive balloon and its retaining ropes.

4thly. The greatest velocity of wind in which a balloon can be safely retained to the earth and conveniently used for reconnoitring.

In conclusion, I would briefly recapitulate the different heads of the subject upon which this paper has treated. It firstly enumerated the various propositions which have been from time to time entertained for the employment of balloons for military purposes; these having been considered and reduced to one (that of reconnoitring), the various instances were described of their actual use in this capacity, and their employment in the English service advocated on the supposition that they would be found of similar utility to our armies. The most customary objections to them were then considered, an inquiry made into the description of balloon best suited for the purpose, and those experiments noticed which appeared most necessary to ensure their efficiency and success.

For the military balloon service, though its uses have been already practically tested on several occasions, has never yet been thoroughly reduced to a complete system, and this is most necessary, since, according to the present Emperor Napoleon,* "whatever is complicated fails in producing good results in warfare; the promoters of systems forget always that the object of progress ought to be to obtain the greatest possible effect with the least possible effort and expense."

The subject is certainly worthy the consideration of the Scientific Corps of the English army, more particularly in the present day, when the resources of science are so especially directed towards the attainment of success in all military operations.

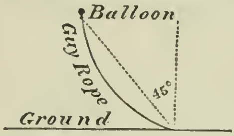
G. E. GROVER,

Lieutenant, Royal Engineers.

* In the preface to his Treatise on the Past and Present of Artillery.

APPENDIX.

Supposing the balloon to be inflated with hydrogen gas having specific gravity $\frac{1}{8}$th, and to be retained to the earth by two round iron-wire guy ropes (each having sufficient strength to take the entire strain). To find a relation between its size, altitude, and the continuous force of wind, on the assumption of the most unfavourable case allowed, viz., when the guy ropes are so deflected by the pressure of the wind upon the balloon that the line between the two extremities of each rope shall form an angle of 45°, with the vertical, thus—



Let $2r$ = transverse diameter of balloon.
„ l = length of each guy rope.
„ B = ascending power, or excess of buoyancy sufficient to raise the balloon to the required height under the specified conditions.
„ P = pressure in lbs. of the wind upon 1 square foot.
„ W = „ „ the balloon.
„ S = strain exerted upon one retaining rope, as the resultant of B and W.

Then evidently

Ascensional Force of balloon. } = { Weight of the guy ropes } + { Weight of party, car, silk bag, and other accessories + Ascending power.

This equation has to be reduced to such a form as will determine the size of the balloon, with reference to its height in the air and the force of the wind.

Ascensional Force of Balloon.—Assuming the balloon to be a sphere with radius r (as balloons are seldom perfectly inflated, and to allow for contingencies) its cubical contents $= \frac{4}{3} \pi r^3$.

Then, as 1000 cubic feet of atmospheric air weigh 75·3 lbs., and the hydrogen employed in this case is assumed to have a specific gravity of $\frac{1}{6}$.

$$\text{Ascensional force of balloon} = \frac{5}{6} \times \frac{75{\cdot}3}{1000} \times \frac{4}{3} \pi r^3 \text{ lbs.}$$

$$= \frac{r^3}{3{\cdot}804} \text{ lbs.}$$

Weight of Guy Ropes.—As the pressure of the wind upon the balloon is so great as to make the line between the two ends of each guy rope form an angle of 45° with the vertical,

The length of this line = (height of balloon) $\sqrt{2}$.

But the rope itself will not follow this line, being formed into a curve partly by its own weight and partly by the pressure of the wind upon it. Allowing then $\frac{1}{10}$th as additional length to that of the line, we have length of each rope = height $\sqrt{2}$ + $\frac{\text{height } \sqrt{2}}{10}$.

Hence,

If the balloon were (Feet.)	high, the length of line between the two ends of each rope would be (Feet.)	and length of each rope would be (Feet.)
100	141·4	155·54
200	282·8	311·08
300	424·3	466·73
400	565·6	622·16
500	707·0	777·70
600	848·4	933·24
700	989·8	1,088 78
800	1,131·2	1,244·32
900	1,272·6	1,399·86
1000	1,414·0	1,555·40

As the guy ropes are constructed of round iron wire rope, which weighs as many lbs. per fathom as it will sustain a safe strain ($\frac{1}{3}$ breaking weight) of tons*,

$$\left.\begin{array}{l}\text{Weight of guy rope}\\ \text{per fathom}\end{array}\right\} = \frac{S}{2240}.$$

$$\begin{aligned}\text{but } S^2 &= B^2 + W^2\\ &= W^2 + W^2\\ \therefore\ S &= W\sqrt{2}\end{aligned}$$

and $W = \pi r^2 P$ (supposing the wind to act only upon a plane circle with radius r, as it probably would in actual practice.)

$$\therefore\ S = \pi r^2 P \sqrt{2}.$$

Then substituting this value of S in the above equation, we have—

$$\text{Weight of guy rope per fathom} = \frac{\pi r^2 P \sqrt{2}}{2240}$$

$$\text{,, \quad ,, \quad foot} = \frac{\pi r^2 P \sqrt{2}}{6 \times 2240}$$

$$= r^2 P(\cdot 0033).$$

Weight of Party, Car, &c.—This may be taken at—

Two men (at 11 stone)	308 lbs.
Silk bag of balloon, car, network, &c.	180 -
Instruments	12 -
Total	500 -

and this may be taken as a constant quantity, since the only variable element in it (the weight of the silk bag) will alter so very slightly.

Ascending Power.—Ascending power in this case = force of wind (W).

$$B = \pi r^2 P.$$

Hence, substituting all these values for the different terms of the first equation, we have (if two guy ropes are employed)—

$$\frac{r^3}{3{\cdot}804} = 2r^2\ P\ (\cdot 0033)\ l + 500 \text{ lbs.} + \pi r^2 P$$

$$\text{or } r^3 = 3{\cdot}804 r^2\ P\ (\pi + \cdot 0066\ l) + 1902 \text{ lbs.}$$

and this is the equation required.

Example.—Supposing, with the fore-named conditions, $P = 1$ (*i.e.*, a wind blowing continuously at the rate of 15—16 miles an hour) and the balloon were required to attain an altitude of 100 ft., so that $l = 155{\cdot}54$ ft.

$$\begin{aligned}\text{Then } r^3 &= 3{\cdot}804\ r^2\ (3{\cdot}14159 + \cdot 0066 \times 155{\cdot}54) + 1902\\ &= 3{\cdot}804\ r^2\ (3{\cdot}14159 + 1{\cdot}02656) + 1902\\ r^3 &= 15{\cdot}855\ r^2 + 1902\end{aligned}$$

whence $r = 20{\cdot}315$ ft.

and the balloon would have a transverse diameter of 40·63 ft.†

G. E. G.

* But vide foot note to page 82.

† A somewhat similar process was adopted by Lieutenant Locock, R.E., in the calculation referred to in page 74.

PAPER XI.

ON RECONNOITRING BALLOONS.*

By LIEUT. G. E. GROVER, R.E.

One has naturally much diffidence in advocating the cause of a novel and untried proposition. The proverbial pound of theory and ounce of practice are usually quoted in opposition at the very outset, and seldom can this comparison be more aptly made than with reference to the subject of the present paper. For few as are the actual balloon ascents that have been already undertaken for the purpose of military reconnoissance, the practical experience we might expect to derive from such ascents is considerably diminished by the unsatisfactory nature of the various accounts we have of them†; these accounts are very confusing, almost, indeed, contradictory. Thus, for instance, with reference to the French balloon reconnoissance at Solferino, one‡ historian of the war tells us that the entire Austrian position was most minutely examined by the aëronauts; another§ author states that the reconnoissance resulted merely in the discovery of three Austrian soldiers near the village of Pozzolengo; a third|| actually ignores the balloon reconnoissance altogether (which seems to imply a want of success); and the account of the ascent given by the aëronauts themselves tends rather to increase the confusion, than to supply our want of an authentic and impartial report of the experiment.

Similarly with the American balloon reconnoissances, which are described with the same accuracy and exactness that characterise their newspaper reports of all military operations in the present civil war. One ascent in particular, made last March at Island No. 10, was said to have been of great service to the artillery, by showing the effect and correcting the range of their projectiles. But from a detailed account given by the special correspondent of the *New York Times*, and copied into our *Times* of Wednesday, April 16th, 1862, there is reason to doubt whether the reconnoissance was really so useful as was stated.

* A paper read at Chatham, 14th November, 1862.

† The above was written, it is hardly necessary to remark, without any knowledge of Captain Beaumont's paper, which was however read at the Royal Engineer Establishment on the same evening.

‡ Carlo Bossoli, *Times*' correspondent. "War in Italy."

§ Bazancourt. "Campagne d'Italie."

|| Ferdinand Lecomte, Major à l'état-major Fed. Suisse. "Relation historique et critique de la campagne d'Italie en 1859."

We cannot, of course, accept implicitly the un-official accounts of official transactions, and it would be absurd to generalise too rapidly from these two cases, and assert that the accounts of all balloon reconnoissances are similarly unsatisfactory, but it must be confessed that the evidence in our possession on the subject generally is scarcely sufficient for one to undertake the part of advocate on either one side or the other, and it is certainly not satisfactory enough to justify a decided judgment on the case. Under these circumstances, the present paper can aim at nothing more than a ventilation of the subject, and it may, perhaps, have the much desired effect of directing attention to an interesting, though at present merely speculative, branch of military science.

It appears surprising at first sight that our government have taken no steps* towards investigating the comparative merits and defects of reconnoitring war balloons, particularly as much attention has been lately directed towards this subject among the scientific men of the French, Austrian, and American armies. Probably the experiments already conducted have not been considered sufficiently encouraging to justify the outlay of the few hundred pounds that would be wanted for the purpose. Unfortunately, the management of these experimental ascents has been too generally entrusted to professional and civilian aëronauts, which evidently alters the circumstances of the case to a very considerable extent. No one doubts that a balloon will rise in the air if inflated with a gas of much lower specific gravity, for its floatation may be as easily calculated as that of a boat. What we really wish to ascertain is whether the results justify the means. If the means can be definitely reduced to reasonable limits in the items of time, expense, and portability, there is little doubt but that balloons would be found very valuable auxiliaries in warfare.

But the ominous silence observed by foreign powers with reference to the results of their experiments appears to answer this question in the negative. During the last few months we have heard very little of the American balloon reconnoissances, and this can be scarcely accounted for by the capture of Professor Low's aëronautic apparatus in the week of battles before Richmond, since other balloons could be easily obtained, and they appear to have been previously most successful in observing the Confederates' movements at different times. Thus the *New York Times*' correspondent in a letter from the Chickahominy River, dated May 23rd, says†: "Observations made by balloons would lead to the belief that the Confederates were moving out of Richmond and concentrating in force on the Manchester side of the James River. The reconnoitring balloon must have been a conspicuous object from Richmond, the word *Constitution* painted on its side being designedly turned towards the city." And again,‡ with reference to the battle of the Chickahominy, June 1st—"During the whole of the engagement on Sunday morning, Professor Low's balloon hovered over the Federal lines at an altitude of about 2,000 feet, and maintained successful telegraphic communication with General M'Clellan at his head-quarters. It is asserted that every movement of the Confederate armies was distinctly visible,

* Since this paper was written the subject of reconnoitring balloons has received the attention of the military authorities, and experimental ascents (the report of which is not yet published) were made at Aldershot on July 14th.—Ed.

† *Times*, June 12th, 1862. ‡ *Times*, June 17th, 1862.

and instantaneously reported." A letter from Fort Monroe,* dated June 22nd, says: "General Hooker answered—throwing heavy shells, which were seen to burst among the rebel attacking party by persons in one of Professor Low's balloons, causing the rebel artillerymen to skedaddle in the most approved style;" and a German officer in the Federal Army before Richmond, writes† on June 11th:—"The enemy has retired some miles, as we learn from our balloons, which are active when the weather allows." We are also told‡ that "Mr. Allan, of Rhode Island, for whom the United States Government have instituted an office with the title of Aëronautic Engineer, has (it appears) made a successful attempt to communicate with the earth from a balloon by means of the electric wire. The first despatch was sent from above Washington, and the Professor describes himself as having been able to take observations over a diameter of 50 miles." §

A history of war ballooning has been given in the Paper preceding this, and the French reconnoissances in Italy do not seem to have effected any very great success, apparently in consequence of some official blunders or mismanagement. M. Prevet, who was commissioned as the Emperor's *mandataire* to organize the military balloon service for the French army in Italy, applied to the aëronauts Godard for their assistance in the undertaking. Though they were anxious to construct a war balloon especially adapted to the requirements of the service, yet (according to their own account) the *mandataire*, who wished to use as little as possible of the 50,000 francs with which he had been supplied for the necessary expenses, desired them to set out at once with such simple apparatus as they happened to have by them. However, the experiments they conducted at Milan induced the Emperor to order the construction of a regular war balloon, and in the mean time the Montgolfière in the aëronauts' possession accompanied the army. It was this balloon which made the ascent from Marshal M'Mahon's head-quarters at Castiglione on the day before the battle of Solferino, and (as the Godards express it) the results were quite insignificant, though the moral effect upon the troops was great. It is probable that Marshal M'Mahon would have been better pleased with less moral effect and more tangible realities; the actual war balloon only arrived at Solferino when the articles of peace were being signed. This machine appears to be well adapted to the purpose for which it was made, and it is unfortunate that no opportunity was afforded for a practical test of its utility in the field. It is made of silk, holds about 30,000 cubic feet of gas, has buoyant power sufficient to raise 3 men to an altitude of from 1,000 to 1,200 feet, will retain its gas for a whole month, and photographs have been often taken from it on a calm day by M. Nadar. It can be inflated in one hour by the ordinary illuminating gas (carburetted hydrogen) when near a town,

* *Times*, July 8th, 1862. † *Times*, July 16th, 1862.

‡ *News of the World*, May 4th, 1862.

§ According to American news received since the reading of this paper, reconnoitring balloons have been also used by the Federals at Bolivar Heights, Harper's Ferry, November 1st, and at the Battle of Fredericksburg, December 13th.—Vide *Times* of November 17th and December 29th respectively; and in the impression of January 19th, 1863, the general American news contains the following paragraph: "A balloon reconnoissance from Falmouth had disclosed the fact that a considerable portion of the Confederate army had left Fredericksburg."

and in the same time by hydrogen manufactured from a special apparatus for field service. After being inflated at Milan, it was moved to Gorgonzola—a distance of 20 miles—and it then remained for two days at the artillery park without suffering any perceptible loss of gas. These details have been supplied me by the MM. Godard themselves, to whose courtesy I am indebted for much information on the subject generally.

One of the most interesting points of consideration with reference to the employment of military balloons is the question concerning the respective merits, for the purpose, of Montgolfières (smoke balloons), or Charlières (gas-inflated balloons). The Americans appear to have used the latter description, since we read* of General FitzJohn Porter being carried away by his reconnoitring balloon, when observing before Richmond last April, in consequence of the retaining ropes having given way at a spot which had been accidentally touched by the sulphuric acid used in generating gas. The French reconnoissance at Castiglione was made from a Montgolfière, as has been already stated, but the MM. Godard, who made this ascent, and have practically tested both methods, express a strong opinion against this species of balloon. Without a cumbrous furnace in the car it will remain stationary in the air only for about 5 minutes, and even then it is scarcely capable of sustaining one aëronaut, in consequence of the high specific gravity of the inflating gas. If it be freed from the weight of a retaining rope, and consequently untethered to the earth, a reconnoissance of about 20 minutes' duration would be possible, supposing the wind to blow in a direction from the enemy. The least wind hinders its inflation, which may, under ordinary circumstances, be made in about 20 minutes. This rapidity of inflation is unquestionably a strong point in the favour of Montgolfières, but the MM. Godard say that out of six ascents recently advertised to take place from the Pré Catalan at Paris, only two ultimately succeeded. Of course the objection on the score of low buoyant power might be obviated by increasing the dimensions of the machine, but then it would be of an almost impossibly gigantic size. The Austrian Engineer Committee state that a Montgolfière of the very slightest useful power must have a diameter of 60 feet, the contents being upwards of 113,000 cubic feet.† At the same time they consider it infinitely preferable for military purposes to the Charlière. A report on the subject by Lieutenant Colonel Baron Ebner, of the Imperial Engineer Staff, thus specifies what he conceives to be the six necessary conditions of the war balloon service: 1st. The balloon should be able to make an ascent soon after the order has been received. It would be of little use in the field if the preparations necessarily occupied half or even a whole day. 2nd. The ascent should not be prevented by a wind of average force (about 1 lb. upon the square foot). A free ascent is then out of the question, since the slightest breeze would drive the balloon from

* *Times*, April 29th, and May 1st, 1862.

† Mr. Coxwell's "Mammoth" Balloon, probably the largest Charlière ever constructed, is 69 feet in longitudinal diameter, and 54 feet in transverse diameter. It is composed of 46 gores, each 44 inches wide, and contains 95,000 cubic feet of gas. Mr. Green's celebrated "Nassau" Balloon, also a Charlière, contains 85,000 cubic feet of gas, having a longitudinal diameter of 60 feet, and a transverse diameter of 50 feet. It can raise 4,000 lbs., including its own weight and that of all the accessories (about 1,000 lbs.) The extreme breadth of each gore is 41 inches.

the place where it is wanted to observe. 3rd. An average height of 100 klafter (622 feet) may be assumed as the proper altitude, which is limited in the case where the balloon is attached to the ground, by the weight of the retaining rope. At this height a surface of ground of about 12 meiles diameter (40 miles English) can be distinctly examined with a good field glass. 4th. The number of persons making the ascent should be two at least. Only in the company of an experienced aëronaut is it possible for an officer to make a reconnoissance with the proper confidence. There is always danger of a sudden gust of wind or a bullet from the enemy tearing asunder the rope that retains the balloon, and thus changing its captive state into one of freedom; one at least, therefore, of the persons making the ascent should be fully capable of managing a balloon thus liberated. A trustworthy and experienced aëronaut is, therefore, an essential condition of the whole undertaking. 5th. The balloon should be in *telegraphic* communication with the ground, since it would take too much time to send written questions and answers up and down the retaining ropes. Hence two skilled telegraphists must be employed during the reconnoissance. 6th. Ascents should finally be practicable at any given spot, and as often as required. And these conditions, Baron Ebner considers, would not be properly fulfilled by the employment of Charlières, or gas-inflated balloons. The production of sufficient hydrogen by the action of sulphuric acid upon zinc or iron would be a complicated, unsafe, costly, and dilatory operation. Even the conveyance of hydrogen in a compressed state would be objectionable, since (if it were compressed to $\frac{1}{20}$th its ordinary volume) the metal casks would require at least 800 cubic feet of contents, and they must be strong enough to resist a pressure of 20 atmospheres. In this case there would be a saving in time, but a very considerable increase in expense.

No notice seems to have been taken by the Austrians of another method of generating hydrogen, viz., by passing steam over red hot charcoal or iron turnings, but they have evidently decided, as far as theory goes, in favour of Montgolfières as the proper species of balloon for military service. For the inflation, however, they propose hot air in place of the smoke of straw, wool, &c., as used by the first aëronauts. For the purpose of heating the air they employ a wrought iron stove, something after the fashion of the boiler of a steam engine; into this the air is driven by powerful bellows, and, after being brought to the proper temperature in parallel flues, it enters the balloon. To counteract the refrigeration which evidently would take place over the surface of the machine, either a lamp apparatus must be carried up in the car, or else an additional supply of hot air must be conveyed to the machine by means of a flue communicating with the earth.

The more then that we examine the investigations into the subject that have been conducted by foreign officers, the more do we learn, not of what has been done, but of what has not been done; the more do we become convinced that there has not been yet discovered a satisfactory system of military ballooning, one fit (that is to say) to satisfy all the evident exigencies of actual warfare.

The present paper has discussed aëreal reconnoissances only. It may not, however, be thought foreign to its purpose to quote the opinion of a celebrated aëronaut, Mr. Coxwell. This gentleman has attracted so much public attention of late in consequence of his ascents with Mr. Glaisher, and more recently, by the so-called military ballooning from Winchester Barracks, that considerable weight is naturally attached to any opinion he may express on the subject. In a letter to the *Army and Navy Gazette* of 11th of January last, he writes :—" The use of balloons in warfare should not alone be confined to reconnoitring but to destructive purposes as well. Dr. Lardner, in a letter to the *Times* on March 31st, 1859, mentions some chemical compounds of a highly poisonous character, which may be used in shells. But if ever ballooning should become a recognized auxiliary in military science, it is most probable that aërial shells raised by balloons, and disunited by means of a fusee, may be used with as much precision as iron shells thrown from mortars. I have no doubt it would be possible to drop, with tolerable nicety, a host of aërial vessels charged with agents calculated to produce stupefaction, if not fatal effects. If by this method our warriors could secure prisoners instead of increasing carnage, humanity would rejoice at so desirable a consummation by such ingenious means."

One feels inclined to doubt the practical feasibility of this proposition, even setting aside the moral objections to it. At the same time one cannot, from theory, dispute the opinion of a man of such experience as Mr. Coxwell, and the foregoing extract has consequently been copied out at length.

To return to the question of aërial reconnoissance. A slight elevation of from 40 to 50 feet may be easily attained by means of the scaling-ladder tripod described in Vol. VII of the Royal Engineer Professional Papers. But if it is required to ascertain, for instance, the effect of breaching a scarp wall, to attain a position in the air in prolongation of the plane of the opposite side of a hill (where an enemy might be massed), or even to assist a fleet by extending its horizon; then some peculiar scheme is necessary in order—1st, to raise the observer *at once* to the required height; 2nd, to sustain him *steadily* in the attained position. The very nature of a balloon militates against the fulfilment of these requirements. The time occupied by its inflation, its unwieldly form when filled, causing it, if retained to the earth, to vibrate at the slightest breeze, besides numerous other objections, all point out that this machine will not, in its present state, supply *satisfactorily* the desideratum for aërial reconnoissances. Whether the advantages of its employment do not counterbalance the drawbacks, whether any improvements may be effected in its shape or any other important point, whether air-screws may ever be constructed with a degree of power sufficient for the purpose—all these are at present merely matters of conjecture. At first sight it certainly appears that, for an air-screw with dimensions requisite to raise the proper weight, motive power is literally unattainable, at all events as far as we can judge from the present state of our scientific knowledge. Some force must be employed of much less weight than the elevating power produced, and steam issuing from the extremity of each vane, after the manner of Hero's first steam engine,* may be suggested as one method of producing the required rotatory motion. But the consideration of all the numerous attendant diffi-

* This is unquestionably a very extravagant way of obtaining power from steam, and it is merely suggested as a means of obviating the use of machinery, which, even if constructed with hollow wrought-iron connecting rods, &c., would be much too heavy for the purpose.

culties opens out such an immense field for conjecture and invention, that it is useless now to pursue the subject further, particularly as we have no data concerning the relation existing between the impelling force, the rapidity of rotation, and the elevating power acquired by any given air-screw.

The problem how to raise heavy bodies in the air by mechanical means has been solved by nature in a wonderful variety of ways. All attempts, however, to copy her in this point have most signally failed, and the mysterious muscular power, exerted on the effort of volition, is rather an object for the anatomist to admire than for the Engineer to hope to imitate.

It is unsatisfactory to reflect that no definite results have yet appeared from all researches into the question of aërial reconnoissance. Balloons have been advocated by some as most suitable for the purpose; they have been condemned by others on the score of their short-comings.

Much, therefore, remains yet to be discovered, and though no practical results seem at present likely to be produced in this country from our investigations, yet a consideration of the subject of Reconnoitring Balloons may possibly effect beneficial results eventually. It will, at all events, prevent what has proved the death-blow to so many ingenious though crude propositions, viz., deferring the consideration of both principle and details to the proper moment for action, this being the evident method of ensuring failure; and hence the comparison of soldiers in time of peace to chimneys in summer.

In default of practical experiment, even theoretical conjecture will not be without its uses, and in this case, in particular, it may tend ultimately to the advancement of military science.

G. E. GROVER,

Lieutenant, Royal Engineers.

Portsdown Hill, November 11, 1862.

PAPER XII.

ON BALLOON RECONNOISSANCES

As practised by the American Army.*

By CAPTAIN F. BEAUMONT, R.E.

Preliminary Remarks.

I have been asked to give some account of my ballooning experiences in the States of America, and I do so the more readily—firstly, because I believe that the art, even as it at present stands, is capable of being turned to practical account; and secondly, because the practice of ballooning, with reference to military manœuvres, being so little known, any remarks on the subject based on actual experience, must, from that cause alone, be of some value; the nature of the art, moreover, is such that to form a just appreciation of its applicability, one must turn, I may say entirely, to the results of experience on the subject, rather than to theoretical considerations connected with it. Lieutenant Grover's paper, which I have read, for all practical purposes exhausts the theory of ballooning; as, indeed, after having compared the specific gravity of the atmosphere within and without the balloon, and referred the result to the work to be done, there is little more to be said; always bearing in mind that to be on the safe side it is well to allow, for various reasons, a considerable excess of buoyancy over the weight to be lifted; the difference being made up with ballast adjustable at pleasure; in the case of a free ascension this is absolutely necessary, and circumstances may, at any time, render it imperative, even on a reconnoissance, to cut away the guys that hold the balloon to the earth. In the remarks I have to make, I shall, therefore, with the exception of a few notes on details, at the end of this paper, confine myself to an account of the apparatus used by the Americans, and my own experiences in connection with the reconnoissances I made.

American Apparatus.

There were two sizes of balloons used; one of small size with a capacity of 13,000 cubic feet, corresponding to that 28 feet in diameter, mentioned by Lieutenant Grover as suitable for the general purposes of a reconnoissance; and the other of about double this size. This 13,000 cubic feet gives about 30 feet as the diameter of the corresponding sphere; and to fulfil the requirements properly laid down by Lieutenant Grover, this is not too much. In practice he would find that his calculations—on the assumption that two people were to be lifted—would not allow sufficient buoyancy, for the following reasons: no allowance is made for ballast, three in place

* A Paper read at Chatham on 14th November, 1862.

of two guy ropes should be used, and they should be 1,000 feet long at least, as that is by no means an unnecessary elevation to provide for. The larger sized balloon was, however, the one that the Americans decidedly preferred, it was constructed because the power of the other was found to be insufficient, and was used exclusively in place of the smaller one, which it superseded. I myself should decidedly think the larger size the best, for many reasons; amongst them—the extra cost is not nearly proportional to the increased size, nor is the trouble and expense of management; while size gives steadiness and safety when in the air, which is a great point to those using it; it is also frequently desirable to take up more than two people, which the smaller one will only do—(take up two people), when quite full of gas, a condition happening even in its most perfect state only periodically, *i.e.*, after it has just left the gasometer.

Balloons.

The balloons were made of the best and finest description of silk, double sewn and prepared with the greatest care; the summit of the balloon containing the gas valve being made of either three or four folds of cloth, to ensure sufficient strength in that part subject to the greatest strain. The varnish, on which the success of the apparatus much depends, was a secret of Mr. Low's, the chief aëronaut, his balloons kept in their gas for a fortnight or more, and their doing so he laid to the fact of the varnish being particularly good; there was always a small amount of leakage, still at the end of a fortnight sufficient gas remained in the balloon to enable him to make an ascent without its being replenished. In balloons for military purposes this is an important point, as they must be kept ready to ascend at any moment. I have little doubt, however, that many well prepared varnishes could be found to answer the purpose as well; the network covering the bag was gathered in, in the usual manner, and ended in a series of cords attached to a ring, hanging about level with the tail of the balloon, and from this hung the wicker-work car, the ring being about level with a person's chest when standing upright in the car. The string for working the valve passed through the centre of the balloon, and coming out at the tail was loosely tied to the ring, to which were fastened the guys, three in number; thus the car, though swayed about by the motion of the balloon, hung always nearly vertically beneath it.

Car.

Generators.

The gas generators, two in number, were nothing more than large tanks of wood, acid proof inside, and of sufficient strength to resist the expansive action of the gas; they were provided with suitable stopcocks for regulating the admission of the gas, and with man-hole covers for introducing the necessary materials. The gas used was hydrogen, and indeed for practical purposes, all things considered, there is none other that is nearly so suitable; its low specific gravity makes it a *sine qua non* for a military aëronaut, as independently of the ease with which it is produced, when a balloon is attached to the earth it is of the first importance that it should offer as little resistance to the air as possible, as its stability depends upon this point. The hydrogen was generated by using dilute sulphuric acid and iron; any old iron, such as bits of the tires of wheels, old shot broken up, &c., was used; so that it was necessary to provide only the sulphuric acid, which in large quantities is cheap, and with proper precautions very easy to carry.

Purifiers.

The gas generated passed through a leathern tube into a lime purifier, and thence in a similar manner into a second, the action of the lime simply absorbing the carbonic acid and other extraneous gases, and sending the hydrogen, quite, or very nearly pure, into the balloon. On leaving the generator its temperature was high, even the leathern pipe being so hot that the hand could hardly bear to touch it, but after passing the second purifier it was delivered, barely warm, into the balloon. The whole of the apparatus was so simple that nothing more remains to be said about it.

Use.

In using it, the balloon is unpacked and laid in well ordered folds on a carpet spread on the ground to receive it; the tail is then placed ready for connection with the last purifier, properly charged with lime and water, and the connection by leather pipes between the purifier and the generator having been established, the latter is charged; care must be taken not to complete the communication between the last purifier and the tail of the balloon until a clear stream of hydrogen is obtained, so as to avoid getting foul air into the machine. Under ordinary circumstances, in three hours from the time of the machine being halted, it can be prepared for an ascent; but this, should circumstances require it, might be shortened by employing two generators and making a suitable alteration in the purifying arrangement. Such alteration, however, would rarely be necessary, as the balloon, when inflated, can, unless in very windy weather, be very readily carried; 25 or 30 men lay hold of cords attached to the ring and march along, allowing the machine to rise only sufficiently to clear any obstacle that there may be in the way. I have frequently seen it carried thus without the least difficulty.

Inflation.

Balloon Staff.

The balloon staff with M'Clellan consisted of one chief aëronaut whose exact rank I could never quite make out, but it was not lower than a captain, or higher than a brigadier, he was a civilian and by profession an aëronaut, he was very highly paid, the same as a brigadier, and as the military rank, I believe, in America, is in some way attached to, and determined by, the pay received, I fancy Professor Low must have been a brigadier, at any rate he was a very clever man, and indefatigable in carrying out his work; by night or day, whenever the weather gave a chance of seeing anything, he was up, engaged on his observations; under him was a captain of infantry who had been instructed previously at West Point (the American Woolwich) in the art of ballooning. The captain commanded the men, some 50 in number, attached to the machine, and superintended generally every arrangement in connection with its inflation and use; he was also responsible for its transport, and that a due supply of materials was kept ready. The captain never went up himself, indeed he informed me that he liked the work below best, and confined himself entirely to it. Under the captain were a proportion of non-commissioned officers who knew more or less of the management of it, and the men, who, besides having a sort of reverential awe of the machine, knew nothing whatever about it. Either one or two sentries were always on guard detailed from the captain's party, who had the strictest orders to allow no unauthorised person to approach.

Carriage.

Each generator required 4 horses to draw it, and each balloon, with the tools, &c., 4 horses. The sulphuric acid it is essential to keep in a carriage to itself, but two horses will draw a sufficient quantity of concentrated acid to last for a long time. The undermentioned is a *resumé* of the balloon corps and apparatus with General M'Clellan's army:—

BALLOON CORPS.

1 Chief aëronaut, 1 Captain, assistant do., 50 Non-Commissioned Officers and Privates,	Requiring 2 instructed men.

APPARATUS.

2 Generators, drawn by 4 horses each,
2 Balloons, " " 4 horses each, (including tools, spare ropes, &c.)
1 Acid cart, " " 2 horses.

Whether the acid cart was considered as part of the equipment of the balloon, or whether it was put into the first waggon that came to hand, I cannot with certainty say; but, of course, in a well organized apparatus one would be necessary. When the machine is inflated it is kept to the ground by a series of sand-bags which are hooked on to the network, so that they can be disengaged at a moment's notice; thus confined, with the sentry to guard it, the machine remains unhurt in any weather short of a very violent wind storm, in which case it should be hauled down altogether.

Application of Apparatus.

When it is required for an ascent, the captain and some 30 of his men get round the balloon and carry it to the appointed place; the weight to be lifted having been put into the car, the ballast is so adapted, that including a couple of bags of sand, which it is not safe to go up without, there should be a buoyancy of, say, 20 or 30 lbs.; the three guy ropes having been attached the men leave go of the car together and seize the ropes, one of which is led through a snatch-block attached to a tree, or some securely fixed object; the ropes are then paid out, and the machine rises to the required height; the motion of the guy ropes is regulated by the aëronaut through the captain on the ground. Of course, on the proper manipulation of the ropes the convenience and safety of the aëronaut depends. I have been somewhat lengthy in the details of the working, but I have done so for the reason I have stated at starting, viz., that of the actual practice of balloon reconnoitring, little is, I believe, known. I will now say a few words on the application of the apparatus, and the results obtained from it.

Remarks on results obtained.

At the time I joined M'Clellan's army it was encamped on the Pamunkey river, one march below the now celebrated White House; it was pushing its way slowly up the Peninsular, driving the Confederates before it. The character of this part of Virginia is much the same as that of most parts of the agricultural districts of our own country, except that it is somewhat more undulating and not nearly so highly cultivated, including woodland perhaps not half the land is under cultivation; thus the character generally of the country is such as to render all reconnoissances, though the more desirable, very difficult to make. My first acquaintance with the balloon was made during the advance of the army; I had ridden forward from the main body and joined General Stoneman's command, then occupying, for the first time, the west bank of the Chickahominy river. I found the balloon snugly ensconced in a hollow, protected from view by the hill in front, from the top of which a convenient position for an ascent was gained; the Professor's tent and those of the rest of the balloon corps were scattered round, forming a small distinct encampment. I received from them great civility, and was afforded every opportunity for obtaining the information I desired. It may be thought somewhat odd that such a thing as a balloon should accompany the advance of an army, but there appeared to be no difficulty in its doing so, and, of course, it was more likely to be of use there than further to the rear. It was employed in making continual ascents, and a daily report was sent by the principal aëronaut to M'Clellan, detailing the result of his observations; of course in the event of anything very unusual being noticed a special report was made. The observer, by continual ascents, and by noting very exactly each time the position and features of the country below him, soon knows it, as it were, by heart, and a glance is sufficient to assure him that no change has taken place in the occupation of the country.

Topographical remarks.

The balloon never got more than about a mile nearer to Richmond than when I first saw it; it may, therefore, be interesting to describe generally the position of the army, and to state what the balloon did, and what it did not do. At that point the Chickahominy runs within about 7 miles of Richmond, its nearest point is $4\frac{1}{4}$ miles, at the village of Mechanicsville. It is in dry weather a sluggish stream, fordable almost at any place, but in wet weather it requires bridging, and sometimes overflowing its banks converts the valley, in which it runs, into a swamp a mile wide. High wooded ground borders the valley on either side, one of which was occupied by the Confederate army, with Richmond in its rear, it having retreated across the Chickahominy in front of M'Clellan's advance guard; and the other bank by the main body of the Federals, who, with an army of 100,000 men, were extended over a front some 12 miles in extent, about the centre of which the balloon was stationed. So near to Richmond, the wished-for gaol, it may be well believed that the results of the balloon ascents were looked for anxiously. From them were obtained the first glimpses of the Confederate capital, the capture of which, it was hoped, would virtually put an end to the war. Independently though of curiosity, most anxious enquiries were made from the observers in the balloon, as to the difficulties that lay on the road to Richmond. Were there any fortifications round the place? Where were the camps, and for how many men? Were there any troops in movement near the present position? and many other questions of equal importance. Now these questions were difficult to answer; and even from the balloon many of them could only be replied to with more or less uncertainty. From the balloon to the Chickahominy, as the crow flies, was about 2 miles; thence on to Richmond, 8 more. At the altitude of 1,000 feet in clear weather an effective range of vision of 10 miles could be got; thus the ground on the opposite side of Richmond could be seen; that is to say, houses, and the general occupation of the land became known. Richmond itself was distinctly seen, and the three camps of the Confederates could be distinguished surrounding the place.

Extent of vision.

Looking closer the wooded nature of the country prevented the possibility of saying whether it were occupied by troops or not, but it could be confidently asserted that no large body was in motion. In the same way, on seeing the camps round the place one could form a very rough estimate of the number of men they were for, but it was impossible to say whether there were men in them or not. Earthworks, even at a distance of 8 miles, could be seen, but their character so far off could not be distinctly stated, though one could with certainty say whether they were of the nature of field or permanent works. The pickets of the enemy could be made out quite distinctly with supports in rear, thrown forward to the banks of the stream. The country from its thickly wooded character was peculiarly unfitted for balloon reconnoissances; had it been a plain like Lombardy, the position of any considerable body of troops would have been known; as it was, it was only possible to say that they were not in motion; this could be confidently asserted, as though they might remain hid in the woods while stationary, in marching they must, at some time or other, come into open ground and be seen.

Hanover Court-house.

During the battle of Hanover Court-house, which was the first engagement of importance before Richmond, I happened to be close to the balloon when the heavy firing began. The wind was rather high, but I was anxious to see, if possible, what was going on, and I went up with the father of the aëronaut. The balloon was, however, short of gas, and as the wind was high, we were obliged to come down. I then went up by myself, the diminished weight giving increased steadiness, but it was not considered safe to go higher than 500 feet on account of the unsettled state of the weather. The balloon was very unsteady, so much so that it was difficult to fix my sight on any particular object; at that altitude I could see nothing of the fight. It turned out afterwards that the distance was, I think, over 12 miles, which from 1,000 feet, and on a clear day, would in a country of that nature have rendered the action invisible; had the weather, however, been such as to have allowed the balloon to remain at its usual altitude, the position of the engagement from the smoke created could have been shown; and it could have been said that no retreat had reached within a certain distance of the point of observation. It is quite possible, too, that with an altitude of 2,000 feet the action might have been indistinctly seen, even at the distance of 12 miles.

York Town.

At York Town, where the Federals were attacking the line of works thrown across the Peninsula, between the York and James rivers, the balloon was used continually. I was not there during the siege, but I did not hear that it was there attended with any particular benefit, as, though the works could be overlooked, irrespective of the indefinite feeling of satisfaction in being able to do this, no direct good actually accrued; this might have been imagined, as the prolongations of the various faces of the fortifications were known from the ground, and any movement in front of the works could, of course, be similarly made out. In the case of a siege I am inclined to think that a balloon reconnoissance would be of less value than in almost any other case where a reconnoissance can be required; but even here, if useless, it is at any rate also harmless. I once saw the fire of artillery directed from the balloon, this became necessary as it was only in this way that the picket, which it was desired to dislodge, could be seen; however I cannot say that I thought the fire of artillery was of much effect against the unseen object; not that this was the fault of the balloon, for had it not told the artillerists which way the shots were falling, their fire would have been more useless still.

Telegraphic communication from Balloon.

During the first two days of the heavy fighting by the left of the army before Richmond, which ended in its retreat from the Peninsula, a telegraph was taken up in the car, and the wire being placed in connection with the line to Washington, telegraphic communications were literally sent, direct from the balloon above the field of battle, to the government. In place of this the wires should have gone to the Commander-in-Chief's tent, or, indeed, anywhere better than to Washington, where the sole report of the state of affairs should have been received from no one but the officer in command of the army. If balloons or telegraphs are to be turned into means for dividing authority, every true soldier will look upon them as evils hardly unmitigated, but this with us need not be the case, for as military machines they would be solely under the control of the Commander-in-Chief.

Opinion on value.

General Barnard, the Commanding Engineer with M'Clellan, of whom I particularly asked the question, said that he considered a balloon apparatus as decidedly a desirable thing to have with an army; but at the same time it was one of the first incumbrances that, if obliged to part with anything, he should leave behind. I myself think that it is a thing, which, if properly organized and worked, may be occasionally of considerable advantage, and occasions might occur when the absence of such information, as the balloon gives an opportunity of obtaining, would be very bitterly felt. The observer from the balloon might, and most probably would, often enough, have nothing to report that the general did not know, but the time on the other hand might come when his report would contain facts, or satisfactorily confirm other information received, of such a nature that it would be invaluable. Nothing ought either to be accepted or condemned by its utility alone, but rather by its utility as compared with the cost of obtaining it; now of the utility under certain circumstances of overlooking a tract of country, from a height of 1,000 or 2,000 feet, if necessary, there can be little doubt; at the same time the cost of being able to do so is so trifling that it would appear unwise to neglect the necessary steps to secure the advantage.

Mr. Low.

It may be of interest to mention that the Mr. Low referred to previously, is a man celebrated in America as a very daring aëronaut; he has performed the quickest journey on record, going by balloon from New York (I think it was) to near New Orleans, at an average rate of something like 50 or 60 miles an hour.

Aërial ship.

He is now building, and he told me he had very nearly completed, at Philadelphia, an aërial ship, with which he intends to attempt the passage of the Atlantic; from the earnest way in which he spoke, I felt convinced that he intended to try to carry out his scheme; his appointment to the army, and the distracted state of the country obliged him to put it off for a while. If the Atlantic *is* ever crossed in a balloon it will be the greatest feat by far in the shape of ballooning ever done, and may open a new era in the art. The theory that he goes upon appears to be correct, but he is a bold man who risks his life on an unsubstantiated idea. Mr. Low's ship is capable of taking up some 10 or 12 people with provisions for a considerable time, it will be provided with all necessary apparatus, including a life boat, in case of his being obliged to change his element of support. The main part of his invention consists in a mechanical means of altering his elevation at pleasure without an expenditure of ballast or gas, thus allowing him to remain an unlimited time in the air. If he is able to do this, and the apparatus holds together, I do not see how he can help making a wonderful voyage somewhere, whether across the Atlantic, or not, is another thing; nor do I think the venture would be so hazardous as I daresay most people would consider it to be.

Theory of currents.

Mr. Low's theory, respecting the direction he is likely to take, appears correct; he, in common I believe with other aëronauts, has noticed that at various altitudes there are currents of air running in various directions; this is only probable, as a current in a fluid in one direction induces a compensating one in another. He proposes, therefore, to rise through successive currents of the atmosphere, as it were, until he finds one setting the way in which he wishes to go. These theories are somewhat visionary, and decidedly apart from the present question.

Apparatus proposed.

I shall conclude with a few remarks on the apparatus I would recommend for experimental purposes. Though for actual use, I think the larger sized balloon the best, a capacity of 13,000 cubic feet would give sufficient buoyancy for experiment. I would alter, however, the shape of the envelope, as the one commonly used is the worst that could be devised for the purpose; in the case of a free ascent, shape matters little, as the machine must go with the wind, but when the balloon is anchored it is of paramount importance to present the least possible surface to the action of the air. I would therefore give to the balloon a cylindrical form, and to the car a boat shape, and I believe that with the decreased resistance offered, such stability might be obtained as to allow of ascents being made in weather that, with the old shape, would preclude their being thought of. I would also have the whole of the network and the guys of silk, for the sake of lightness. Comparatively speaking, the first cost would be unimportant, and with care they would last a long time, while if it was thought desirable, common cord might be used for ordinary ascents, and the silk ones brought out only in case of great altitude being required. A very thin wire would enable telegraphic communications to be kept up, if necessary, with the ground, and an alphabetical instrument would place the means of doing so within anybody's reach. The cost of an apparatus, perfect in every respect, would be about £500, and one for experimental purposes might be got up for much less. The officer in charge of it would require to have practical experience, but his assistants might be men taken from the ranks, and a few hours would make them sufficiently acquainted with their duties.

Management.

The management of a balloon would seem to be a simple operation, and in perfectly calm weather when everything goes well, so it is; but to feel confident under adverse circumstances, and to know exactly what to do, and how to do it when difficulties arise, can be the result only of experience. It has been supposed that the swaying motion of a balloon when tied to the earth would occasion a nausea in some people akin to sea-sickness; I do not think this would be the case (with me it certainly was not so) as if the motion were so great, fear would in all probability overcome any other feeling, and at the same time under such circumstances it would be useless to think of observing.

I hope that the capabilities of balloons for military reconnoissances may receive a fair test, with properly prepared apparatus, as, should it be suddenly required to use them, it is quite possible that want of practice would turn what should have been a success into a failure, and the faults of the executive would be borne by the system. I am confident myself, that under certain circumstances, balloons would be found useful, and no one could say after all, more against them than that, like the fifth wheel to the coach, they were useless.

F. BEAUMONT,
Capt., Royal Engineers.

Since writing the above paper, an experiment has been carried out under the direction of the Ordnance Select Committee, a brief account of which is subjoined. Should the matter be proceeded with, I shall be glad on the completion of the experiments to furnish a complete account of them.

On the question being brought before the Committee, the points they wished to establish were, first, that the fact of being able to overlook a tract of country from a great elevation really conveyed the advantages it was represented to do; and secondly, that there was nothing in the abstract situation which made it impracticable to reconnoitre from the car of a balloon.

With this object only in view, an ordinary balloon inflated with coal gas would suffice, for though unfitted for the purposes of a reconnoissance, still by choosing a calm day it could be used. Arrangements were therefore made for the hire of one of Mr. Coxwell's balloons, the necessary guy ropes, gas, &c., being provided by government. Aldershot was the place appointed for the ascent, as the gas-works happened to be conveniently situated, and being a camp, there would be no difficulty in obtaining the concurrence of the military.

The authorities at the Horse Guards sent down orders to Aldershot that on a suitable day for the ascent the troops should be marched out in different directions, so that the value of the balloon, as a point of observation, could be practically determined.

The first time appointed proved a failure, owing to the boisterous state of the weather, and the experiment was put off till the 13th of July. A field-day, however, for the Prince of Wales being fixed for the day after, the ascent took place on Tuesday the 14th. This so far modified the experiment, that no observations could be made on troops at the extreme distance at which it was anticipated they would be visible from the balloon.

The inflation was completed before eight o'clock in the morning, as the ropes and men being new to their tasks, it was considered advisable that a few preliminary ascents should be made. Mr. Coxwell had been no higher than about 600 feet in a partial ascent, so that, except myself, no one had before been to the height of 1,000 feet, which it was now proposed to attain; and in a matter where any accident would in all probability carry with it serious consequences, it was proper to take every precaution. After inflation, the balloon was carried to Thorn Hill, some 300 yards from the gas-works, where the ascents were made. Three guy ropes were used, one of which, stronger than the other two, was passed through a snatch-block fixed to the ground. The ropes were manned by a party of Engineers entirely new to the work. No difficulty was experienced in either raising or lowering the balloon, the latter operation being done in about 15 minutes from the height of 1,000 feet. The greatest elevation reached was 1,200 feet, and varied from that to 1,000 feet, the balloon remaining for upwards of an hour and a half hovering over the camp. It was raised and lowered at pleasure, to enable the observers to be changed, and made some eight or ten ascents before it finally left the ground for its free flight.

As to the practical results obtained, the whole apparatus being unsuited for a war balloon, the experiment afforded no criterion of the difficulty or otherwise of inflation on active service, where the gazometer would have to be carried; or indeed of the amount of stability a captive balloon might be capable of attaining. It was shown, however, that the transport of a balloon when filled was simple, and that it could be easily raised and lowered; a tract of country altogether unseen from the ground below was brought under observation, and the movements of troops on the top of Cæsar's Camp, otherwise out of sight, were clearly discernible. From the top of Thorn Hill, the range of hills known as the Hog Edge, of which Cæsar's Camp is a part or adjunct, bounded the horizon on that side at a distance of somewhat less than two miles; from the elevation of 1,000 feet, such a boundary no longer existed, the slopes of the opposite sides of the hills even being visible, in fact an effective horizon of 20 miles' diameter was obtained—that is, no large movements of troops could take place within a radius of 10 miles without being seen.

The day of the ascent was very still, exceptionably so, and how far it may be possible to overcome the difficulties which arise when the air is in motion can only be determined by experiment.

My own idea, however, is, that with a properly constructed apparatus, balloon reconnoissances may be made in a wind moving at any rate up to 20 miles per hour; the higher the wind, the less would of course be the altitude attained; however, a height of even two hundred feet is more than that of the spires of most churches—points of observation eagerly sought for when on the march in an enemy's country.

It would appear, therefore, that, under certain circumstances, the balloon affords means to an army of carrying with it a lofty point of observation, and so far as the experiment went, it bears out the opinion I expressed on the matter in the paper to which this is an addendum.

With reference to the general subject of ballooning, I believe that some useful results might be obtained by photography applied from a balloon. A series of panoramic views might be taken by moving the machine along, which would be sufficiently intelligible to enable a draughtsman to make a sketch from, and which would have been taken far more rapidly than any survey on the ground could have been executed; this, however, is somewhat a matter of speculation, but I hope, should an experimental reconnoitring apparatus be got up, to be able to make some experiments in the matter.

F. BEAUMONT.

PAPER XIII.

THE PRINCIPLES OF DESIGN IN ARCHITECTURE.*

By J. FERGUSSON, Esq., F.R S., F.R.I.B.A.

On being requested to deliver a lecture at this Institution on "*The principles of design in Architecture*," I willingly consented to do so; the result of long and patient thought on the subject having led me to conclusions so different from those which generally prevail, that I am glad of an opportunity of explaining my views to such an audience as this, feeling confident of the correctness of the reasoning I am about to lay before you; and being, at the same time, impressed with the importance of a juster appreciation of the true conditions of the problem being generally diffused. It seems to me that unless this is the case, it will be impossible for any improvement to take place in the present very unsatisfactory state of architectural design. Unless, also, architects are agreed in the principles on which the science of their art is based, all criticism must be empirical and worthless.

Before, however, I attempt to define what architecture really is, let me first try to explain what it is *not*, for I feel convinced that one-half of the errors in design, and nine-tenths of those in theory, arise from mistaken analogies with other arts with which it has no real affinity, and from false theories based on these erroneous data. First, then, architecture has no affinity in principle with painting and sculpture. These arts are what are properly called phonetic arts—that is to say, are voices, or represent what may be expressed by words. In Egypt painting was the only mode of perpetuating thought, but since the invention of the alphabet, painting has become subsidiary to writing; still all our paintings are either repetitions in a different form of what has been written, or representations of things which might be expressed more or less clearly in words; Hogarth's Rake's Progress, for instance, or his Marriage à la Mode, is a novel written with the brush. The thousand and one pictures which illustrate Milton's Paradise Lost, or the Vicar of Wakefield, are only transcripts into another form of expression of the original poem or novel, and even our landscape or animal painters are only doing in a vivid manner what words would paint, if not so well, yet in some respects with more distinctness of detail. Sculpture is an art which has the same tendencies and objects as painting, only that it expresses by form what its sister art accomplishes by the employment of outline and colour. Still

* A Lecture delivered at the Lecture Theatre of the Royal Engineer Establishment at Chatham, December 9, 1862.

the pen, the brush, and the chisel, are only instruments for doing precisely the same thing though in different ways. But architecture has nothing to do with words. No amount of eloquence will build a house, and no conjuration of words will keep out the weather, or warm the inside of a dwelling; words cannot make a house, and a building can only express a very small and limited class of ideas, and these only very imperfectly. Notwithanding all this, nothing is so common as to group these three arts together, and painters, sculptors, and architects are supposed generally to be men following different branches of the same profession, and are joined together in the same academies as if they had everything in common. Yet, unless you can thoroughly eradicate from your minds all idea that there is any analogy between them, it seems to me impossible that you can ever acquire any clear ideas as to what architecture really is or means.

If, however, architecture has no real affinity with these phonetic arts, there is another group of arts with which its relations are intimate, and all the analogies drawn from them are true. The group I allude to is that of the Useful or Technic Arts, and without attempting to go into any classification of these it will be sufficient at present to define them as those arts which provide for mankind *Food*, *Clothing*, and *Shelter*. By a beneficent arrangement all these which, in the first instance, are indispensable for his existence, are capable of being refined into fine arts, so as not only to supply the wants but to gratify the tastes of mankind. It is the desire to possess these refinements which is the greatest incentive to exertion, and it is practically their possession which distinguishes the civilised from the savage races. To take an instance, man cannot eat raw meat, and even raw vegetables or fruit are very poor food to work upon, so that roasting and boiling become quasi necessities; but when men have leisure and means they soon become dissatisfied with even these, and stews and compounds of various kinds become indispensable, till at last the useful art of cookery is refined into the fine art of gastronomy.

It is the same with clothing, a sheepskin and a blanket are sufficient to keep out the cold, but these have been refined, by steps I need not trace, into art as elaborate and as expensive as any other. The fairer half of the creation, at all events, spend more time and money on making their dress beautiful, than, I fear, is spent on architecture; and even men are not always quite free from hankering after the beautiful in this form.

It is no doubt comparing great things with small to compare architecture with gastronomy and tailoring, but this is not the question; what I assert most unhesitatingly is, that the useful art of building is refined into architecture by the identically same process by which cookery is refined into gastronomy, or tailoring into an art without a name. The same process which refines a boiled neck of mutton into a dish of cutlets *à l'Impériale*, or a grilled fowl into a *poulet à la Marengo*, or any other elaborate compound, is the process by which a hut to shelter an image is refined into a temple, or a meeting-house into a cathedral; and so essentially is this the case, that if you wish to acquire a knowledge of the true principles of design in architecture you will do better to study the works of Soyer, or Mrs. Glass, than any or all of the writers on architecture between Vitruvius and Pugin. Architecture is in fact nothing more nor less than a useful art, necessary for the existence or convenience of man, refined into a fine art in order that it may also minister to his intellectual gratification. In order to make this clearer let us take an example—I have here a drawing, Fig. 1, of one of the most utilitarian class of buildings which deface our land, a plain cotton mill. If the same quantity of bricks were disposed as in Fig. 2, keeping

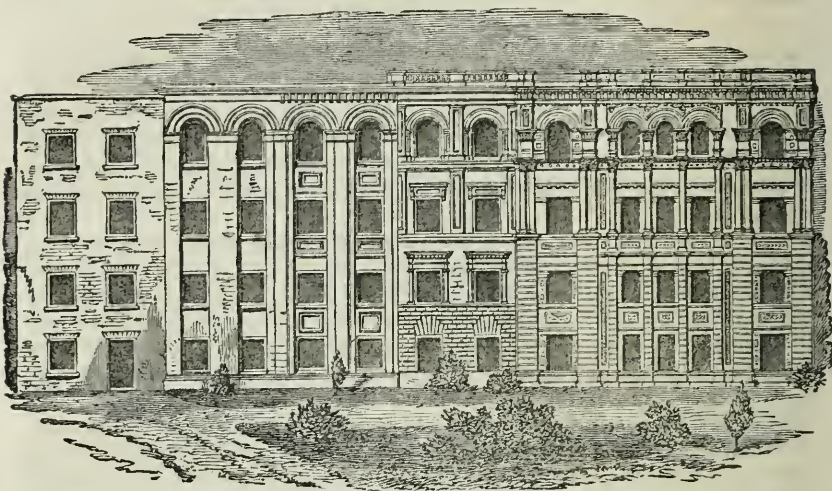


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

the dimensions and openings exactly where they were it would be a better building. Fig. 3 is a still greater improvement without any alterations, except in the disposition of the materials, and it may be called a good building, but still not architecture. Fig. 4, on the contrary, passes the line, a certain amount of ornament is applied, which at once takes it across the boundary line that separates the useful from the fine art; and in Fig. 5 we have a still further advance; not only is ornament employed which cannot be called either useful or necessary, but the parts are grouped and arranged so as to produce a more pleasing effect than could be done by the merely mechanical arrangement of the blocks in the former diagrams.

The first is plain slovenly cookery, but it cannot be denied that it may be such as would be sufficient to prepare food for human digestion; 2 and 3 are good plain cookery, the second better than the first; 4 and 5 are dishes prepared with additional condiments, and by more elaborate processes, so as to gratify the taste as well as to afford mere sustenance. If this is judiciously done, they may be not only more useful as nutriment, but may afford, to some at least, infinite gratification in the second category. In this country the civil engineers are the plain cooks, and though most excellent in that capacity, generally make a sad mess of it when they borrow a cookery book and try their hands at a higher flight. The architects with us are what the French call "des Artistes," and like their confrères are very indignant when asked to superintend the spit or to look after the boiling of a leg of mutton. Both are excellent in their way, but the fact is that no line can be drawn between them, and no one can say where the useful art ends, or where the fine art begins; it changes with times, places, and subjects, but the process is the same in all branches; and whenever you desire to refine any useful art into a fine art there is only one path by which it can be done, and that is the same for all; if you deviate one hairbreadth from that path you get into difficulties, from which no talent has ever yet been able to recall the wanderer.

If it were worth while, it would be easy to point out how almost all the other useful arts have become fine arts, by following the same process by which building became architecture. How, for instance, horticulture, or the production of vegetables for food, became floriculture, an art whose sole aim is beauty; how agriculture and arboriculture became landscape gardening; how the making of earthen pots and pans resulted in the manufacture of the exquisite vases of the Greeks or the elaborate productions of Sèvres; how working in metals led up to all the refinement of gold and silversmith's work, or all the multiform products of the jeweller's art; how weaving led to embroidering; how, in short, every useful art has been, or may be, refined into a fine art. An attentive study of the process, by which these or any other useful arts are refined into fine arts, proves that the artist cannot go wrong so long as he confines himself to the legitimate and appropriate use of the material in which he is working, and never loses sight of the real utilitarian purpose which must always form the basis of his design. So far from architecture proving an exception to the rule, it is the best and most pointed illustration of its universality. It is, however, so much larger and more important than most of the others, that many have thought there must be something new or different in its principles. My conviction is that it differs no more from its sister refined arts than a giant differs from a man of diminutive or ordinary stature—while those who would mix it up with incongruous analogies seek simply to create a monster, which can neither be useful or permanently agreeable to anybody.

It is hardly necessary to enter into the argument whether it is expedient to build beautifully, or to cook elaborately, or generally to seek beauty in art, or whether we ought not to be content with plain roast and boil, or plain undisguised brick and unhewn stone, and with the plainest and most utilitarian forms in all the other arts. All, I fancy, will agree that the element of beauty or refinement, if it can be obtained without unnecessary inconvenience, or without materially enhancing the cost, ought to be aimed at; and that this, when it is accomplished, is a gain to the refinement and dignity of mankind.

If all this is as clear and simple as has just been stated, it may well be asked why it is not universally acknowledged, and how was it that men ever came to believe that there was any connection between architecture and the phonetic arts, or ever came to practice it on these mistaken principles? The answer to this is unfortunately only too easy and obvious. When in the fifteenth and sixteenth centuries men re-discovered the literature of Greece and Rome, they were so much struck with the immense superiority of the classical literary models, as compared with anything that had been done in Europe during the middle ages, that they one and all became enthusiastic classicists. So far as literature only was concerned they might be right; and they were also, perhaps, not far wrong in reproducing the refinement of the classical ages in the sister arts of painting and sculpture. The error was in jumping to the hasty conclusion that the same reasoning applied to architecture also. In fact, that the principles of the phonetic arts might be applied to the technic, or useful arts. No sooner was this false analogy conceived than architecture was taken out of the hands of the true experts—the master masons who had brought it to such perfection—and was handed over to such men as Alberti, a scholar, Michael Angelo, a painter and sculptor, Raphael, Perruzzi, Sansovino, Guilio Romano, and others who were painters—in short, to the artists who practiced the phonetic branches of fine arts, but who had no real knowledge of construction or any definite idea of the principles on which the art of architecture ought to be carried out. From that day to this the error has never been thoroughly corrected. The architect has become a man who elaborates the conception of a building " ab externo" as a painter conceives the design of a picture; and very rarely indeed a man who works out his form " ab imo," or from the real essential necessities of the case. The idea of a man sitting down in his office to prophecy buildings of all sorts and kinds, for all purposes and all places, never occurred to any one in the middle ages. They did not then believe that any human intelligence was capable of foreseeing the ultimate form of 50 or 100 buildings; of drawing, measuring, estimating, and describing every detail, before a stone was laid on the ground. They set to work in a very different style; one man devoted his whole life to one particular class of building, and undertook one building at a time; and assisted by masons, carpenters, carvers, and ornamentalists, each of whom had devoted his life to his speciality, and was devoting his whole time to that one work in hand, they elaborated among themselves, during a long course of years, those buildings which we now so much admire, and admire simply on account of the amount of honest, earnest, skilful thought that has been devoted to their elaboration. The one simple object that these men set before them was how to produce the best possible building for the purposes entrusted to them with the means at their command. The last church, the last castle, or the last mansion, nearly of the dimensions of that they were undertaking served them as a model; and with such altered conditions as their purposes necessitated, they set to work, introducing as they went on every amendment in construction that had been devised since the last was built; every improvement in arrangement, and every new form of ornament that had come to be admired in the interval. They thus went on gradually accumulating experience, till at last they reached that degree of perfection which so much astonishes us now, but which then enabled any village mason in the Fen country, or in the Moors of Cumberland, or Wales, to produce buildings which our greatest and most learned men are now trying to emulate in vain.

The commonsense system which prevailed during the middle ages, as in all anterior times and places, had the further advantage that every body understood it. If a priest wanted to build a church, a baron a castle, or a gentleman a mansion, each knew what was the model that suited him best, and each knew also where to find the man best suited for his purpose. The conditions of the problem were so simple that every one could understand them. There was no looking back to past ages, or to other countries. No learning or antiquarian skill was needful, nothing in short, but a knowledge of what was going on around them. It was then with architecture, as it is now with ship-building, engine-making, or any other useful art. A merchant does not require any deep knowledge of the art of ship-building to know where to find the man who can build him exactly the ship or steam vessel he may want, for carrying or for speed. If a man wants a marine steam-engine of a certain quality, he knows where to find the men who can supply it. If he requires one for pumping there exists another class who make this their speciality; and if he wants a locomotive he knows also where to go. Thus without any special knowledge of ship-building or engineering, any man may now be sure of getting exactly what he wants, and of the quality he requires, by applying to those men who have made it the special study of their life, and who, consequently, know all that has been done or can now be effected. It was precisely the same in the middle ages; priests, barons, gentry, all knew what they wanted, and they knew also where to find it; and they have found it too in a manner we well may envy, but have hitherto failed to compete with.

With the Renaissance a new element was added to all this; besides the necessities of convenience and construction, the building, if a church, was to look like a Roman Temple; if a palace, like a Roman Amphitheatre, or Bath; and if a villa, like what that of Pliny or Lucullus was supposed to have been. This was not the work of an architect or builder, but of a scholar or antiquary, and his subordinate workmen knew nothing of all this; so the architect was obliged to spin the whole out of his own head before commencing, and deliver it complete to be carried out by men who had not the smallest conception of its meaning, or of the purposes the various parts were meant to subserve or express. In fact the whole secret of the problem lies in this, that during the middle ages, and during the existence of any true style, men practised architecture precisely as we practice any other useful art. Precisely the same process that converted the galleys of Edward into the three deckers or ironsides of the present day, converted the rude churches of our Saxon forefathers into such cathedrals as those of York and Lincoln, or the spinning wheel of the cottage door into the hundred spindled mule of our cotton factories; bit by bit progress towards a well defined end, steadily persevered in for years without ever turning to the right or left, or ever admitting the introduction of any extraneous element. Since that time we have added the new element of the problem in architecture alone of all the sister technic arts; we have insisted that besides convenience of arrangement, perfection of construction, and beauty of ornament, the building shall look, or try to look, like something that was done in some other clime or at some other age, and was probably intended for some other purpose. It is as if we were to go to Scott Russell and ask him to build us a steam-boat, but insist at the same time that it shall have three tiers of oars, and look in every respect like a Roman Trireme; or to go to John Penn and order a steam-engine, but stipulate that it must be so arranged that it must look like a wind or water mill. These orders would not be so ridiculous as insisting that an architect shall build you a museum, but shall put up in front of it a screen of columns intended for, and only appropriate to the temples of classical times; or shall build a Protestant place of worship in which you can neither see nor hear, nor sit with safety and comfort, and all because in the middle ages seeing and hearing were not important, and because our forefathers were too rude to suffer from draughts or hard seats.

The fact of an æsthetic element being introduced into the practice of any art makes no difference in the argument, for, as before hinted, all arts, phonetic or technic, are capable of this species of development. Thus, prose is capable of being developed into poetry; narrative into eloquence; a mere photograph into a highly imaginative painting; a figure in wax work into an Apollo Belvedere, or a Venus de Medici; by exactly the same process by which cookery becomes gastronomy, tailoring costumery, or building architecture. Each is developed into beauty within its own limits, there is no shunting of one art into the province of another to obtain this result, nor is it possible within the limits of the art itself to tell where use ends and beauty begins, and certainly no new principle is developed by the change in the manner in which the art is practised in its various phases. So far as I know, there is no instance in the history of the world of one art invading the territory of another, except in the solitary case of architecture during the last three centuries, and the experiment has been so unsuccessful that it is not likely to be repeated. If it had succeeded the anomaly might have been overlooked, and the apparent absurdity forgiven, but as the result is entirely the other way it is time it should be abandoned. It is, perhaps, not too much to say that though more money has been lavished, and more talent employed in building during the last three centuries than at any previous period, not one single building has been produced which is entirely satisfactory, and thousands which are very much the contrary; while during the three preceding centuries it would be as difficult to find a single edifice in any part of Europe which is not beautiful in itself, or which we cannot now contemplate with delight. The latter were the work of men comparatively ignorant and rude; the former of men in the highest state of civilization and refinement which the world has yet known, and this difference in result can only be ascribed to the difference in the principles on which the art was carried out during these two periods. It is high time, therefore, that architecture should recover her true position as one of the most important of the useful arts in the utilitarian stage of her development, and as the one most suited for artistic development, and perhaps the only one capable of rising to grandeur or sublimity in the second or æsthetic stage. Her true career is so grand, and her purposes are so noble, that she can very well afford to repudiate any connexion with the phonetic arts which belong to a totally different class, and need not borrow shreds from their adornment. Her own principles suffice for all her own purposes, and when these are honestly carried out she has no rival among human arts except among the highest flights of poetic literature.

Elements of Design.

Without further preface, then, let us come to the practical point. What are the means by which a satisfactory architectural design may be obtained? The best general answer that can be given to this question is, perhaps, that which was given by the painter Opie to a young artist from the country who, struck with the brilliancy of Opie's colouring, timidly ventured to enquire with what he mixed his colours; to this the gruff old painter briefly replied—*Brains!* In that one word is the whole theory of architecture. If a man will only think of what he is doing, and think of that only, I defy him to produce a bad design. A vulgar man may impress something of his own vulgarity upon it; a weak man, something of his feebleness; but if the position of the art is up to the mark of the age, these will not be perceptible to the general eye. An earnest purpose-like design, pretending to be nothing but what it is—going straight to its object, and giving evidence of careful study and thought—must always be pleasing, not only to its contemporaries, but through all ages, even if neither ornamented nor ornamental; while no extravagance lavished on a falsehood can remain tolerable beyond the fleeting fashion that gave rise to it.

To descend a little more to particulars, the principles of design in architecture may be classed under four distinct heads, thus:—

1.—Convenience in arrangement.

2.—Economy in construction.

3.—Ornamental arrangement.

4.—Ornamented construction.

The two first belong, properly speaking, to the builder, or to the engineering part of the profession, and only the latter two, strictly speaking, to architecture; but unless he gets them done for him, which sometimes, though rarely, may be an expedient arrangement, no architect must neglect the former two. Indeed the first is the foundation of all good architecture, for unless a building is so arranged as to meet the purposes for which it is intended in the best possible manner, it is impossible that any good can be done with it at any subsequent stage. This alone will not suffice to make a building beautiful, but it will go as far towards it as almost any other quality, and nothing that can be added will redeem the want of it.

By economy is meant that all the material used in a building should be so employed, that the greatest possible amount of work shall be got out of it. When this precept is carefully attended to, it frequently happens that a stable and elegant building may be erected with a certain proportionate amount of material, while with twice that quantity less scientifically applied, a clumsy, rude edifice, is all that is obtained, crushing itself by its own weight. It is, in fact, doing by reflection and science what too often is attempted by brute force. Like any other good principle, it may be carried too far, but it may safely be asserted that nothing adds so much to the charm of Gothic buildings as the scientific economy displayed in every part of their construction.

The third principle, enumerated above, is the foundation of all good architectural design, and consists in arranging the various parts of a building or of a group of buildings, so as to be in harmonious proportion one to another, and so that each may aid every other part in producing the effect desired. By thought and care, this may generally be obtained without any extra expenditure of money or materials, or with only the slightest, if any, loss of convenience. As such it ought always to be the principal study of the architect, and is also the means by which the most permanently satisfactory results may be obtained.

The fourth principle, which is the special province of architecture, ought always to be treated as an addition—something very useful towards architectural effect, but not as essential. It ought never to be allowed to interfere in any way with convenience, nor with economy of materials; its main use is to aid and refine ornamental arrangement, to accentuate the constructive details, and, if I may use the expression, to tell the whole story of the building in an agreeable manner.

Ornament is extremely useful in conferring on buildings a degree of elegance and richness which it would be difficult to obtain without it, and it may also be made to convey an impression of wealth and magnificence which, in its absence, could only be attained by increased dimensions, or massiveness, and these would be as expensive, and, in some instances at least, less effective. Ornament is also extremely useful in altering the apparent proportion of buildings; thus by the employment of strongly marked horizontal lines, a building which is too tall may be reduced to proportion, or one that is too low made to look nearly twice as high by employing only vertical features. Buildings that from the inherent necessities of their construction look weak, may be made to appear of any desired degree of strength, and sparkling gaiety of effect be given to those that otherwise would be too massive and heavy.

Internally, the architect cannot very often control the dimensions of his apartments; but by a judicious application of ornament he may always make low rooms look higher, narrow rooms broader, and reduce long rooms to a better proportion. More than even this, ornament enables an architect to give to every part of his design exactly that degree of prominence and dignity, and that class of expression, which suit its position or purposes. These are all legitimate uses for the employment of ornament, and when used for these purposes it is never offensive. It always becomes so when it is employed to conceal either use or construction, or to make a building try and look like what it is not or cannot be.

Ornamental Arrangement.

In order better to explain what is meant by ornamental arrangement, let us take an example. It is proposed, for instance, to erect a barrack for, say 1,000 men. The first thing, of course, is to study the economy of the regiment, and to ascertain exactly what is wanted. There must first be dormitories and living rooms for the men—quarters and a mess room for the officers, quarters probably for married soldiers, an infirmary or hospital, an entrance gateway, main guard and canteen, &c. If you arrange all these in a row any how, you will get a very commonplace effect. But supposing you divide your men's barracks into four nearly cubical blocks, and place them at the angles of your square, fill up the longest curtain opposite the entrance with the officers' buildings, and let the married men's quarters and the infirmary or other offices fill up the other two. If all these buildings are well proportioned to each other, and each appropriate to its own use, you may get a very pleasing and stately effect without one shilling of extra expense. But if, on the other hand, you make the officers' quarters exactly like those of the men—as is done in this (Brompton) barrack—if you make the field-officers' quarters like those of subalterns, you lose one of the principal elements of architectural expression, and the design loses all the meaning it might otherwise convey. In the example just proposed it is suggested that the principal masses should be placed in the angles, not only for sanitary purposes, but because in nine cases out of ten it is better architecture to accentuate the angles than to attempt to dignify the centre. We have got into the contrary practice from the habit of using porticoes, which can be applied only to the middle of a building, but half the weakness of modern design is owing to this cause; in military constructions especially it is most prejudicial.

The above assumes that the barrack is built on a perfectly plain site, but if the ground undulates, there is nothing which gives so perfect an architectural result as a design suited to, and following all the accidents of the situation; no matter how irregular the result may be, the evidence of thought and design, which a motived irregularity gives, redeems any other fault; but it must be motived—irregularity for irregularity's sake is mere affectation, and ought never to be indulged in.

One of the best and most important modern examples of ornamental arrangement that can be quoted, is, perhaps, the recent junction of the Louvre and Tuileries, by Visconti. When the latter building was erected, it was so distant that its architect never thought of making its plan range with that of the older building, and in the least artistic age of French architecture, Henri IV joined the two by the long gallery without ever thinking of the principles of ornamental arrangement. The consequence has been that, for more than 200 years every French architect of eminence has tried to remedy this defect. Diagrams of fifty of their plans have been collected and are now exhibited, some of great ingenuity, but on the whole perhaps the best is that by Visconti, which has just been carried into effect by the present Emperor of the French. It does not remedy all the defects introduced by the negligence of the first designers, though it goes a great way towards it, and generally speaking, it produces a grand and harmonious effect, even irrespective of all ornamental details; but the Place de Concorde is still too large for the buildings that surround it, and unless it is broken up by some erections in its centre, these will always look low and comparatively mean, while a judicious ornamental arrangement would add immensely to their beauty, and give them a dignity they do not now possess.

But, besides the ornamental disposition of masses, any one building may be so ornamentally arranged as to produce the best possible architectural effect without ornament, or with only the smallest possible amount of applied decoration. The Gothic architects were the great masters in this department of art; take, for instance, Salisbury Cathedral; the windows are without mullions, the buttresses without pinnacles, and with very few mouldings, while the walls are singularly plain; yet, with all this, the nave, the two transepts, and the choir are so pleasingly arranged as to produce the best effect. If closely looked into, you will find that supposing the problem to be given of how to produce a vaulted hall of a certain height, covering a given area of floor space, it would be hardly possible to do it at less expense. The buttresses, for example, on which the external effect mainly depends, are the most economical way of disposing of the quantity of materials required for the purpose, and the intersecting transepts the cheapest conceivable mode of roofing a great area of floor space, and at the same time of making a small building look large internally as well as externally. The Italian architects, who neglected these expedients, used, in consequence, three or four times the quantity of material which the Gothic architects employed. In St. Paul's for instance, one of the most mechanically perfect of modern buildings, the area of the solids, as compared with the voids, is as 1 to 6; in St. Peter's as 1 to 4, in St. Isaac's and other churches about the same, while in Salisbury, and in most early Mediæval buildings, it is as 1 to 8, and in later Gothic buildings it may be quoted as generally 1 to 10, being in some in even a lower proportion than that.

In fact, when carefully studied, it will be found that every Gothic building is made up of ingenious contrivances as purely mechanical as the parts of a steam-engine or a spinning machine, and barring a certain amount of superadded

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ornament, as directly utilitarian in design. Take for instance the buttresses on the south side of the nave of Westminster Abbey, nothing can be more purely mechanical than they are, but nothing can at the same time be better adapted to resist the thrust of the vaults of the aisles and nave, which, owing to the interposition of the cloister, they could not approach. A modern architect would probably have built a plain wall at right angles to the thrust, sloping slightly inwards, and thus have met the difficulties of the case. In so far as expense of execution is concerned, the Mediæval plan may be the most so; to cut the stone of each arch into voussoirs and to put a moulding under each flying buttress would probably cost from 5 to 10 per cent. more than to build a plain wall, the amount of materials and the height being the same in both cases; but to do the same amount of duty the wall in this instance would require at least a third more material, because its mass would be near its base, where there was no work to do, so that the ultimate expense would probably be greater. The real objection, architecturally, to the modern system, is that the wall would be a hideous deformity, the buttress a thing of beauty, because it is thoughtful and truthful.

There is at the present day a class of architects among the younger members of the profession who, struck with the fact that truth is one of the great, perhaps the greatest element of architectural beauty, carry this system to excess. In their churches, the plain brickwork is shewn inside as well as out, the timber work of the roof is all shown, and not arranged symmetrically, but according to the mechanical exigencies of the case only. In dwelling-houses the timbers of the drawing-room roof are equally exposed, rudely squared, the bolts and screws all shown, the doors are plain deal, the windows heavily timbered. Notwithstanding all this, if the proportions are good, the light judiciously introduced, and you can trace the evidences of thought through the design, the effect is certainly pleasing and satisfactory, because truthful; but these men are mere builders, not architects. To produce an architectural effect a certain amount of symmetry is indispensable, as well as a certain amount of refinement, combined with the greatest possible amount of mechanical excellence. All these can frequently be superadded without any material increase of cost, and when these are conjoined with truth of design and construction, a very perfect architectural effect may always be obtained, even without the addition of ornament. It is, however, quite a mistake to suppose that rudeness can ever be a desirable quality in modern times, or that proclaiming the fact that the mechanical have overruled the artistic elements in a design, can ever be productive of that expression of beauty we are aiming at in architectural art.

Ornamented Construction.

The elements of construction in classic architecture are so simple, that they do not afford striking illustrations of the principles of ornamented construction. The base and capital of a column are of very little constructive value, but the one gives apparent stability to the shaft, the other seems to confer on it a power of supporting an entablature, and both are appropriate for their purposes, as may easily be tested by reversing their positions. In like manner the division of the entablature into three parts—architrave, frieze, and cornice—does not add to its strength, but does to its appearance of stability, and the plain string lines of the architrave help this considerably; the frieze, as the neutral part in the centre, is generally the most ornamented, while the cornice, which is to crown all, and give shadow, is always the most broken, first, because a plain shadow is always heavy, while a broken shadow is sparkling; and secondly, because the cornice, having nothing to support, is the part of an order that may be most playfully treated.

In the classical orders every ornament is appropriate to the use of the part to which it is applied, and is elegant in itself, so that all the requisites of good architecture are satisfied, and the result has commanded the approval of all succeeding generations. If you analyse in the same way the ornaments of any Gothic building, you will see that their architects followed out precisely the same system; take, for instance, the vaulting shaft which appears to support the springing of the vault in all the stone roofed churches, you know that it is of no more use than the torus of a classic base, or the foliage of a Corinthian capital, but take it away, and it immediately appears as if the vault would slip down the wall; sometimes it rests on a bold bracket, at others on the capital of the main pillars, and in later times was brought down to the floor, but it was always felt to be so beautiful and so essential an ornament that it was very seldom dispensed with. Originally, the great circular pillars that supported the main walls of the building were ornamented, as in Westminster Abbey, by four such shafts, one pointing to the main vault of the nave, another to that of the aisles, and two more which appeared to carry the mouldings of the pier arch. These afterwards were multiplied to a very great extent, but never lost their apparent meaning, and thus retained the characteristic of good architectural ornament. In early times they always had capitals, and rightly so, because in spite of the practice of later architects, the change from a straight line to a curved one ought always to be marked in good architecture, and can seldom be marked too strongly. Instead of doing this by mass, which is the most obvious mode, the Gothic architects accomplished it by sharply marked and deeply cut mouldings; and again, frequently made their shadows still more prominent and sparkling by partially filling the hollows with foliage. If we turn to the vaulting of a Gothic cathedral, we again find it constructed on precisely the same principles. A rib, especially on the angle of an intersecting vault, is a purely mechanical necessity, but it may be built flush with the face of the vault or may be concealed. The Gothic architects, on the contrary, took care to display it so as to give the appearance as well as the reality of strength; they then accentuated it by deep mouldings and sharp angles, to give it an appearance of power far greater than if it had been either simply square or round. Afterwards they were so pleased with the effect of these ribs that—in this country especially—they spread them all over the vaults in the most complex and varied patterns; they tied them together at their intersections with bosses, and varied their dimensions with the relative quantity of work they were supposed to be performing. All this was perfectly legitimate, for though no one supposes that all these ribs are really mechanically essential to construction, the mind never draws the line too closely between use and ornament; it is satisfied when the ornament is based on mechanical principles, and used where it may be, or might have been, mechanically correct, or even where it suggests such a purpose. On the other hand, we are always pleased with a great display of labour and ingenuity, and when elegance is added to this elaboration, success is certain.

It would be easy, though I fear tedious, to go on analysing all the parts of

Gothic ornamentation; the windows with their mullions, the buttresses with their pinnacles, the towers and steeples. All obey the same laws; all are based on mechanical exigencies, but these are made gradually to yield a part at least of their demands to ornamental arrangement, and small details at last frequently merge into mere ornaments, but in good architecture they are never employed except where their protoplast would have been useful: or where they do not at least suggest that they may originally have done good constructive work. When this is the case we have no right to enquire too minutely whether this is absolutely true or not. But if a single ornament is used, where under no circumstance it could have been useful, its employment is wrong, and if executed in any material which could not constructively be employed for that purpose it is especially offensive. In a few words, the best architectural ornament is that which most clearly expresses the purpose and the construction of the building, or of that part of the building to which it is applied; and it approaches perfection in the ratio in which it is elegant in itself and pleasing to contemplate, irrespective of its architectural position and its power of constructive expression.

The Gothic instances above quoted are, perhaps, the best examples of how little ornament is really required for architectural effect, and in many of the Mediæval buildings—those devoted to domestic uses especially—the amount of ornament is frequently so small as not to increase the expense 1 or 2 per cent., while the result is most satisfactory.

The circumstances, that generally lead modern architects into extravagance, are that instead of truth in construction and beauty of form, they attempt to disguise their buildings in either classic or Mediæval costume; and the moment they attempt this they plunge into incongruities from which they can only extricate themselves at great expense and by using ornament to conceal their want of thought, and thus hoping to distract attention from the falsehood they are perpetrating. There are so few truthful buildings in modern times that it is difficult to get examples to illustrate these propositions, but two clubs in Pall Mall—the Reform and the Army and Navy—will suffice for present purposes. The former has no ornament but a cornice (which would have been better if less expensive), slightly ornamented string courses marking the floors, and dressings to the windows; all this is perfectly legitimate and would have been ample had it been accompanied by a more ornamental arrangement of the building; unfortunately, however, its architect—though more free than most of his compeers from the vice of copying—was haunted by the idea of the Farnese Palace at Rome, while trying to accommodate the wants of the Reformers in London, and he has, consequently, produced a building too gloomy for the climate, and especially for the northern aspect of its principal façade. Even a slight grouping of the windows would have done a great deal for it, as may be seen by observing how much that has improved the western front towards the Carlton, or how beautiful the garden front of the Travellers' Club is, simply in consequence of the windows being grouped ornamentally; and this latter, with the smallest amount of ornament, has produced one of the most beautiful façades in London. The Army and Navy, on the contrary, is covered with most expensive ornament, a great deal of it good in itself, but utterly inappropriate to the place and the climate, and only tolerated because a palace in this style was erected in Italy in the 16th century; but there is no evidence of design in the building, no accentuation of the angles, nothing to tell of the internal arrangements. In fact, a most unsatisfactory result for an enormous outlay. But this is by no means the worst form of the borrowing system. Take, for instance, University College, London. Here is a great portico, beautiful in itself, but at the top of a staircase no one goes up, and leading to a door that won't or can't open. But having put the portico there the whole building is sacrificed to it. The wings are plain and quiet enough, but it would have been an immense convenience to have had a third story. It would have given dignity to the building, and afforded immensely increased accommodation at less expense than by any other means; but because there was a portico this became impossible; so that not only have we the direct expense of building the useless portico, but the indirect result of being debarred from using the most obvious means of obtaining the accommodation we require. In like manner, the portico of the British Museum may not have cost more than £50,000, but it has caused the waste of half a million, and half the funds of the Fitzwilliam Trustees were wasted on a portico, the only use of which was to ruin the building for the purposes for which it was intended. In like manner one architect proposes that a nobleman's or gentleman's mansion in the country shall look like a Mediæval Fortalice; another, that it shall be a Gothic Abbey; a third, a Tudor Manor-house. It is the useless towers and pinnacles, the mullioned windows, and all the concomitant deceptions that are the great cause of expense as well as of inconvenience. It is this absurd system which has brought discredit on architecture; but if only a very small fraction of the money wasted on these very unsatisfactory excrescences had been applied to express the meaning of any carefully thought-out and purpose-like design, to accentuate its construction, to enliven its façade, or to refine its more utilitarian parts, the result would have been widely different. But the melancholy truth is—it is so easy to borrow, it is so troublesome to think. When we have Gothic and Grecian details all ready made to our hands, why must we set to work to invent new ones, and to think about every detail? While we have books which enable us to make up a design without thought or risk of responsibility, why should we be forced to try and invent every detail, and to spend days and weeks in fitting every part to every other, with the painful suspicion that the result may be unsatisfactory after all? So architects have reasoned during the last three centuries, and the result is what we see, failure everywhere, and failure so complete as to prove beyond all power of contradiction that the moment an architect, no matter what his talents may be, once wanders from the path of simply *ornamenting ornamented construction*, and tries to reproduce the architecture of any other age or country—once he deviates one inch from the path of truth and of common sense, combined with taste—he fails. He always has failed hitherto, and so far as can be seen he always must fail in future.

Materials.

There is only one other point which I shall have time to dilate on now, and that is the influence which the materials employed ought to have in regulating a design. Taking brick, stone, and granite, as the three degrees of comparison, it frequently occurs that an architect is, from the nature of the locality, restricted to one or the other, and when this is the case it is a fatal mistake not to accept the condition promptly, and to try to do the best he can with the material at his command. In doing this, however, it must be borne in mind that a design suitable for one class of material is, in fact, unsuitable for any other; with brick, for instance, it is almost impossible to obtain anything like grandeur, at least, if there are openings in it; a great solid bastion or tower of brick may be grand, because we lose the material in the mass, but the moment it is pierced or broken up, we see how small the material is, and that effect is lost. This is, however, no reason against its employment in architecture, it is only a reason for treating it in conformity with its nature; the consequence is, that a brick building can hardly be too much broken into small parts, or too carefully accentuated at the angles, or wherever strength is required, or too much fitted with discharging arches or other expedients to express strength of construction. Coloured bricks may also be used to accentuate arches and to mark string courses, and moulded bricks, or *Terra Cotta*, to ornament mouldings or cornices.

The first class—or accentuation by construction—was largely employed by the Romans, and the result is that some of their brick buildings look almost as monumental as if of granite. The last—by mouldings and colour—is largely employed in the north of Italy, and the result is the production of buildings as artistically architectural as any in stone, or even of marble, and quite as durable as either; but it must not be concealed that when so used it is very nearly, if not quite, as expensive as stone, and requires an amount of thought and skill on the part of those employing it, which there is little hope of finding in the present day. Generally speaking, it may be asserted, that in almost any locality, in Great Britain at least, the moment you pass a very low quality of design, a better architectural effect may be obtained for the same expense by the employment of stone than by the use of brick. The stone itself gives a certain architectural character to the building, and requires very much less ornament.

When brick must be employed, the first aim of the architect ought to be to *strengthen*, to get rid in fact, as far as he legitimately can, of the inherent defect of smallness, and consequent apparent weakness in the material he is employing. The employment of tiles in forming arches, as done by the Romans, is one of the most obvious expedients for this purpose, but vertical projections and reveals may also do much. Horizontal projections are not so easy with so small a material, but something may be done by a change in colour; and if moulded or ornamented bricks are not available, or too expensive, a string course of darker colour will assist, though it must be confessed that a very slight projection will do more.

When stone is employed, especially if it is of light colour, all the required relief may be easily obtained by projections, and thus shadow and ornament can always be added to the extent justified by the money at the disposal of the architect. Granite is seldom used for domestic purposes; when employeed in engineering it cannot be left too plain or too solid, its greatest merit is its mass and hardness, and these ought always to be left to tell their own tale. When employed in smaller structures, still squareness and simplicity ought to characterise the outline of the mass and the design of the mouldings or ornaments; of these last, however, there can hardly be too little.

Of late years it has been the fashion to cry out against stucco, and to proclaim that it should never be used in external architecture. This, however, is hardly just; a stuccoed Grecian portico of colossal dimensions, or a stuccoed gothic cathedral, or even parish church, a stuccoed palace, or college quadrangle, are abominations it is true; all these aspire to be monumental, durable buildings, in the erection of which expense is not a primary element, and the use of so perishable a material is a mistake and a sham; but stucco applied to the external walls of brick dwelling houses is not only a reasonable means of keeping these walls dry, but adds to the lightness and cheerfulness of their aspect, and also allows of an amount of ornament being applied which would be unattainable under other circumstances in consequence of the expense. The only rule to govern its application is that it shall be avowedly stucco, and shall not attempt to look like granite or stone; nor shall pretend to monumental forms, or attempt to look as if designed to last for ever. With these restrictions its use is as legitimate as that of any other material, provided a more durable one cannot be attained, or the means are not otherwise available for obtaining a suitably decorative character.

There is a class of monuments, such as triumphal archways, columns, tombs, &c., to which I have not alluded in the above remarks, partly because they are not such as would interest you especially, and more because it would take long to explain their peculiarities. All of these which we use were invented by the Romans, who, though wonderful builders, were very indifferent architects. They took a city gateway, for instance, and by the process described above, first arranged its parts ornamentally, and then ornamented it till, from an object of engineering, it became a work of architecture. So far they were right; but when they detached it from the wall and stuck it up where no one need, and few did go through it, then it became an absurdity. So, too, with their columns. What Trajan wanted was a place on which to engrave a record of his exploits, so he took a column, covered it with bas reliefs, and placed it in the centre of a small court with galleries all round from which they could be easily seen; all this was tolerably reasonable. The absurdity arises when we copy without understanding, and stick up plain columns for no purpose except to place a statue where it cannot be seen, or archways which no one may go through. Even the Arc de l'Etoile at Paris, which is, perhaps, the best modern example of its class, would have been a far finer monument if it had contained a Hall of Victory in its centre instead of being pierced by an unmeaning arch. All this merely bring us back to the point from which we started. If you wish to do what is to be permanently good and satisfactory, first design your building wholly with reference to the purposes for which it is to be erected, or the uses to which it is to be applied; secondly, arrange the parts so obtained as ornamentally and symmetrically as can be done without interfering with the purposes of the building; thirdly, ornament the parts so arranged to such an extent as the nature of the building requires, or as the means at your disposal will admit of; and, lastly, let the ornaments be appropriate to the building and to the age in which it is erected.

If these rules are attended to, it will not be easy to go wrong, and good architecture may be attained at a very slight cost indeed.

In conclusion, let me try if I can, by repeating in as few words as possible what I have been saying, make myself more clearly understood.

The first thing I ventured to insist upon was, that there were two great classes of human arts—the *Phonetic*, or those concerned with the utterance or recording of speech, which is the exclusive privilege of mankind; and the *Technic*, or useful arts, which are not so exclusively man's property. But without insisting too much on this, the great point for us to remember is, that these two families, or groups of arts, are cultivated for totally different purposes, and aim at totally different results. Both are capable of an æsthetic development—Prose and narrative can be elaborated into eloquence or poetry, and every useful art into a fine art, without our ever being able to draw the line distinctly between the end of the prosaic or useful, and the beginning of the poetic or fine art. A still more important point is, that there is no affinity or connection between these two groups as to their processes or principles, but that, while thus repudiating her reputed sisters, architecture takes her true position as the queen of the useful arts. If not absolutely the most important of these, she can at least claim to be the most capable of æsthetic expression, and the only one that has hitherto been refined into forms of permanent beauty, or has aimed at the attainment of grandeur or sublimity.

In Europe down to the 16th century, and in all other countries of the world down nearly to the present day, this art continued to be practised, and everywhere with success, on the same principles which governed and still do govern the development of all the sister useful or technic arts. At the Reformation, a new and extraneous principle of imitation was superadded, and for three centuries we have been labouring under the delusion that it was neither science that advanced the art, nor truth that rendered its production pleasing, but some strange notion that it would be beautiful if it could only be made to look like something it was not, or with which it had only some very slender connection. What is now wanted to restore the art to its pristine pre-eminence is a return to those simple principles, which guided the architects of Egypt, India, Greece, Rome, or the Middle Ages, and which are identical with those that now guide our shipbuilders, or machine or engine makers, or the engineers who construct our bridges or our forts. There is absolutely no mystery about it; all that is required is strict and undivided attention, first to convenience, next to constructive necessaries, then to the ornamental or harmonious arrangement of the parts, and lastly, when it can be afforded, to their ornamentation.

In the present state of the art, it may require more thought and self-negation to succeed by this path, than by following the fashion of servile copying; but by the one path certain success may be easily and permanently obtained by even the most moderate abilities, while by the other path, no genius will enable any man to erect a building which will be considered successful many years after its completion. This may appear a daring assertion, but it is justified by the experience of 4,000 years, during which the first path, was followed by all the nations of the earth with uniform success, and by the experience of the last 400 years, during which the other process has been cultivated, and you yourselves can judge how far during it men have succeeded in attaining what they sought for. Taking into consideration the amount of money spent, the amount of talent employed, and the amount of knowledge available, the result has been the most complete and lamentable failure in the artistic history of the world.

J. FERGUSSON.

PAPER XIV.

ON THE DRESS OF SOLDIERS.

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

Of the elements which contribute to the perfect composition of that artistic being, a good soldier, some have naturally attracted more notice than others, and it may be said that some have obtained less systematic attention than they deserved; among these, I think we may include, till within the last few years, the clothing.

We have now, in the clothing branch of the War Department, with its working and inspecting establishment at Pimlico, an admirable organization for seeing justice done to the public and to the soldier; whatever remarks then may be made in this paper, must be considered as in aid of the working of that establishment, and not with the object of criticising any of our present arrangements.

The qualities to be sought for in the soldiers' dress, placed in the order of their relative value, will be—

1. Utility.
2. Comfort.
3. Economy.
4. Appearance.

And yet, it is the last that formerly obtained by far the greatest, if not the only influence; and of this it may be doubted whether we do not still retain some prejudicial remains.

Marshal Saxe declared that the success of a campaign depended more upon the legs than the arms of the soldier; and the Duke of Wellington, on being asked what was the best requisite a soldier could be provided with, replied,—"A good pair of shoes." What the second? "A spare pair of good shoes." What the third? "A spare set of soles!" May we not then assume, that the quality of his shoes bears a greater proportion in value, as compared even with the weapons with which he is armed, than would usually be considered the case.

Sir Francis Head, who is well known for original and valuable observations on many practical matters, writes :—

"In the year 1820, when I had occasion to walk a great deal, in shooting, I *felt*, rather than discovered that fashion had prescribed two formulas for covering the human foot, as follows :

1. Let x be the breadth of a man's foot. Then let x minus 1 be the breadth of his shoe!
2. The human foot being crooked, make the shoe straight!

The result of these two fallacies produced corns, and made a man footsore, especially when carrying a load of game for a day or two, and *a fortiori*, when carrying a musket, ammunition, and a knapsack, for weeks.

The remedy was obvious, to give the shoe the breadth and twist of the foot.

To effect this, I trod with my whole weight on a sheet of white paper, traced on it the breadth and twist of my foot, had a last made therefrom, and the result was the difference, in walking, between purgatory and paradise. I induced many others to try it, and all with the same satisfactory effect.

I have always thought that the system would be peculiarly valuable to the army, whose profession it is not only to walk, but to carry weight, and to whom being footsore on a retreat frequently results in capture or death."

As regards the act of marching, he adds, " we drill our soldiers (as well as our children) to stand and walk with their toes turned out; and accordingly, in the forests of America, the red Indian sneers as he points to the footmarks of the white man, which are always strangely and strongly contrasted with his own. The red man never turns his toes out, and accordingly in the snow, in the sand, or in the mud, the contrast is thus,—

Track of the feet of the red man.	Track of the feet of the white man.
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|	/

Now, at a glance, you will perceive the immense mechanical advantage of the red man's gait, as compared with the mechanical disadvantage of the white man's gait. The action of walking is a continuous movement from the heel to the extremity of the great toe, which is made big by nature to give spring and elasticity to each step. The white man (by turning his toes out) throws this simple mechanism out of gear; and though the attitude is *said* to be more elegant, (which it is not), yet, in the long run, or in a long *march*, especially when he carries weight, the white man's feet get distressed, while the red man's feet, protected by moccasins, which do not distort his great toes, continue fresh. Our soldiers should, therefore, be drilled to stand and march like the red Indian, with their feet pointing straight before them. The heel of the shoe should not be raised, as it is, for real comfort, and to enable the feet to do their maximum of work. The raised heel of a shoe throws the weight of the body, pack, musket, and ammunition of the soldier unscientifically on the toes, which are meant for *spring*, instead of on the heel, which is meant to *bear* the weight. The elevated heel is a cheat, to make a man appear three-quarters of an inch taller than he is; but what he gains in height he loses in power of walking."

Mr. Howlett, (Royal Engineer branch of the War Office), in 1856, advocated similar principles on similar reasonings, as printed in Nos. 1717 and 1755 of the Mechanic's Magazine, to which he added two others,—one, without objecting to the raised heel, to round it off in the original make of the shoe, in the manner it always wears in use, and the other, to curve the soles slightly up at the toes, so as in walking, to avoid so much of the joint and creasing of the upper leather.

Among the hints that may be gained on the care of shoes, it has been observed in some works, that it is a common practice with French soldiers to forego the use of stockings in heavy marches, and to procure the best fitting and most easy shoes they can; these they keep not simply greased, but thoroughly soaked in grease,—a system, which they say will, more than any other, prevent their being galled or becoming footsore.

Another most admirable protection for the foot, is the Spanish *Alpargata*, or sandal: the foot is wrapped in linen or cloth; and for the tread, a sole of a particular kind of rush is made or cut to shape, and fastened round the instep and ankle as a sandal. It is very generally used by the soldiers, as well as by the people of the country, in Spain, and on it they travel and march great distances without inconvenience; but it would no doubt be difficult to imitate. The people in Spain are brought up to it from early days, and thoroughly understand how to adjust it for all occasions; and there may be something in the nature of the country, that may make it suitable there, though not elsewhere.

After the shoes, the great coat will be the next consideration, and perhaps capes or hoods, neither of which are however provided for British soldiers. The hoods are admirable articles for comfort, under many circumstances; but there may be some doubt whether they would not too much impair the hearing, the sight, and consequently altogether the vigilance and efficiency of the sentinel on duty. As appearance is of little or no consideration with regard to shoes or great coats, there will be less difficulty in obtaining the best attention for those two items.

With regard to comfort in the different articles of dress, a useful lesson may be imbibed from the experience of the service in the Crimea, where, during the winter of 1854-55, the troops, under considerable hardships, were allowed to take certain liberties; and it might be observed that one of the first exercises they made of this little freedom was that the stiff stock and the schako were very generally abandoned for a pliant neck tie and the foraging cap. This naturally leads to the reflection, whether something of the nature of those substitutes could not be adopted, if not at all times, at least for a recognised equipment for real, active service.

The Russian infantry, in that campaign, were almost, if not entirely, in grey great coats and a very low cloth cap, partly, it is presumed, for economy, and partly for comfort, and yet they always looked like thorough good soldiers, well cared for, and certainly they were never to be despised.

National taste and national pride may lead to retaining the great shaggy grenadier caps, and the kilts and caps of the Highland regiments, for ordinary peace parade and show; but they might be dispensed with for something more appropriate in campaigning, and not even be allowed to encumber the baggage or stores that accompany the army.

There is a circumstance worth remarking, and one which raises a presumption of the unfitness of the present form of dress, for some of the duties required of the soldier, that when recruits are at any description of drill which requires the full play of their arms, the preliminary word of command is to remove the waistbelt and to unbutton the coat. The reason of this injunction is that the men cannot raise their arms above their heads while the coat is closely confined round the waist by a belt: they are, in fact, in a modified form of strait waistcoat; and yet, it is easy to conceive many operations in war (such as the assault of breaches and escalade of works, when the men have to surmount obstacles and to climb ladders), when they must raise their arms above their heads to perform the work required of them.

Some irregular troops, such as those led by Garibaldi, and some of our own volunteers, have overcome the difficulty presented to the free use of the arms by the waistbelt and tight tunic, by substituting for the latter a species of loose woollen shirt; as a portion of this garment is allowed to hang freely about the hips, it affords sufficient play to the arms, even when the waistbelt is retained. It is probable, however, that it would be considered too free and easy a style of dress for regular troops.

That the difficulty of combining a soldierlike and smart looking dress with the free use of the limbs is not insurmountable, is proved by the well-known dress of the soldiers of the period of the Civil Wars, in which the crossbelts and buff jerkins afford no obstacle to the free use of the arms in any direction. Allowing for the difference of the material employed, and the objects sought for, the dress approximates very closely to that worn in the present day by our sportsmen; and what gentleman in his senses would go out shooting in a tight tunic and waistbelt? The fashion of modern dress following our soldiers into the army led to the universal adoption of trousers in place of knee breeches; but it may be doubted whether our men did not suffer by the exchange. Trousers, if made sufficiently loose, certainly give great freedom to the limbs, though even in that particular, they are surpassed by the Dutch or Zouave breeches; but they possess a serious disadvantage, inasmuch as one portion of the garment, viz., that which extends from the knee to the foot, has more than its fair share of wear and tear thrown upon it; in marching, collects all the mud and dust; and in operations in the bush and jungle, must be sometimes torn into shreds, besides offering no protection to the leg. It would therefore appear both advantageous and economical to separate the covering for the lower limbs into two parts at the knee. This would do away with the necessity of carrying a second pair of trousers into the field, a second pair of gaiters being substituted for them; and a great additional comfort would be afforded to the soldier by this arrangement, if the gaiters for summer wear were made of strong linen, as is believed to be the case with some of those in use in the French army. In alluding to the Dutch and Zouave breeches, it is not meant that the extreme fulness given to them is at all necessary or advisable.

Very much connected with the dress of the soldier is the kit that he is to carry.

One great merit of a thorough good soldier, is to strive to keep himself strong and healthy, and to avoid going into hospital: this is so much the case that it is doubtful whether the time he is in hospital should not be more systematically recorded against each, in the periodical returns, as an index of moral or physical defect for the service. At all events, the endeavour to take care of himself is a most valuable quality, and greatly to be encouraged.

Now, on that principle, it may be always observed in the field, that the best soldiers carry the largest kits: by a little early spirit and exertion, they become accustomed to the extra load, and the period of actual marching is so small, as compared with that of their being stationary, that they find the balance greatly in favour of having with them as many comforts as they can. Here again the French soldiers show very favourably, for they usually carry very large kits. As examples of what soldiers will do under this consideration, there was a man in one of our regiments, a shoemaker by trade, who actually carried, throughout several campaigns in the Peninsula, a favourite *lapstone!* Another had a small dog, which in wet or in long marches, he frequently carried in a little receptacle he had contrived on the top of his knapsack.

As a matter of dress, the uniform is not only the distinctive mark of the soldier, and tends to give him a becoming pride in his position, but it assists in collecting and keeping together the masses of respective corps, and stimulates to precision and uniformity of exercise, besides restricting the articles to the quantity and form that are to be considered the most desirable; therefore, uniformity in clothing is valuable, even independent of its attraction and show. But as a special ingredient for the soldier, in that capacity alone, it is a costly and an additional and somewhat onerous charge to those who, like the volunteers, are, at all ordinary periods, soldiers only occasionally. Arms, and certain other military equipments, must necessarily be prepared exclusively for the purpose, but a great relief might be given to this inconvenience in the article of clothing, by making the uniform partake more than it does of the dress of civilians, so as to be applicable to either.

In Great Britain, the shooting jacket of the gentleman and gamekeeper, and the frock coat of the artizan, are very much of the same character; or they might be so assimilated and arranged as to make a most convenient habit for any purpose of soldiering, or for work or exercise; adopting some uniform colour and pattern,—adding, if you please, a uniform button—uniformly coloured plain trousers, with a foraging cap, would constitute a thoroughly soldierlike uniform; while, at the same time, every item in it would be perfectly serviceable, and applicable for all the ordinary business and intercourse of life.

There is no volunteer but is in a position to have a superior set of clothes for Sundays and holidays, and these he would use for field days or extraordinary parades, while the others would be in every day wear; and by this system, the soldier clothing, though neat and uniform, would, it may be said, cost nothing.

I have one more point to advert to, and that is the national colour of our uniform. Towards the end of the last, or early in the present century, an inquiry was instituted as to the possible disadvantages of scarlet uniform in the field, in addition to that of tarnishing more quickly than others; and it was shewn by trial, that not only was it much more readily seen and distinguished at a distance, but that in practice at targets of scarlet, as compared with others of dark colours, (the men employed in firing not being at all aware of the object of the trials), the red, at the longer ranges in particular, were more frequently hit, and in a much greater proportion than would be supposed: but the result was not deemed sufficient to lead to the abandonment of the old national colour, in which we take so much pride.

Very recently, indeed, there has been a shewing of a contrary tendency, in trials at Wimbledon, on "a running man," or target in motion,—one side of which was painted red, and the other grey. On this occasion the grey man suffered most; but as it was remarked that the red man moved from left to right, and the grey from right to left, every sportsman will be well aware why the latter would be under a great disadvantage. Some alteration in effect of colour is also produced by the back ground to the object fired at, whether it be the soil, or trees, or sky.

J. F. B.

PAPER XV.

RECENT GUNNERY EXPERIMENTS UPON IRON ARMOUR.

By CAPTAIN INGLIS, R.E.

In last year's volume of these Papers, when treating the subject of the application of iron to defensive works, I gave a brief account of most of the experiments which had been made, up to June, 1862, upon iron armour.

I propose now to give an outline of the principal experiments made since that time, with a few remarks upon their results.

Minotaur Target. 7 July, 1862. This experiment was made at Shoeburyness to test the merits of the construction adopted in the *Minotaur*, and her class of iron clad steam frigates.

In these ships the armour is $5\frac{1}{2}$ in. thick, instead of $4\frac{1}{2}$ in. as in the *Warrior*, but the thickness of the teak backing is reduced from 18 in. to 9 in.—9 in. of teak being very nearly equivalent in weight to 1 in. of wrought iron. The skin and ribs are the same as in the *Warrior*.

The target now used was therefore constructed on these principles, and presented a front of three armour plates: one made by Messrs. Brown, of Sheffield, measured 12 ft. 6 in. by 3 ft. 4 in.; another, made at the Thames Iron Works, measured 9 ft. by 3 ft. 7 in.; and the third, made by Messrs. Beale, measured the same as the first named.

Each plate was secured by three rows of bolts, the upper and lower rows being $1\frac{3}{4}$ in. diameter, and the middle row $1\frac{1}{2}$ in. diameter; all but a few of the bolts round the port passed through the teak and skin.

The proportion of bolt to surface of the ship's side was as one bolt to about $3\frac{1}{2}$ ft. superficial; and the aggregate sectional area of bolt to a given area of surface was rather greater than in the *Warrior*.

There were junction pieces, $1\frac{1}{4}$ in. thick, at the back of all the joints of the plates.

The guns used against this target were the 12-ton Armstrong muzzle loading gun, throwing spherical 150-lb. cast-iron and 162-lb. wrought-iron shot, with 50-lb. charges of powder, the former having an initial velocity of 1,750 ft., and the latter of about 1,700 ft. per second; and a service 68-pdr. throwing 67-lb. cast and 71-lb. wrought-iron shot with 16 lbs. of powder—the cast shot having an initial velocity of 1,580 ft., the wrought-iron about 1,530 ft. per second; all at 200 yards range.

The first 150-lb. cast shot struck the Thames Iron Company's plate and made a hole about a foot square through the armour and bedded itself deep in the teak. The plate was buckled considerably, several bolts were started, two ribs cracked, and the skin much bulged in: four bolts were broken and a number of rivets.

The second 150-lb. cast shot struck the Sheffield plate, made a hole 13 in. by 12 in. in the armour, and sent pieces of armour plate, shot, and teak, through a large irregular hole in the skin: the armour plate was buckled, three bolts broken, and other damage done.

The third 150-lb. cast shot struck Messrs. Beale's plate and did similar injury, making a hole through everything; the diameter of the hole in the armour being about 13 in., and in the skin about 1 ft. 4 in. by 2 ft. 6 in.

The 162-lb. wrought-iron shot stuck in the Thames Company's plate, buckling it and shaking the whole target very much indeed; two ribs were broken and the backing of the target very much displaced and injured. At this round the 12-ton gun burst, the breech being blown out some 30 yards to the rear, and, but for this, no doubt, the target would have suffered even more severely.

The 71-lb. wrought-iron shot made an indent about $\frac{1}{2}$-in. deep, but neither it nor the 68-lb. cast-iron shot did much other damage: about 750 lbs. weight of shot struck this target.

From this experiment it has been learnt that the powers of resistance of the ***Minotaur*** are very inferior to those of the *Warrior.*

Armour plates protected by a facing of wood and iron. 31 July, 1862.

This experiment was made with 68-lb. solid service shot, and 110-lb. Armstrong live shell with a bursting charge of $8\frac{1}{2}$ lbs. of powder, at 200 yards. The facing consisted of an inch plate with a backing of 12 in. of oak. The indentation on the armour made by the solid shot was about $\frac{1}{3}$rd of what it would have been without the protection of the facing, but the effect of the live shell in blowing away the facing was so destructive as to render this construction worse than useless, unless considerably modified.

About this time some experiments were made to test the value of compressed millboard as a backing to armour plates in comparison with teak, and the result went to show that, weight for weight, the millboard offers a greater resistance to penetration than teak.

Compressed millboard weighs	54 lbs. per cubic foot.
Teak	46 lbs. to 50 lbs. - -

After this, some compound targets, consisting of iron, cork, and india-rubber, and iron, wood, and layers of wire, were tested in comparison with solid wrought-iron plates of equal weight per foot superficial, and failed in establishing any superiority in their resisting powers.

It must be admitted that these experiments were on a very small scale, but the results were too marked to admit of any doubt as to the result in trials on a larger scale.

Horsfall 13-in. gun versus *Warrior*. 16th & 25th Sept., 1862.

The target used for this experiment was of the *Warrior* construction (10 ft. by 12 ft.) and consisted of three plates, made at the Parkhead forge, all $4\frac{1}{2}$ in. thick, and varying from 12 ft. by 3 ft. to 12 ft. by 3 ft. 4 in.

As compared with the plates used in the original *Warrior* target, their quality was very inferior indeed.

The weight of gun was 24 tons 3 qrs. 2 lbs.; diameter of bore, 13·014 in.; diameter of shot, 12·8 in.

It was first fired at 200 yards range, with a solid cast-iron shot weighing 279 lbs., and a charge of powder of 74·40 lbs., which gave an initial velocity of 1,630 feet, reduced at 40 yards to about 1,610 ft. per second.

This shot completely pierced the target through and through, making an irregular hole in the armour about 2 ft. square, and cracking but not buckling it: about 3 square feet of the skin were driven in, two ribs were completely smashed, and another one injured, a number of bolts were broken and started, and a quantity of fragments of shot and splinters were sent to the rear.

The effect of this shot was so complete as to render any further experiment at 200 yards quite unnecessary.

The gun was therefore moved to a range of 800 yards, and a solid shot of annealed cast-iron weighing 285 lbs. was fired at the same target, with the same charge as before, giving a terminal velocity of 1,300 ft.

The firing at this range was by no means accurate, so that out of 4 shot fired on the second day only one gave a result worth recording, and even that grazed 17 yards short. It however did not lose by this any appreciable velocity or direction, and struck the target in the junction of two plates, breaking a large hole about 2 ft. square through the armour and burying itself in the timber backing. By this blow two ribs were broken through, and the skin considerably bulged, several bolts were broken and rivets driven out.

To show the inferior quality of the iron in these armour plates, a service cast-iron 68-pdr. shot was fired at it, and it had the effect of making an indent of upwards of 4 in. deep, with a number of cracks in and around it. The indent made by a similar shot on the original *Warrior* target was little more than 2 in. deep.

The lesson learned then from these experiments seems to be this:—That, at 200 yards, the real *Warrior* ship would be completely pierced by the Horsfall shot; but that at 800 yards, although inflicting very severe injuries upon her, the skin would not be penetrated by an individual shot.

It may be worth noting that previous to these trials some serious looking flaws existed in the bore of this gun, but they underwent little or no apparent change during the five rounds fired from it.

Penetration of Whitworth projectiles. 16th and 25th Sept., 1862.

These interesting trials were made with a 12-pdr. breech-loader, $9\frac{3}{4}$ cwt.; a 70-pdr. muzzle-loader, 76 cwt. 2 qrs. 14 lbs.; and a 120-pdr. muzzle-loader, 148 cwt. 3 qrs., all Whitworth guns.

The 12-pdr. was fired at 200 yards with a solid, homogeneous metal, cylindrical, flat-ended shot, weighing 12 lbs. 1 oz., and with a charge of 1 lb. 14 ozs. of powder (giving an initial velocity of about 1,360 ft.), against a $2\frac{1}{2}$-in. plate without backing, through which it made a clean hole and fell 20 yards to the rear.

This gun was next fired at the same range, with a shell of homogeneous metal weighing 12 lbs. $2\frac{1}{2}$ ozs., with a charge of 1 lb. 14 oz., and a bursting charge of 6 ozs., but no fuse, against a 2-in. plate, with a backing of 12 in. of timber; it passed through both plate and backing and buried itself in the earth beyond;

there was however no appearance of the shell having burst in passing through the plate.

It may be well here to explain, that the explosion of these shells without fuzes was supposed by Mr. Whitworth to be due to the heat generated in the metal of the projectile on impact, he having specially constructed them with that view, and having also provided an arrangement of flannels covering the bursting charges by which he could govern the time of explosion; but whether the heat was thus generated, or whether it was due to the violent friction of the particles of powder among themselves or against other substances, or the sudden loss of velocity in the projectile, appears a fair matter of doubt. Be this as it may, he certainly obtained some very satisfactory, and, at that time, unprecedented results.

The next gun fired was the 70-pr., with a charge of 12 lbs. of powder, at 200 yards, and with a shell formed of similar material to the others, weighing 69 lbs., having a bursting charge of 2 lbs. 6 ozs., but without a fuze. The initial velocity of this shell was 1,275 ft., and the loss of velocity in 40 yards, about 10 ft. per second.

The target used on this occasion was made in the form of a box, with the object of putting to the test Mr. Whitworth's boast, that he could drive a shell through the side of an armour clad ship and make it burst between decks. The front of the box was made of 4-in. armour on a 9-in. backing of timber; the back of the box was of 2-in. armour plate on 4 in. of wood, and its sides were of 4-in. timber, the cubical contents of the box being about 35 ft.

The shell fired on this occasion, with an initial velocity of 1,275 ft., passed completely through the 4-in. armour plate and its oak backing, and exploded on the rear side of the box, the plate of which was indented 2½ inches, bursting the box and blowing all six sides outwards.

The great success of this and the 12-pr. shell must of course be mainly attributed to the superior quality of metal in the shell, which admitted of its passing through so great a thickness of iron unbroken; previous experience having presented no instance of a shell passing through even 1 in. of iron without breaking up, and 2 in. of iron having hitherto broken even solid shot of steel.

Soon after this Mr. Whitworth followed up these experiments on a larger and more important scale by practice with the 120-pdr., at 600 yards, against the new *Warrior* target.

In this trial a solid homogeneous metal shot, weighing 129 lbs., was fired with a 23-lb. charge of powder, giving a striking velocity of about 1,280 ft., and punched a clean hole through the 4½-in. armour, lodging itself in the timber backing against the skin, which was a good deal injured; a rib previously cracked by the Horsfall gun was now completely broken in two, and some bolts gave way.

A shell of homogeneous metal, weighing 127 lbs., with a bursting charge of 3 lbs. 8 ozs., and without a fuze, was next fired at the same range with a charge of 25 lbs. of powder, giving a terminal velocity of about 1,263 ft. This shell went completely through every thing, much to the astonishment of every one present. It apparently penetrated the armour without breaking up, and burst when in the act of passing through the timber backing, most likely when approaching the skin, as the diameter of the hole in the skin was not more than

13 in., and the injury to the skin was confined to this hole. Portions of the shell and the piece of armour punched out by it were picked up at the back of the target; the timber backing was of course very much shattered, and one rib broken.

Looking at the completeness of the penetration in this instance it may be fairly inferred that this shell would have gone clean through this target at any range up to as much as 1,000 yards; but it does not follow, nor do subsequent experiments prove, that it would have done the same to a target composed of armour equal in quality to that upon the real *Warrior* ship.

Whitworth projectiles. 13th and 14th Nov. 1862.

These experiments were made in continuation of those last recorded, and with the same guns, under the following circumstances:—

A box target, presenting a front measuring 12 ft. by 9 ft. 6 in., and having an interior cubical space of 435 ft., was constructed for the purpose.

The front was a target composed of three armour plates on backing, skin, and ribs exactly representing the backing, skin, and ribs of the *Warrior*. The upper plate was 4½ in., and was one of those which had been used on the original *Warrior* target; therefore this portion corresponded in every respect with a ship of that class. The two lower plates were 5 in. thick, taken from the Samuda target, and therefore represented a ship's side stronger and heavier than that of the *Warrior* by the difference between ½ in. of iron and ½ in. of teak, or about 18 lbs. per foot superficial.

The box was placed in front of the old Committee target, which therefore formed its back, while the two sides, the roof, and floor, were composed of 12-in. timbers, strongly bolted and secured.

The principal object of the trial was to mark the effect of the Whitworth homogeneous metal shells constructed so as to be capable of holding larger bursting charges than those used in September, and also to correct any false impressions caused by the very inferior quality of iron in the *Warrior* target used on those occasions.

Two flat-headed shells of homogeneous metal, weighing 151 lbs. each, with a bursting charge of 5 lbs., without fuzes, fired at a range of 800 yards, with a charge of 27 lbs. of powder, giving a velocity at 780 yards of 1,175 ft., penetrated into the box; the one having punched a hole through the 4½-in. plate, the other through the 5-in. plate. In each case they made a hole of 10 in. diameter in the skin, carrying some splinters and fragments into what may be called the between decks. In the first instance the shell burst, evidently when passing through the timber backing, or rather too soon. In the second, it exploded rather later and did somewhat more execution; but the effect, in both cases, resembled that of a solid shot penetrating the target more than that of a live shell.

A hollow cast-iron flat-headed shot, weighing 130 lbs., next struck one of the 5-in. plates, at a velocity of 1,200 ft., and made an indent of 2·3 in., breaking one rib and injuring some bolts and rivets. The shot of course broke up, and showed the great superiority over ordinary cast-iron of the metal used for projectiles by Mr. Whitworth.

A flat-headed shell of homogeneous metal, weighing 130 lbs., with a bursting charge of 9 lbs. 8 ozs., was also fired from the same gun, and struck a 5-in. plate, at a velocity of 1,240 ft. It punched a hole through the armour, and burst in breaking through the skin, in which it made a large irregular hole, carrying on some splinters and fragments of plate, skin, rivets, bolt heads, &c.

A solid 130-lb. shot of the same metal and form from this gun, at a velocity of about 1,200 ft., struck a 5-in. plate and went clean through the target, carrying a quantity of fragments into the box.

The range at which the above were fired was 800 yards.

The 70-pdr. gun was next fired at the same target at 600 yards. A shell of homogeneous metal, weighing 81 lbs., fired with a charge of 13 lbs., and having a bursting charge of 3 lbs. 12 ozs., struck a 4½-in. plate at a velocity of 1,100 ft., and penetrated it, afterwards bursting in the teak backing which it injured very much. The skin was not penetrated.

Another shell of the same kind burst immediately on striking a 5-in. plate, in which it punched a hole 4¼-in. deep, but had no effect on the inside of the target.

Another shell, weighing 72½ lbs., with a bursting charge of 2 lbs. 10 ozs., penetrated a 4½-in. armour plate, and burst in the wood backing, but did no damage to the skin; and a blind shell, weighing 70 lbs., striking with a velocity of 1,140 ft., broke to pieces on a 5-in. plate, after making an indent of 1½ in.

All these projectiles were of homogeneous metal and flat-headed.

The general result of these experiments may be summed up in a few words. Mr. Whitworth has, by the use of a superior metal, produced shells which will penetrate, without breaking up, as much as 5 inches of armour and burst afterwards; but with ships of the *Warrior* class, these shells would have no great effect in board, as, although the skin is broken through by the explosion of the shells, in no case have they been made to pass through the skin before explosion.

Whitworth projecticles at sloping plates. Nov., 1862.

In this trial some cylindrical flat-headed 12-pdr. shot, and blind shell of homogeneous metal and of common cast-iron, were fired at a range of 200 yards at 2½-in. plates, sloping back at an angle of 45°, the charge used being 1¾ lbs.

It is almost needless to say that the cast-iron shot broke up and only made a slight indent.

The homogeneous metal shell and shot completely penetrated the plates and were almost uninjured themselves.

It is interesting to notice here that the fragments of the cast-iron shot, when picked up afterwards, were too hot to be handled, while the homogeneous metal projectiles were quite cool.

Effect of shot varying in weight and velocity, but with equal *vis viva*.

The object of this experiment was to ascertain the difference of effect between cast-iron shot from 68-pdrs. and 110-pdrs., striking iron plates at such velocities as would make Wv^2 equal in each case.

For this purpose the following were used:—

The 68-pdr. threw a 66-lb. shot, with a charge of 16 lbs. of powder, at a velocity, at 200 yards, of 1,367 ft.

The 110-pdr. threw a shot of 110½ lbs., with a charge of 11½ lbs., at a velocity of 1,056 ft., and the same gun threw a shot of 200 lbs., with a charge of 11 lbs., at a velocity of 786 ft.

The plates fired at were 3-in., 3½-in., 4½-in. and 5½-in.

It was difficult to mark the general result of this experiment, but the deepest indent was decidedly made by the 68-pdr., and the least indent by the 200-lb.

shot; all the shot of course broke up, and, but for the difference of work thus consumed, there is little room to doubt that the total effect produced upon the plates would have been equal for all three shot, local and clearly marked with the lighter shot and higher velocity, more general and less defined with the other shot, but, as is stated above, the result was somewhat obscure.

Armstrong shot of various weights against iron plates. 14th Nov., 1862.

The 110-pdr. Armstrong gun was made to fire on this occasion lighter shot than its proper projectiles at higher velocities, and, of course, with increased charges of powder. The range was 200 yards, and the plates were $4\frac{1}{2}$ in. and 5 in. thick.

The comparison made was between the service 68-pdr., throwing spherical cast-iron shot at a velocity of 1,367 ft., and an Armstrong 110-pdr., throwing cylindrical cast-iron shot varying from 60 lbs. to 68 lbs., at velocities ranging between 1,580 and 1,475 ft.

The result of this was that the indent made by the 68-pdr. service gun was 2 in. deep, and that by the Armstrong gun from $2\frac{1}{2}$ to 3 in. deep, and the damage altogether appeared to be in the same proportion, which corresponds pretty nearly with the relative values of Wv^2 in the different shot.

Whitworth and Armstrong 12-lb. steel shot. November, 1862.

This comparative trial was made with 12-pdr. breech-loading rifle guns, against a target covered with $4\frac{1}{2}$-in. armour, at 100 yards. The shot were of steel, charge of powder, 2 lbs. One of the Armstrong round-headed shot made an indent rather more than 2 in. deep, and a flat-headed one made an indent of 1 in.; the former was slightly broken, the latter only set up.

The Whitworth made an indent of 1·4 in. and broke up.

Projectiles of various forms and qualities of metal. December, 1862.

At this time several cast steel shot, and shot made of other patented materials, were tried, with a view to determine the best form and material for projectiles intended to penetrate iron plates.

Some were tried with flat ends, some with flat ends in steps, some with conical ends, and others slightly concave in front.

On the whole the conical end answered best, and the steel manufactured by Messrs. Makin, of the Attercliffe Works, Sheffield, gave highly satisfactory results.

Armour plates suddenly cooled. December, 1862.

This experiment was made to set at rest a question which had been much disputed, and upon which there had been some contradictory results in former trials. The plates used were $4\frac{1}{2}$-in., made by Messrs. Beale, of Rotherham, and had been rapidly cooled down from a high temperature by sudden immersion in cold water; they were tried by 68-pdrs. and 110-pdrs., in comparison with plates manufactured by the same firm in the ordinary manner.

The indents made on the cooled plate were about twice as deep as those on the ordinary plate, and altogether no advantage seemed to be gained by the cooling process.

2nd casemate shield of my own construction. 29th Dec. 1862.

In the Paper in Vol. XI, before referred to, a short account is given of the trial of the first shield proposed by myself, and the Committee on Iron having formed a favourable opinion of the results then gained, recommended further trial of the principle.

Accordingly, a new shield was made of which the following is a description :—

It measured 11 ft. in length, by 8 ft. 2 in. in height, and contained an embrasure 3 ft. 6 in. high and 2 ft. 4 in. wide.

It was composed of vertical face planks of hammered iron of various sections, namely, 23 in. by 8 in., 23 in. by 7 in., 19¼ in. by 8 in., 19¼ in. by 7 in., and 19¼ in. by 6 in.; these were backed by horizontal planks of rolled iron 14 in. by 5 in., and secured by 3-in. screw bolts and rivets to a framework in the rear. This framework consisted of four vertical pieces 14 in. by 4 in., and two horizontal pieces 14 in. by 5 in , and the whole was supported at either end by a boiler plate diagonal strut having a base of 3 ft., and made up of a web of 1-in. plate, and angle iron stiffening pieces 8 in. by 5 in. by 1 in., and 5 in. by 5 in. by 1 in.

These struts were secured to sill pieces 14 in. by 4 in., running front and rear, and these again secured to a cross beam 18 ft. long, 11 in. wide, and 3 in. deep, placed 6 ft. in rear of the shield.

This beam was heavily weighted, and secured at each end in a mass of masonry in precisely the same manner as it would be in the real piers of a fort, and formed the sole means of holding the shield in its place.

One half of the target was made to represent half of a shield 12 ft. wide, and the other half, one 10 ft. wide.

At the end, representing the 10-ft. shield, the strut, being brought nearer to the embrasure than the other one, was splayed outwards at an angle of 15° from the perpendicular, as this would be necessary in actual practice to admit of the gun being traversed through an arc of 70°. The other strut stood perpendicular to the shield.

Between the surfaces of the front and rear planks, sheet lead, weighing 6 lbs. per foot superficial, was introduced to check vibration in the mass; and under the nuts of the screw bolts elastic washers of various descriptions were used. Some of these washers were of the nature of buffers, composed of 3 in. of india-rubber inside a strong wrought-iron cylinder; others were of coils of wire-rope similarly confined; and in other cases several lead washers, and washers of iron and brass were used.

The shield was made by the Millwall Iron Company.

For this experimental work it was of course out of the question to go to the expense of providing rolls for producing all the various sections of planks used in it, and therefore hammered iron had to be adopted for the face planks, yet the shield is designed with the special view of using rolled iron throughout in actual practice; and as upon this depends very much the expense of the structure, it is important that it should be mentioned here.

The following guns were used on the first day's trial :—

One 120-pdr. Whitworth rifled gun.
One 110-pdr. Armstrong " "
One 68-pdr. Service smooth-bore gun.
Range 200 yards.

Twelve shot from these guns struck the shield fair, namely:—

From the 120-pdr. { One round-ended cast-iron shot, 119·5 lbs.
One flat-ended homogeneous metal shot, 130 lbs.

From the 110-pdr. { Three cast-iron solid shot, 110 lbs. each.
Two " " 68 lbs. "

From the 68-pdr.—Five cast-iron solid shot, 67 lbs. each.

In all, 1,050 lbs. weight of shot struck the shield on this first day's trial.

The effects produced were highly satisfactory.

The indents made by the 68-lb. and 110-lb. solid shot from the 68-pdr. smooth-bore and Armstrong guns varied from 1·15 in. to 1·6 in.; those made by the 68-lb. shot from the 110-pdr. were 2·3 in. and 2 in. respectively; and the indents of the Whitworth shot were 1·8 in. in the case of the cast-iron, and 2 in. in the case of the homogeneous metal, which latter shot broke up.

With the exception of one small crack in a 7-in. plank, where a shot had struck near its edge, the shield was really none the worse for the day's firing.

The lead between the planks was squeezed out a good deal under some of the blows, some of the lead washers were flattened, and other minor effects were visible, but nothing to render the shield at all unserviceable.

Such being the case, it was determined to reserve it for the Armstrong 300-lb. rifle projectiles, and a batch of other monster guns soon expected to be ready.

Further trial of my second casemate shield. 3rd March, 1863.

The guns placed in position at 200 yards in front of this shield for its further trial, consisted of four of the most formidable pieces of ordnance ever before brought together in a battery. They were as follows:—

One 300-pdr. Armstrong muzzle-loading 10 grooved shunt gun, weighing $11\frac{3}{4}$ tons, calibre 10·48 in.

One 7-in. 130-pdr. Whitworth rifled gun, weighing $7\frac{1}{2}$ tons.

One 7-in. Lynall Thomas rifled gun, weighing $7\frac{1}{4}$ tons.

One 9-in. Armstrong muzzle-loading smooth-bore gun, weighing 6 tons.

The first shot fired was from the Whitworth rifled gun. It was of Frith's steel, solid of course and flat-headed, weighing 148 lbs., length of shot, 17·3 in.; charge of powder, 25 lbs.; velocity, at 12 yards short of the shield, 1,240 ft. per second.

The accumulated work in this shot on striking or $\frac{Wv^2}{2g}$ was 35,557 lbs., or, in other words, sufficient to raise about 1,587 tons 1 ft. high.

It struck on the joint of an 8-in. and 7-in. plank, and stuck there; two very small cracks appeared in the planks, and at the back of the shield a very slight bulge of less than $\frac{1}{2}$-in. might be detected, a little of the sheet lead was also squeezed out, but no injury of any consequence appeared.

The shot which thus adhered to the face of the shield was subsequently got out by means of heavy sledges, and the indent made was found to be only from $2\frac{1}{4}$-in. to $3\frac{3}{4}$-in. deep; the impression made is a very remarkable one, and testifies to the superiority of the metal of the shield and the wonderful hardness as well as tenacity of the metal of the shot. The effects of this blow, and of a subsequent one soon to be described, are interesting, as they exhibit with an unusual distinctness the work done by the shot during its action upon the shield, and no doubt a very large part of the work accumulated in the shot on impact could be accounted for in the effects produced upon the shield.

After this, the 9-in. smooth-bore Armstrong gun was fired. The shot was of wrought-iron, spherical, weighing 102 lbs., charge of powder 25 lbs., velocity, at 12 yards short of the shield, 1,461 ft. per second.

The accumulated work on striking or $\frac{Wv^2}{2g}$ = 1,537 tons raised 1 ft. high.

It struck close to the edge of a 6-in. plank, and a bolt, with lead and iron washers, distant about 3 ft. from the point of impact, was broken; also one of the horizontal backing pieces was cracked through in a vertical direction, and one of the vertical frame pieces slightly curved.

The indent made by this shot was 2·4 in. deep, and in diameter from 10·4 to 11·3 in.

The next shot was from the 300-pdr. shunt gun; it was of cast-iron, cylindrical, with a hollow hemispherical head, and weighed 230 lbs.; length of projectile, 19 in.; charge of powder, 45 lbs.; velocity, at 12 yards short of the shield, 1,400 ft. per second.

Accumulated work on striking or $\frac{Wv^2}{2g}$ = 3,145 tons raised 1 ft. high.

This shot struck on an 8-in. plank, and made an indent of 1·45 in. deep, and 9·5 to 10 in. in diameter. The plank was cracked through the indent, and at another place distant from the point of impact, two bolts were broken and two or three others more or less injured. Some other minor injuries were inflicted but nothing of a serious character.

The Lynall Thomas gun was next fired; the projectile was of wrought-iron, cylindrical, with a round head, weighing 151 lbs. Its length was 16½ in. The charge of powder was 25 lbs., and the velocity at 12 yards in front of the shield was 1,215 ft. per second.

The accumulated work on striking or $\frac{Wv^2}{2g}$ = 1,547 tons raised 1 ft. high.

It struck a 7-in. plank within 5 in. of its edge, making an indent 1·8 in. deep, and 7½ in. to 8 in. in diameter; the plank was cracked through a bolt hole rather more than a foot from the point of impact, and at another bolt hole about 18 in. below the point of impact.

The shield seemed to be generally shaken, though not materially so, and little or no further injury appeared at the back.

The next round was from the 7-in. Whitworth, with the same shot and charge as the first round.

This shot struck an 8-in. plank, and broke up, but a large portion of it remained imbedded in the face of the plank. When subsequently removed, this indent was found to be from 2½ to 3 in. deep, or rather less than on the other occasion before described; two bolts were broken, and some minor injuries received elsewhere, but nothing worth speaking of.

After this the 300-pdr. shunt gun was again fired, the shot this time weighing 307 lbs.: it was of cast-iron, cylindrical, with a round end, 18½ in. long. It was fired with a charge of 45 lbs. of powder, and at 12 yards in front of the shield had a velocity of 1,225 ft. per second.

The accumulated work on striking or $\frac{Wv^2}{2g}$ = 3,186 tons raised 1 ft. high.

This shot struck at the joint of an 8-in. and 7-in. plank, and of course broke up. It made an indent varying from 1·3 in. to 2 in. in depth, broke a bolt, and enlarged some cracks previously made. The shield showed general symptoms of having been shaken by this terrific blow, but on the whole bore it remarkably well.

The Lynall Thomas gun was next fired with a solid steel shot weighing

138 lbs., and a charge of $27\frac{1}{2}$ lbs. of powder, but the gun burst, and the shot did not hit the shield.

After the success of this day it was deemed proper to reserve the shield for further experiments proposed in connection with a masonry casemate about to be erected at Shoeburyness, by which arrangement the Armstrong 600-pdr., lately mounted there, will probably be brought against it.

The chief lesson to be learnt from this experiment is that,—given a big gun, a shield of wrought-iron can be made that shall resist it, and that being decided, the problem narrows itself into a simple enquiry as to how the necessary resistance can be obtained at the least cost.

It would be too much of course to say that the principle here tried fulfils these conditions better than any other that can be invented, but that it fulfils them better than any other that has yet been tried, all that witnessed the experiment admitted beyond question.

Numerous modifications and alterations to meet the various conditions of strength and resistance necessary in different works have been drawn up since this experiment took place, but it seems hardly desirable or possible to describe them now.

It is enough to say that the very simplicity of the principle makes it easy to adapt it to almost all circumstances, whether it be for the purpose of filling the front of a casemate, or for a small embrasure only, or for constructing a work of iron altogether, or for covering a masonry wall.

To all of them the principle is applicable, and it only requires to be treated with a little practical skill in its development.

Trial of thick armour. 17th March, 1863.

This experiment was made to test the resistance offered by some rolled armour plates, $5\frac{1}{2}$ in., $6\frac{1}{2}$ in., and $7\frac{1}{2}$ in. thick, manufactured by Messrs. John Brown and Co., of Sheffield.

The plates were of the following dimensions :—

One 13 ft. $4\frac{1}{2}$ in., by 3 ft. 7 in., and $5\frac{1}{2}$ in. thick.
One 12 ft. $2\frac{3}{4}$ in., by 3 ft. $7\frac{1}{2}$ in., and $6\frac{1}{2}$ in. „
One 11 ft. 9 in., by 3 ft. $8\frac{1}{2}$ in., and $7\frac{1}{2}$ in. „

They were secured by $2\frac{1}{2}$-in. screw bolts, to the skin and frame of Mr. Samuda's old target; one half of each plate had a backing of from 7 to 9 in. of teak, and at the back of the other half, it was left hollow for an equal interval between the plates and the skin. India-rubber washers were used under the nuts.

The guns in position for this trial were—

One 300-pdr. Armstrong muzzle-loading shunt gun.
One 9-in. Lynall Thomas gun.
One 7-in. Whitworth rifle gun.
One 110-pdr. Armstrong breech-loader.
One 68-pdr. service 95-cwt. gun.

All were fired at a range of 200 yards.

The first three shots (all cast-iron), were fired from the 68-pdr., one shot struck each plate and made indents $1\frac{1}{2}$ in. deep in the $6\frac{1}{2}$-in. and $7\frac{1}{2}$-in. plates, and 2 in. deep in the $5\frac{1}{2}$-in. plate.

These were followed by three shots from the 110-pdr., also of cast-iron; the indent upon the 5½-in. plate was 1·9 in. deep, that upon the 6½ was 2·05 in. deep, that upon the 7½ was 1·65 in. deep. There was scarcely any other effect visible.

The next shot was from the Armstrong 300-pdr., with a cylindrical steel shot weighing 301 lbs., and fired with a 45-lb. charge of powder. This shot had a velocity of 1,295 ft. per second at 30 yards in front of the target, and struck the 7½-in. plate, where it had the teak backing. The indent made was 6·2 in. deep, and its diameter about 12 in., or rather a circular piece of this diameter was driven in to a depth of 6·2 in., and nearly, if not quite, separated from the plate, which was of very good quality. There is therefore here a well defined measure of the full force of this shot. Besides this local effect, the target had evidently received a serious shake: one rib was cracked through and bent out, a number of small rivets were broken; the plate struck was buckled about 1½ in. and slightly cracked. The shot which rebounded from the target was set up about 2½ in., and was of excellent material.

A cylindrical steel shell, with a cast-iron head, made on a principle designed by Sir William Armstrong, for the purpose of penetrating iron plates by directing the force of the explosion of the bursting charge *forward*, was next fired from the same gun. It weighed 288 lbs., had a bursting charge of 11 lbs., and was fired with a charge of 45 lbs. of powder, which gave, at 25 yards in front of the target, a velocity of 1,320 ft. per second. It struck the 5½-in. plate on a part supported by the teak backing. It completely penetrated the armour plate, leaving a hole about 14 in. in diameter, burst in the teak backing, tearing away the inner skin and breaking a rib, and carried a shower of fragments and splinters in board. The teak was set on fire by the explosion but easily extinguished, one bolt was broken, and other injuries done.

Altogether, for completeness of penetration and for the destructive effects which would have been produced both upon the ship and crew, this experiment carries with it great significance.

After this, a cylindrical flat-headed homogeneous metal shell, weighing 148 lbs., with a bursting charge of 5 lbs. 12 ozs., was fired from the Whitworth 7-in. gun, with a charge of 25 lbs. of powder, which gave a velocity, at 30 yards in front of the target, of 1,265 ft. per second. This shell struck the 5½-in. plate near the hole made by the last Armstrong shell, punched out a clean cut hole about 9 in. in diameter, and burst in the teak backing; beyond blowing out some of the timber, it added very little indeed to the injury done by the Armstrong shell.

Lynall Thomas' 9-in. gun next missed the target with a round-headed solid steel shot, weighing 327 lbs., fired with a charge of 50 lbs. of powder, which, at 546 ft. from the gun, gave a velocity of 1,220 ft. per second.

The same gun next fired a wrought iron solid flat-headed shot, weighing 302 lbs., with a charge of 50 lbs. of powder; the velocity of this shot was not obtained with certainty, it struck partly on the 6½-in. and partly on the 7½-in. armour; the greatest depth of impression on the latter plate was 6 in., and on the former 4 in. The 7½-in. plate was cracked through a bolt hole and round the indent, as was also the 6½-in. plate; but, altogether, the injury done was less than had been expected.

A hardened steel shot was next fired from the same gun; it weighed 330 lbs., was round-headed, was fired with a charge of 50 lbs. of powder, which gave a velocity of 1,220 ft. per second at 25 yards in front of the target. It struck close to the lower edge of the 7½-in. plate, and made an irregular indentation measuring about 1 ft. by 1 ft. 8 in., and 7 in. deep; two bolts were broken, one rib broken through, two others much bent, and the skin bulged in. The shot itself broke in half lengthways.

After this the 300-pdr. Armstrong shunt gun fired a spherical wrought-iron solid shot, weighing 163 lbs., with a charge of 45 lbs., which, at 30 yards in front of the target, gave a velocity of 1,630 ft. per second. It struck the 7½-in. plate where it had no teak backing, and made an indent 3¾ in. deep, and 13 in. in diameter, with a crack on the face of the indent; the plate was considerably bulged in, and at the back it showed a large starred crack. The shot was flattened out to a diameter of 13 in.

The material of which these armour plates was made proved itself to be of uniform and excellent quality.

The practical lessons to be learnt from this day's experiments seem to be these:—

1st. That guns are already in existence which can completely penetrate with shot the best 7½-in. armour that can be made, and which can, with shell, pierce the sides of a ship built, as to frame, much more strongly than our best ship, and protected with our best 5½-in. armour.

2nd. That iron plates can now, with the improved manufacture of the country and the energy brought out by the occasion, be made of dimensions hitherto quite unattainable, and yet without losing anything in quality.

Chalmers' target. 27th April, 1863.

The next experiment of any importance was made at Shoeburyness to test the merits of a principle of construction proposed by Mr. Chalmers for iron clad ships of war.

The chief features of the system advocated by this gentleman (and with such confidence that he made the target to test its value at his own expense, a thing not thought of in recent times by any other inventor), may be thus described:—

The ribs and skin constituting the frame of the ship are very similar to those of the *Warrior*, and the difference consequently lies in the external protection; this, instead of being obtained by armour in one thickness with a simple backing of teak, as in all the ships yet building or afloat, is composed as follows: first, he presents to the shot an armour plate 3¾ in. thick, of hammered iron, which is backed by a compound mass of iron and teak 10 in. thick; this backing is made up of alternate timbers 10 in. by 5 in., and wrought-iron ribs 10 in. by $\frac{7}{16}$ in., laid horizontally, and bolted together at frequent intervals by vertical screw bolts of 1 in. diameter. This compound backing is supported in rear by, and attached to, a plate 1¼ in. in thickness, this being called an intermediate or second armour plate; and the intermediate armour is again backed by a thickness of 5 in. of teak to form a cushion, behind which come the skin and ribs before described as being similar to the *Warrior's*. The armour is held on by 2¼-in. screw bolts formed with a peculiarly shaped stepped head, instead of the usual conical form, and nutted at the back of the skin.

Thus the side consists, exclusive of skin and ribs, of 5 in. of armour and 15 in. of backing (10 in. of which is a compound of iron and teak), against 4½ in. of armour and 18 in. of teak in the *Warrior*, and this difference accounts as nearly as possible for this structure weighing about 20 lbs. per foot superficial heavier than the *Warrior*.

The object aimed at by the inventor was to give a better support to the outside armour than is afforded by timber only, and at the same time to avoid rigidity of structure which he considers so destructive to both armour plates and fastenings.

The target for this experiment presented a front measuring 13 ft. 4 in. by 10 ft. high; and to give it support equivalent to what it would receive from adjacent parts, if forming part of a large structure, it was surrounded on all sides by a casing of boiler plate, which, if included in the weight of the target, would add about 48 lbs. per foot superficial to the weight already given.

It is not necessary here to describe minutely the practice at this target. It will be sufficient to say that it was carried on by 68-pdr. service guns and 110-pdr. Armstrongs, at 200 yards, firing first with shells filled with sand, then with live shells, then with solid cast-iron shot, then with 200-lb. bolts from 110-pdrs., first singly and afterwards in a salvo of three, in one instance a salvo of five guns being fired against it; the object of the experiment being to give this target a battering as nearly as possible equal to that received by the original *Warrior* on its first trial.

After this the Armstrong 12-ton gun fired two spherical cast-iron shot and one cylindrical steel shot; but this last shot bore no part in the comparison with the *Warrior*, as that target was never struck by a *steel* 300-lb. shot.

The shells filled with sand did of course little or no damage beyond the usual marks on the armour: in the case of the 110-pdr. about ½-in. deep, and of the 68-pdr. about 1¼-in. deep.

The live shells did much the same.

The 68-pdr. cast-iron shot indented the armour about one-third more than the *Warrior*, the depth of the impression itself being about 2½ in., and of the more extended bulge about 1 in. more.

The 110-pdr. cast-iron shot also indented altogether from 2½ to 3½ in., including some local bulging, the depth of the impressions themselves being from 1¼ in. to 1¾ in. deep, or about twice as much as in the *Warrior*.

A few rivet heads were broken off by these shot and the plates were cracked slightly, especially the lower one, which was of inferior manufacture, but no bolt was broken, and the plates were only slightly displaced.

The salvo from the three 110-pdrs., throwing 200-lb. cast-iron shot, did little damage.

That from the two 68-pdrs. and three 110-pdrs. did somewhat more injury, but still the target stood remarkably well; the first through-bolt broken occurred in this salvo. At the rear some of the ribs were slightly buckled and slight curvatures appeared, but nothing whatever of any consequence.

After this the 300-lb. steel, cylindrical, round-headed Armstrong shot, fired with 45 lbs. of powder, struck at the junction of two plates, and completely penetrated the target, making a hole in the armour of about 1 ft. 2 in. by 1 ft. 1 in. The hole in the skin measured about 2 ft. by 1 ft. 6 in.; one rib was smashed and a quantity of fragments were carried through to the rear.

One 150-lb. cast-iron spherical shot from the Armstrong 12-ton (10½-in.) gun, fired with a 50-lb. charge, struck on the junction of two plates, just as a similar shot fired with a 40-lb. charge did on the *Warrior*: it made a hole in the armour of about 1 ft. 2 in. by 11 in., and buried itself about 1 ft. deep in the backing, bulging the skin considerably and slightly opening it in one place; two through-bolts were broken and other minor injuries done.

Altogether it may be said that about the same injury was done to this target by the 300-lb. shot as was done to the *Warrior* by the same shot.

Another 300-lb. shot did much the same damage.

The result of this experiment appears to be—that Mr. Chalmers' compound backing is superior, as a support, to the simple backing of timber, and although his 3¾-in. armour plates were more injured than those of the *Warrior*, yet, on the whole, his target resisted better than that target.

Whether or not the advantage was in a greater degree than is due to the excess of weight over the *Warrior*, or whether it is at all due to the peculiar distribution of the armour in two thicknesses, are fair subjects for question. To decide these there should now be made a target, similar in every respect to the original *Warrior*, only instead of the simple teak backing 18 in. thick, the 4½-in. armour should have a compound backing about 10 in. thick, with an elastic cushion for the compound backing to bear upon.

Clark's target. 7th July, 1863.

This target was constructed to test a system of naval armour, with compound dovetail fastenings and iron cellular backing, advocated by Mr. George Clark.

The object this gentleman had in view was to gain greater solidity and strength of structure by means of a rigid backing, and so to give his armour plates greater power of resistance; while, at the same time, he hoped to get an increase of holding power, without weakening his armour, by means of dovetail bars let into the back of his plates, and forming as it were continuous heads to sets of 3 or 4 bolts.

The target was a somewhat complicated one, several different principles having been introduced in it. It presented a front measuring 13 ft. 6 in. by 10 ft. in height, and was covered with seven armour plates, which, with their backings and fastenings, may be described as follows:—

No. 1 Plate measured 6 ft. by 3 ft., and was 4½ in. thick. It was held on by three dovetail bars let in flush into the back of the armour, each bar forming the head to three bolts, in one case, 2½ in. diameter, in the other two, 3 in. in diameter. This armour plate had a cellular backing formed by angle irons 7½ in. by 5 in. by 1 in., laid horizontally, one side of the angle being attached to the skin of the target, the other projecting to the front, and thus forming cells 6½ in. deep by 5 in. wide. The cells were divided transversely into lengths of about 2 ft., and were filled with compressed millboard.

No. 2 Plate measured 7 ft. 6 in. by 3 ft. by 4½ in., and was held on by 10 through-bolts instead of the dovetail fastenings; six of the bolts were 3-in., and four 2½-in. The cellular backing was the same as in No. 1 plate, but the cells were filled with teak instead of millboard.

No. 3 Plate measured 7 ft. 6 in. by 2 ft., and was 4 in. thick; but on its back were formed three vertical projecting ribs 2½ in. deep and about 9 in. wide, in which ribs vertical dovetail slots were cut to receive the dovetail bars, which were very similar to those in No. 1 plate; these dovetail bars had six 2½-in. bolts attached to them.

The cellular backing was similar to that in the two former cases, only that the angle irons were made of ¾-in. iron instead of inch, and the filling was of millboard.

No. 4 Plate was the same as No. 3, only that the filling in the cells was of teak instead of millboard.

No. 5 Plate measured 6 ft. by 4 ft., and was 4 in. thick, with ribs at the back, and slots as in Nos. 3 and 4 plates. It was held on by twelve 2½-in. bolts, attached to three continuous heads. The cellular backing was the same as that of Nos. 3 and 4 plates, and the filling of teak.

No. 6 Plate measured 6 ft. by 3 ft., and was 3 in. thick, and had at the back 4 horizontal ribs, across which, in a vertical direction, were cut three slots to receive three continuous heads as before, to each of which were attached three holding-on bolts; six of these nine bolts were 3 in. diameter, and three were 2½ in. The cellular backing was formed of vertical angle irons 6½ in. by 3½ in. by ½ in., and thus the cells ran vertically and were 6½ in. deep and 4⅓ in. wide; the filling was of millboard. The structure, in this case, received additional support through some stiffening pieces or double knees attached to the ribs of the ship and abutting against the back of the skin.

No. 7 Plate measured 7 ft. 6 in. by 3 ft., and was 3 in. thick, with three vertical projecting ribs at the back, very similar to those on plates 3, 4, and 6. There were three continuous heads running vertically in the three ribs, and to each head were attached two 2½-in. and one 3-in. bolt.

The cellular backing was composed of double angle irons 9 in. by 2½ in. by ½ in., forming horizontal cells 8½ in. deep and 4 in. wide, filled with teak. Teak was also filled in at the back of the skin between the ribs, and the ribs were likewise stiffened in a similar manner to those in No. 6.

The iron representing the skin of the ship was ½ in. thick, and the ribs 10 in. deep, and 15 in. apart.

The weight, per foot superficial, varied in the different plates: that of No. 6 was the greatest, and No. 5 the least.

The average of the whole was about 375 lbs. per foot superficial, of which about 25 lbs. were due to extra support given at the sides, top, and bottom of the target.

The guns used in the experiment were the 68-pdr. service, the 110-pdr. Armstrong, the smooth-bore muzzle-loading Armstrong 9-in. (6-ton) gun, and the 10½-in. Armstrong (12-ton) gun—all at 200 yards.

The firing commenced with two live shells from the 68-pdr., and one from the 110-pdr., which made the usual indent, broke 16 rivets at the back, injured one rib, and made a slight bulge in the rear.

These were followed by six solid cast-iron shot from the 68-pdr., which made indents varying from 1·5 in. to 2·3 in. in depth (or a mean of 1·84 in.), breaking 5 bolts, one only of which was a through-bolt; the plates were more or less bulged and cracked, and some rivets at the back broken, but nothing very serious.

After this, two 68-lb. shot struck plates Nos. 6 and 7 in their weak parts, that is to say, where the armour was only 3 in. thick; they broke through the armour, doing some injury to the skin and fastenings in rear, especially to the stiffening pieces or double knees, three of which were broken.

The next four shots were fired in a salvo from one 68-pdr. and three 110-pdrs.; they all struck about the centre of the target, and principally on No. 5 plate. They made indents from ·9 in. to 2 in. in depth, cracked the armour a good deal, and displaced the plates and buckled them an inch or two; at the rear, the skin was found to be cracked, one rib broken, and two others injured, and one bolt attached to the dovetail bar driven in ¾ in.

A steel jacketed cylindrical shot, flat-ended, weighing 109 lbs., from the 110-pdr. gun, with a charge of 16 lbs., struck No. 5 plate, but did little mischief beyond making an indent 1·2 in. deep.

A spherical steel shot, weighing 156 lbs., fired from the 12-ton gun, with a charge of 50 lbs. of powder, went clean through everything, and out to sea, with considerable force left in it. The damage done was very serious indeed, and of such a nature, both as to rupture in the skin and general smashing of ribs and supports, as to make it fatal to a ship at sea. The injury done by the fragments and splinters on board the ship would also have been terrific. One bolt close to the spot struck was driven through.

A 300-lb. steel shell was then fired from the same gun, with a charge of 35 lbs. of powder, and a bursting charge of 12¾ lbs. This shell went as completely through everything as the spherical shot did, and the general damage done was not less serious.

Lastly, a 100-lb. cast-iron shot was fired with 25 lbs. of powder, from Armstrong's 9-in. smooth-bore muzzle-loading gun (6 tons), at the same range. It struck No. 5 plate, and made a hole through it measuring 9½ in. by 10 in., with some cracks round the hole. It did not pass completely through the target, but it broke open the skin and left some timber protruding; the shot itself, broken up, remaining in the hole. One rib, injured before, was broken in two, and one bolt (not a through-bolt) broken; several rivets also were broken. Had this shot been of superior metal—that is of homogenous metal or steel—it would undoubtedly have passed easily through the target.

The results of this day's firing are somewhat perplexing.

It is easy to see some defects in the target, such as that of a single armour plate having different thicknesses in its different parts, and that of the reduced size of the plates, together with some unnecessary complications of design; but it is not easy to account for the structure being so much inferior to Chalmers', and even to the original *Warrior* target.

The *Warrior* presents an extreme of elasticity in its backing to the armour. Chalmers did not depart entirely from this principle, for he provided a cushion of timber, 5 in. thick, behind his inner or intermediate armour. Clark gave up elasticity altogether, and aimed at rigidity. Samuda and Scott Russell did the same, and the Iron Committee in their target also had no elastic substance.

In this no doubt lies one cause of failure in Clark's, as in the other three last named.

Next, the interval between the armour and the skin of the ship in the *Warrior* is 18 in., in Chalmer's 16 in., in Clark's only 7 in.; this may have a good deal to do with the inferiority of the latter, inasmuch as the greater thickness of backing, of whatever material it may be composed, must have more or less the effect of distributing the force of a blow, delivered upon the armour, over a large surface of the inner structure—and it must be observed that the examples of Scott Russell's, Samuda's, and the Committee's target, all point to a similar conclusion.

In addition to other objections to any of the principles advocated by Mr. Clark, there is that great one of extreme complication of design and consequent costliness; the latter consideration might give way to the promise of increased strength, but nothing can compensate for the former. To re-model the ships of the British fleet on Mr. Clark's principle would occupy the greater part of the remainder of this century.

This being the last experiment which can be recorded in this volume, it may be interesting to repeat a few of the most notable results obtained in the year.

First then.—The side of the *Minotaur* has been completely pierced by the Armstrong 10½-in. gun (12 tons), throwing a spherical cast-iron shot at 200 yards range, while similar shot had failed to penetrate the inner skin of the *Warrior*.

Secondly.—The Horsfall 13-in. gun (24¼ tons) completely penetrated the side of the *Warrior*, at 200 yards, with a cast-iron shot; but at 800 yards, it pierced the armour only of the same ship and buried itself in the timber backing.

Thirdly.—Mr. Whitworth's 70-pdr., at 200 yards, has succeeded in passing a shell of homogeneous metal through 4 in. of armour and 9 in. of timber previous to bursting; also his 120-pdr., at the same range, has passed a shell of the same metal through the side of the *Warrior*, bursting in its passage; and the same gun, at 800 yards, has completely pierced, with both shot and shell of the same metal, a ship's side, constructed as to frame of equal strength with the *Warrior*, but covered with 5-in. of armour.

Fourthly.—The Armstrong 12-ton gun has just penetrated 7½-in. armour with a steel shot at 200 yards, and it has completely pierced a ship's side, consisting of 5½-in. armour, 9 in. of teak, and strong inner skin and frame, with a steel shell.

Fifthly.—A shield for land defences has been produced that is equal to resist a battering from guns up to 12 tons in weight, at a distance of 200 yards.

In this state the question of guns against iron armour must be allowed to stand for the present, but it is one which cannot stand still long; already we have a 600-pdr. mounted at Shoeburyness and ready for trial, and there are manufacturers who are anxious to begin upon still larger guns.

Immense activity is being displayed in all our great foundries—an armour plate, 12 in. thick, 19 ft. long, and 3 ft. 9 in. wide, weighing 15 tons, has been rolled at Sheffield with almost as much ease as one of less than one-third its size could be produced, only as it were a few months since; so much science and skill is brought to bear upon the manufacture of improved wrought-iron and steel, as well as in converting cast-iron, by a direct and easy process, into a metal possessing all the good qualities of soft steel and tough wrought-iron, that it may be confidently assumed that we have neither yet seen the full resistance to be got out of a given thickness of armour, nor can we yet see the limit to our power of piercing it; one thing only stands out clear in the uncertainty of the future, and that is, that land defences will ever be superior to attack by sea. Ships of form and power, that we little dream of now, may carry armaments heavier than our most enthusiastic inventors yet dare to suggest; but forts, if made of the proper material, and of form and capacity adequate to the reception of the largest growth of gun, must ever be able to crush anything afloat.

Whatever advance science may make in gunnery, or mechanical skill in the production of monster guns and the means of working them, every step must tell in favour of forts to a greater extent than of ships; so that whatever else may undergo change in this age of monster guns and iron armour, our coast defences must maintain their importance, indeed they must become more important than ever.

T. INGLIS,
Capt., Royal Engineers.

PAPER XVI.

ON THE REPRESENTATION OF GROUND.*

By MAJOR SCOTT, R.E.

The title I have given my paper might be taken to embrace the whole art of the Surveyor and Topographical Draftsman. This includes, first—the ascertaining the dimensions of portions of the earth's surface, so as to enable their forms and details to be represented on paper as horizontal and vertical projections; the measurements and all observations necessary, forming the peculiar work of the ordinary surveyor. Secondly—the plotting and protracting the surveyor's work, and giving to the horizontal projections derived from it, such relief and character as may be required to present a true picture of the undulations of the soil; and this forms the most difficult part of the task of the topographical draftsman, who must, if he is to give them proper expression, unite to a good eye, skilful hand, and correct judgment, an acquaintance with the salient features of geological action.

It is hardly necessary to say that I am not here proposing to attempt so much. I must assume all the ordinary work of the surveyor (whether a careful and accurate piece of work on which much time and labour has been expended, or such a skeleton as a staff officer would generally attempt), already finished, or, at least, the proper modes of executing them decided upon, and confine myself to that branch of topographical art which consists in giving to hill forms the solidity of appearance requisite to convey to the eye at a glance, not only the general conformation of the hills, but also a near approximation to the inclinations of their sides and their relative altitudes. I must limit my task still further. Assuming that whatever the opinion on the possibility of expressing with the pen and pencil nice geological differences, no one will dispute the possibility of depicting on a plan in unmistakeable manner the portions of ground, which are sandy or marshy, or which are rocky or covered with soil, I shall confine myself to an endeavour to arrive at a good method of representing, with the pen or pencil, the slopes and forms of such hills and undulations as generally form the theatre for the tactical operations of armies.

That such a method is still wanting in the British service will need no proof in the minds of those who have to make frequent use of military drawings; but it may have occasioned them surprise that no uniform and systematic plan for expressing ground, should have been agreed upon. The difficulty may, I think, be in a measure attributed to the fact that the engineer, whose duties lead him to a

* This paper was originally read at Chatham on 20th February, 1863.

ready comprehension of the signification, and to an appreciation of the value of contours, has little need, for his own peculiar duties, of the aid to be derived from the more pictorial results produced by shading, whilst the staff officer, who sketches for the tactician, has had no training in the use of contours, which, whether finally left on the plan as marked lines or not, can alone give accuracy of work and certainty of reading. Wanting in these requirements, plans may be beautiful specimens of manipulative skill, but they are often worse than valueless. I feel it a bold thing to hope to supply a deficiency of such importance; but I have not ventured to ask you for your criticisms until I had ascertained the good practical working of the system I have to propose; and my position here as the Superintendent of Topographical Drawing, and my employment as examiner in this branch of military science by the Council of Military Education, appear to me, not only to justify the attempt, but to require that, having felt the want, I should endeavour to remove it.

In dealing with the subject, I shall first enquire, whether it is possible to attain to a perfect solution of the problems involved in this question, and if not, consider what are the points on which we must content ourselves with something short of perfection, and what, considering the means at our disposal, should be looked upon as indispensable. Then I shall enquire how far the attempts hitherto made have met the question. And lastly, I shall describe my own ideas on a uniform system of sketching, as clearly as I can, and endeavour to show that my proposition satisfies the conditions laid down as necessary.

With reference, then, to the degrees of perfection to be aimed at.

1.—A military plan, to be perfect, should convey to the mind the relative altitudes of its various features as readily, and as accurately, as a careful survey of a tract of country imparts a knowledge of the outline of its roads and the boundaries of its divisions. This, however, is no easy matter. We may, by trigonometrical operations, obtain the altitudes of detached points, or by the use of a level arrive at a knowledge of such a succession of points at different heights, as to trace upon our plans equi-distant contour lines; but these, if sufficiently far apart vertically, to be shown on the steeper slopes, would not only leave important portions of flatter country undetermined, but would fail to convey so distinct a picture of the undulations of the ground as would enable an observer to seize their meaning at once, or to retain in his memory the image they may have conveyed. If placed at unequal intervals, depending on the degree of inclination, it would be still more difficult to realize their signification. Supposing, therefore, that the staff officer should receive sufficient practice in the use of contours to employ them readily, however valuable a plan, showing such lines only, might prove in certain cases to the Quarter-master General's department or to the Engineer, it would be a very indifferent aid to a general in enabling him to arrive at a comprehension of the ground he is to occupy. It is an easy thing to understand the meaning of a section, or even of a system of contours, and any one of ordinary capacity would do so after a few words of explanation; but unless the contours are sufficiently close to look like shading, only those who have had some practice in their use can combine their meanings with sufficient facility to gather from them rapidly a correct conception of what they represent. A series of vertical sections would require a still greater exertion of memory and skill to combine into a whole, and it would seem, therefore, in the present state of our knowledge, impossible completely to attain the desired end. Although, however, we cannot arrive at a system free from all defect, it is comparatively easy to attain to such a degree of perfection in our plans, that we may, without either labour or thought, at once determine the relative altitudes of such points on them as we may require, with far greater nicety than can possibly be done by any unaided system of shading. No method of drawing ground, therefore, which does not allow the use of such means of giving information, and is not itself assisted by them, should be adopted.

2.—If the altitudes of any required points can be readily found, it is not necessary to be able to read at a glance the precise inclination of the ground on slopes so steep as not to admit of the movements of bodies of troops in masses, nor is it necessary to show by shading any slope beyond that which, without some peculiar facility for footing, is impracticable for infantry. It is, however, most essential that the eye should be able, very readily, to appreciate differences of slope on ground admitting of manœuvres.

The following table from the work of M. Lehman, who has the credit of being the first to attempt to reduce topographical drawing to something like strict and mathematical rule, will illustrate these remarks:—

1.—*Gradations admitting of Manœuvres.*		
5°.	10°.	15°.
INFANTRY may move with order, and has, down hill, the most effectual fire and charge.	INFANTRY. Its close movements become more difficult.	INFANTRY cannot move any considerable distance with order; their fire up hill without effect.
CAVALRY may also move with order, and has, up hill, its most effectual shock.	CAVALRY can only canter down hill, the charge possible only up hill.	CAVALRY may still trot up, and walk down hill.
ARTILLERY has a more effectual fire down than up hill.	ARTILLERY moves with difficulty, its effectual and constant fire ceases.	ARTILLERY moves with great difficulty, its fire totally ceases.
2.—*Gradations which may be ascended and descended singly.*		
20°.	25°.	30°.
INFANTRY cannot move in order, and can fire only singly with effect.	INFANTRY. Light Infantry as before.	INFANTRY. Chasseurs and Riflemen, as Light Infantry before.
CAVALRY may still ascend at a walk, and descend without order, and that only obliquely.	CAVALRY. Light Cavalry may ascend one by one obliquely, and descend in the same way, but with great difficulty.	CAVALRY. Hussars may ascend as above, but with great difficulty, and when the slope is of soft earth.
3.—*Gradations which may be climbed up.*		
35°.	40°.	45°.
Chasseurs and Riflemen may ascend with difficulty one by one.	Chasseurs and Riflemen, without baggage, may ascend with help of their hands.	Chasseurs and Riflemen accustomed to hilly country, may ascend as above, but with danger of falling.

3.—The system adopted should be such as can be applied with ease and accuracy in the field, can be readily learned, and will not leave the work of inexperienced draftsmen valueless. It should also be such as can be understood without special training, and such as will not, therefore, prove in any way puzzling to those who have had no recent practice in its use.

Whatever the opinion concerning the remarks made under my first heads, I am confident that there is no general in the British service who will not approve of the requisites named under the third.

Plates III and IV. Our old drawings had none of the above recommendations. In the earliest European* attempts at representing the features of ground on maps and plans, whilst these were laid out so as to show the true relative positions and dimensions of the details of the country embraced, just as they would be seen by an eye travelling over each point of them in succession, or by horizontal projection, the hills were represented as if their apparent contours, seen against the sky by a spectator on the earth's surface below them, were projected each on an inclined plane of its own, and these projections were then turned over and confounded with the horizontal plan. This method was revived in great glory during the Russian war. Everyone must remember the wonderful mountain ranges of the Crimea, as exhibited in maps of this class in all the printsellers' windows in London, and, if I mistake not, there are now again to be seen similar specimens, showing the seat of war in America. Highly pictorial as the system is, it can, at best, show only one side of the hills in the drawing, and hides some of the details on the plain behind them, and is therefore evidently quite unsuited for military purposes; and, excepting for the representation of trees, bushes, and a few such conventional signs as cannot possibly mislead, should be absolutely proscribed. It may, perhaps, however, be allowed on nautical charts to assist the navigator in recognizing points on the coast, but it would seem to be a better plan to give little side diagrams with references on the map to the points from which the hills were drawn.

The inconvenience of this method having been felt, the system gradually underwent a considerable modification in the extent to which it was applied. Plate V. Hills were now drawn, as if seen from a very high bird's-eye point of view, so as to diminish the evils of the system, without rendering what is usually termed *natural* representation impossible, and at last the point of sight was supposed to be almost vertically over them, but not quite so. Some Plate VI. very beautiful and clear specimens of this work, of which Plate VI is a good sample, were produced in the earliest part of the 19th century. Towards the end of the 18th century the demi-perspective and bird's eye view systems of representation had however almost given way, for military sketches, to a method in which the dimensions of hill forms were shewn, like the other details of plans, by their horizontal projections; and relief was imparted by a species of shading, consisting of bent or waving strokes, fine at both ends, and swelling in the middle, drawn according to what is termed the vertical style. Great attention was paid to giving them a graceful form, one author devoting

* In Plate I and II are seen interesting examples of the mode in which the topographical draftsman of Kouyunjik represented hills, and of the purely conventional system of the Chinese.

no less than 50 8vo. pages to instructions in the art of making and using them. They were to be commenced with as feeble a touch as possible, to be made gradually thicker towards the middle, and to die out imperceptibly at their tails. The middle of the strokes was not to be too thick, but to be even and proportioned to their length. The sharper the inclination of a hill side, the stronger they were to be; and in proportion as the distance from the summit of the hills was greater, they were to be lighter, and further apart, until they became almost imperceptible. The system would appear to have been made up of purely conventional rules designed to shew, in a graceful manner, the fact of the existence of hills on the ground represented, and little more; nevertheless scientific reasons were soon found for them. Hayne, the author alluded to, says:—"We will adopt the kind of stroke which most resembles the natural form of mountains, that is to say, a stroke of the form of a long /; strokes perfectly straight, may also be used, but they are not so well adapted as the / shape for the expression of what is required;" and his French translator adds, in a note, in further explanation:—"We have to imagine the curves which drops of water would trace on the surface of the ground when rolling by the action of gravity. We must then picture to ourselves the projection of these curves, and by these projections we represent the varied hill slopes, of which they shew in all directions the lines of greatest inclination. This is the system now generally followed in France by geographers and engineers." Unfortunately, however, for the theory, we are told a little further on, that when the hill side is too long to be covered with one stroke, that then several shorter strokes may be used, but they must still have the shape of a long /. Now, if one long / will express the line of descent of a drop of water on the side of a hill, a succession of smaller / strokes in the same direction certainly cannot do so.

Plate VIII.

A comparison of the curved strokes used to represent the sloping sides of the hills in Plates V and VI, with those in Plates VII, VIII, IX, and X, will show the real origin, as it appears to me, of the waving hachure used by the draftsmen of this period. The hill sides in demi-perspective drawings having been represented by the curved lines of vertical sections, and this system having gradually died out, it was not at once felt by field sketchers that the horizontal projections of these curves would be straight lines.

Another writer, Captain Hogrewe, a German Engineer Officer, gets over the difficulty of long strokes by asserting that hills, towards the centre, generally run into flattened gently swelling spurs, so that at the middle of the hill the curved lines may die out and make a fresh start! This author considers that, if this system of shading is well executed, it will represent the hills as they really appear in nature. He allows, however, that it requires much practice, patience, and time, to accomplish the task.

Plate VII.

The practice of making the strokes more forcible at the summits of hills, and very faint in the valleys, though it gave every mountain side and hill slope the appearance of concavity, and, moreover, employed the thick stroke for two purposes, viz., for representing altitude as well as steepness of slope, was accounted for on somewhat better grounds than the / shape of the stroke. The light, it was said, in traversing the atmosphere, was partly absorbed, and reached the lowest points of the ground with a diminished intensity. The valleys were, therefore, proportionally less distinct when viewed from above; but *on paper*, that which is darkest is most distinct, whence the tops of the hills should be made the darkest part of the drawing.

If any further proof is wanted of the fanciful nature of the rules for drawing on this system it is to be found in the variations which had favour with different draftsmen. Some drew three or four strokes forcibly, and of a moderate length, and then, alongside of them in continuation, three or four more somewhat lighter and shorter, and so on alternately; others made four or five strokes, in- Plate IX. creasing in length in succession, and then began with a short one again; a third method consisted in crossing the strokes to represent the steepest ground; and the author, from whom I have already quoted, considers the most elegant method to be this:—to make a succession of long strokes in the ordinary manner, but further apart, and then to fill in the intervals with waving or serpentine strokes of the same intensity and length, and of the same characteristic general form. This method is, however, admitted to be laborious, as it occasions going over the whole surface twice.

In 1803, a commission of officers was appointed by the Republican Government in France, to consider the best means of simplifying and reducing to system, the methods of topography. The subject of giving relief occupied their special attention. They condemned the use of demi-perspective, which they considered absurd, and, retaining the remainder of the ordinary shadow system of representing hills on account of the beauty of its effect, they recommended that all *cast* shadows should be done away with, as such shadows not only obscured the details of the plan, but were very difficult to represent correctly. They also rejected the employment of contours, excepting for the special requirements of engineering works. "The lines of greatest slope," they said, "or of the fall of water, offer this advantage, not possessed by contours:—they represent a material effect of which the eye is witness every moment (à chaque instant) and which recalls the general cause, if not of the formation, at least of the figure and characteristics (accidens) of mountains."

Notwithstanding the authority of the names composing the commission, it must be admitted that they did not much contribute to the improvement of topographical drawing. Demi-perspective had already almost given way, in military drawings, to the representation of hills by vertical strokes; and by retaining the side light—notwithstanding a recommendation to the contrary by one of their number, the citizen Epailly, who appears to have had sound views on the subject—they retarded, probably, the adoption of the far simpler system which the French nation now employs. It was a difficult matter for the artist to apportion to the strokes the degree of thickness required for the varying slopes of ground, and for the different altitudes; but to add to these difficulties, the additional ones of estimating the amount of *light* that would fall upon each point, and to combine this with the intensity of stroke demanded by the first two requirements of the problem, was to lay upon him a task in descriptive geometry beyond the power of any ordinary man. Bewildered with so many difficulties, the sketcher would be sure to content himself with a general resemblance to the features of the ground, and bestow the great part of his attention on picturesque effect. The shadow, too, on the side of the hill, if forcible, tends to the same result as that for which they rejected the cast shadows. It obscures the detail.

It is somewhat remarkable that the commissioners did not perceive that the arguments made use of for drawing the lines in the vertical style would equally well apply to drawing them in the horizontal style, for many of them must have been acquainted with the sound geological views on the formation of the present external crust of the earth, which were at this time beginning to be propagated by their own countrymen, De Luc, Cuvier, and Brogniart. Their reasoning would have been quite as convincing, if they had reported thus :—

The use of continuous lines of level, or contours, offers this advantage over the vertical stroke ; it indicates the successive markings which must have been made by the retreating waters as the continents were elevated to their present altitude, and thus represents a natural effect of which the eye is witness every moment, and which recalls the general cause, if not of the formation, at least of the figure and characteristics of hill slopes.

Their arguments, also, against the contour system of sketching, appear to me to be equally wanting in weight. " Contours," they say, " are difficult to determine without accurate or approximately accurate levelling. To enable one to decide upon their position with any certainty, it would be necessary to be able to hover over the earth. In walking upon hills, the eye often runs over as many different contours as there are points in the circumference of mountains. How difficult, then, is it to estimate its position with respect to the imaginary plane of comparison, to which are referred the other horizontal planes by which the ground is supposed to be cut ? Besides, one knows how easily the eye is deceived in its evaluation of objects situated on a horizontal plane, and how great are the errors which result from lowering or raising the visual line with respect to this plane."

In order to answer these objections, it appears to me to be only necessary to consider in what the great difficulty of picturing to the mind the form of ground, so as to be able to represent it, consists. Is it not in judging the altitudes of the different points of the country above some datum, and comparing their relative positions as they would be seen on the horizontal plane of projection ? Substituting the word "altitudes" for contours and for expressions signifying the same idea, might not the above sentences be fairly employed to describe the chief difficulty of all topographical hill sketching, whatever the system of shading employed ? Having judged the relative altitudes and horizontal positions of the different points necessary to represent the figure of the hill, can it have increased the difficulty of making the judgment because the sketcher had intended subsequently to connect those which are on the same level, by continuous lines, so as to enable him, as well as others, to follow out readily the horizontal sections made by them ? Will not such level lines, indeed, by affording him many planes of reference, enable him, as the work proceeds, more readily to make those comparisons, which the most gifted draftsman will require, in order to complete his sketch to his satisfaction, and to give him confidence in the accuracy of his work ?

Before concluding what I have to say concerning the report of the abovementioned Commission, I must call attention to two propositions made to them which were worthy of more attention than they received. Citizen Epailly, who was in charge of the survey of Swabia, recommended that the system of bringing in the light at the left-hand top corner of the plan should be discontinued, and the hachures representing the shading be increased in thickness in proportion as the slopes were steeper, and, consequently, more points projected on the corresponding bases. He assumed, in fact, that these projected points, instead of overlapping, grouped themselves laterally around the true line of projection as an axis. Here we have a system hinted at, which, with some necessary modification, arising from the difficulty of expressing by it the gentler slopes, has beaten all its competitors.

Epailly, however, was not the only one who was now turning his attention in this direction for a solution of the problem. Several German officers about the same time occupied themselves with the subject. Major Müller, retaining generally the bent or wavy line, proposed that the strokes should be strong in proportion to the slopes they were intended to represent, without reference to any supposed distance from the eye, his slopes being divided into five classes, so as to have distinct gradations. These were gentle, common, strong, steep, and perpendicular, the last being expressed by broken straight lines.

Major Von Bieberstein adopted a scale not broken into classes, and in which the strokes were drawn thicker and darker from 0° to 45°, in proportion to the increase of the angle of inclination of the ground. This scale, it will be perceived, had the advantage of representing the manœuvring slopes better than Epailly's proposition, in which the increase of the thickness of the strokes, being inversely proportioned to the cosines of the angle of inclination, would be very slow for gentle undulations.

The system, however, which attracted most attention, was that of Major Lehman, of the Saxon service, and with some modifications this was adopted in the Russian, Prussian, Austrian, and other armies. It therefore demands a more extended notice than those just mentioned. In this plan the light
Plates XI and XII. is supposed to be admitted in parallel vertical rays from above, and the illumination received by each slope is diminished, on a somewhat peculiar theory, in proportion to its divergence from the plane of the horizon.

"In this vertical illumination," (to use the words of Lehman's translator, Lieutenant Siborn), "the horizontal plane receives the fullest light, because the reflected ray coincides with the vertical one;" . . . . and "the angle of reflection which equals the angle of incidence, increases in the same proportion as that in which the angle of inclination itself increases; until, at the extreme angle of inclination of 45°, when the angle of reflection is also equal to 45°, the reflected ray is perfectly horizontal; whence this declivity is the least illumined. From this it is evident that the power of the illumination varies inversely as the angle of inclination; for as the latter increases, the former decreases, and hence the angle of inclination, and its supplement to 45°, may be considered as the proportional terms of the light and shade upon any declivity."

Since, also, Lehman thinks "according to the laws of gravity no declivity of a hill can be inclined to the horizon in a greater angle than 45°, therefore this slope may be placed at the extreme end of the scale and be represented by absolute black."

The intermediate arc is divided into 9 equal parts, an equal increase in the shaded part of the scale being made for each 5° from 0° up to 45°. This scale was to be copied by the sketcher until his hand and eye became sufficiently practised to make the strokes of the proper thickness.

I will not now quarrel with Lehman's theory; I shall have some general remarks to make hereafter on this and similar attempts to invent a plausible philosophical reason founded on nature's laws for a convenient conventionality; but it is to be observed that this scale is not better adapted than Von Bieberstein's for expressing manœuvring slopes, whilst for higher inclinations the plan is made so dark as to obscure the details. The heights of any required points can only be arrived at by a laborious computation or construction; and the method is not only long and tedious, but so difficult that without great skill and steadiness of hand no draftsman could produce a satisfactory result; nor if he produced it, could one feel any confidence in the generality of men having the nicety of judgment necessary to interpret his strokes with sufficient accuracy to save them from serious errors.

These, however, although the greatest thickness of line does not exceed $\frac{1}{40}$-in., were not the opinions of Lieutenant Siborn. This officer thought that the strokes might be so graduated as to be read within 1° of the truth without difficulty. On Lehman's work as a basis, therefore, he published a treatise on Topographical Plan Drawing, in which he also incorporated the views of the German Schienert, who had many years previously recommended that contour lines should be used where changes of slope occur, to assist in drawing Lehman's strokes, but be afterwards removed from the plan.

Here, then, we have another great step in advance. Contours are introduced to aid in the conception and representation of the ground, but only so long as the pupil is inexperienced. He is recommended to go without these crutches as soon as he can, and, according to Lieutenant Siborn, he should clear the way to doing so by first *purposely* cutting his crutches of different lengths. He is to commence with equi-distant contours, and then to try what he can do with his contours at unequal intervals.

Schienert must have narrowly missed seeing the assistance given by contours in reading representations of ground, for he devotes a chapter to proving topographical plans by constructing sections; and Siborn even explains, in his chapter on hasty military sketches, that horizontal contours and their altitudes above a datum are sufficient to enable a draftsman to complete a plan without having seen the ground of which they indicate the inclinations. Schienert's work was translated into English in 1812, and Siborn's appeared in 1822. The latter contained some good specimens of hill drawing, of which an example is
Plate XIV. given in Plate XIV, and the preface by Schienert's translators—G. H. Gordon, 71st Light Infantry, and J. Bedford Smith, of the Carabineers—contains some very just remarks on the subject.

Rapid progress was now made; General Van Gorkum, of the Netherlands army, improved greatly upon Lehman's system. He adopted certain fixed and equi-distant contours, arranged in groups or classes according to the slope, and he proposed to draw vertical strokes between them, so as to be able to use the length of the normals thus obtained to show, by reference to a scale, the slopes of the hills. The vertical intervals in each class of gradient, calculated to the different scales generally made use of in plan drawing, were so arranged that the normal might not be too short when it had to subtend an acute angle, nor too long when the angle is nearly a right one. On a scale of 4 inches to a mile, the vertical distance is fixed at 24 feet for all angles up to 25°, which will allow the draftsman to represent the slopes fitted for manœuvring troops in masses without inconveniently long normals. For higher angles he doubles and triples the vertical interval of his contours, so as to obtain space for his normals, which he also doubles or triples in thickness. Since the thickness of the normals depends on the vertical distance between the contours, by means of their thickness, and counting the number of normals, the relative altitudes of any required points can also be obtained with comparative facility.

Here we have a system which pretty well satisfies the requirements of a military plan, but the effect produced must be very unpleasing, and unsuggestive of hill forms.

About the same time the French also were making long strides in the right direction. M. Benoît proposed to make use of equi-distant contours, and to draw the hachures at a distance apart proportioned to their length; and this distance, for facility of execution, he fixed at a quarter or an eighth part of their length for gentle slopes, whilst for steeper slopes he made the hachures 2 to 4 times thicker, and placed them from 2 to 4 times further apart. General Haxo devised a system of his own, which was impracticable through aiming at working the problem out on one idea. Subsequently he and Captain Noizet, conjointly published a work, in which for gentle slopes they adopted Benoît's plan; but considering it was not sufficiently expressive for steep inclinations they worked out for these a complicated system of arranging the strokes which they thickened gradually up to 45°; at this point there was as little white as possible left between them.

In 1828, another French Commission on Topographical Drawing commenced their labours, having Laplace for president. They reversed the decision of the Commission of 1803 concerning the mode of throwing the light on a plan—considering that to bring it in at 45° was not only difficult of execution, but, moreover, calculated to mislead, as it gave to similar slopes, according to their position with reference to the assumed direction of the rays, a different intensity of shade.

It was at first proposed by the Commissioners to give relief to hills by employing vertical strokes of one equal thickness normal to fixed and equi-distant contours.

For the scale of		$\frac{1}{5000}$	the distance was to be		2·5	metres between the contours.		
"	"	$\frac{1}{10000}$	"	"	5	"	"	"
"	"	$\frac{1}{20000}$	"	"	10	"	"	"

Thus for equal slopes, the length of the hachure always remained the same whatever the scale of the plan.

It was soon found that if for gentle inclinations the strokes were sufficiently near to express the ground, for the steeper slopes the lines would run into each other.

The next idea was to suppose that the light fell vertically on the ground, and that the slopes were illumined in proportion to the cosines of their inclinations with the horizon; but this proved a failure, because, as the Germans had previously found, the increase in the gradation of the shade, for small angles of elevation, was not sufficiently rapid to express gently undulating ground.

Plates XII and XV. Finally they determined to make no hypothesis respecting the direction of the light, but to increase the intensity of the shade produced by the hachures in proportion to the sines of double the angles of the inclinations diminished by $\frac{1}{15}$.

This plan gives an increase of shade which is more rapid for the gentle than for the steep slopes, thus enabling small changes in the former to be better expressed. For the limit of accessible slopes the scale gives 14 parts of black for one of white paper. In carrying out the ideas of the Commissioners, the practice was to trace fine hachures at a distance apart equal to $\frac{1}{4}$ their length for slopes below 15°, and for steeper slopes to increase the thickness of the strokes progressively, keeping a constant distance between them of $\frac{1}{2}$ millimetre.

By the last instructions issued by the Depôt de la Guerre, the proportion of black paper to white in hill sketching is required to be equal to the fraction Plate XIX. which expresses the slope of the ground $\times$ 1·5. The distance between the hachures from axis to axis is to be found by the expression, *i*, or the distance, $= 2\frac{\sqrt{d}}{m} + n^{mm}$ in which d is the distance in millimetres between two consecutive contours, and m and n are empirical values varying with the scale of the plan, according to a simple rule.

We have now arrived at a system which to a great extent meets the conditions laid down as necessary. It enables the artist to express all that is essentially necessary, and if there were not very strong arguments to induce us to prefer that the stroke producing the relief should be parallel to the contour lines, it would merit our adoption.

It is unnecesary to examine closely the works which have appeared in this country since Lieutenant Siborn's endeavour to engraft the views of Lehman and Schienert on the English mind. With the exception of Colonel Frome's clear and satisfactory views on the subject, as expressed in his work on Surveying, nothing has been published tending to the progress of hill sketching, or likely to lead to the adoption of a general system. Major Mitchell, in 1827, published, at the request of his military friends, a treatise on Surveying which is eminently unsatisfactory though based—as he tells the reader—on 16 years' experience in the art. Not satisfied with the tame idea of directing his stroke in conformity with the direction which a drop of descending water would take, this author considers "the rule would be less theoretical were it compared to the direction in which a cannon ball would find its way over a hill side, and that the effect of the velocity acquired in its descent would better typify the true style of hill shading." (!)

The following year a topographical memoir by Sir J. Carmichael Smith appeared. He highly extols Van Gorkum's system, but thinks it better suited to the slow and patient temperament of the German, than to that of the energetic Englishman. He therefore proposes sketching in the old style, and using Van Plate XVI. Gorkum's scale, slightly modified, along some of the most characteristic lines of slope, their inclinations having been determined instrumentally, and noted in a Field Book.

With all due deference for so great an authority, I think it would disfigure the drawing less, and save trouble, to write along these lines the angles and altitudes in numbers, and so save the necessity both of the Field Book and of reference to a scale.

Both he and the last named author recommend the side shadow system, and put forward some weak arguments against contours.

Many of the sketches of the Ordnance Surveyors are of great beauty, and a general system is pursued amongst them so far that all the lines used in producing relief are drawn in the same direction; but there are wide differences in the treatment of the same slopes by different hands, according to the genius of the draftsman. One man uses several thin lines to express what another would render with a few thick ones. The similarity of style is a family likeness and no more.

Until very recently the Royal Military College preferred, and generally taught, one system, whilst the Royal Military Academy taught another; and as if to show clearly the necessity of the obligatory adoption throughout the British army of one method, no sooner did the Sandhurst authorities give up their own peculiar style for the exclusive use of that which had been taught at Woolwich, than for a short season Woolwich chopped round, and introduced the style which had been chiefly taught at Sandhurst.

The history I have given of the successive improvements in hill drawing will, I fear, have appeared tedious to many, though to myself the enquiry has proved one of great interest. It is, I think, very instructive to watch how men, from the difficulty inherent in the problem of representing longitudinal and vertical extension on one plane, were always driven from their first notion of a natural representation on one simple idea to some conventional mode of expressing relief; and how, then, unwilling to confess to themselves the true nature of the expedients they were employing, they sought for some natural law to which to refer them. How, again, when the law was found which seemed without great violence to fit the case, they held by it, as if the law had led to the rule, instead of the rule to the law, and thereby retarded their progress. Thus, no sooner, was the system of shading hills by vertical radiating lines adopted, than a theory was hit upon to suit the case; these lines it was said represented the action of rain water trickling over the hill sides, and washing them to their present characteristic forms. Straight lines, producing a stiff and unpleasing effect, a graceful curve was given to them, and then it was suggested that strokes of the long ʃ shape better resembled the natural fall of mountains. It was difficult to make very long strokes look well, so the hills were supposed to run out into forms which allowed them to be made short—a degree of impudence surpassing that of Mahomet, who at once gave in when it came to a serious question between him and the mountain. Subsequently, we find the French Commission of 1803 rejecting the assistance of contours, and thus for years retarding their further progress in hill shading, simply for the sake of the fantastic idea that the vertical hachures represent a natural effect of the workings of meteorological and geological agencies. Then, attempts were made to give relief on strict principles of geometrical construction, but the slow increase in the gradations of shade produced on this plan were unfitted to represent slopes of small inclination, and so Major Lehman determined to vary his shade with the angle of inclination of the slope instead of with its cosine, as required by the principles of projection. Unwilling, apparently, to confess that this was simply a conventional arrangement, designed to meet the difficulties of the problem, he accounts for it by a theory based, indeed, on optical laws, but quite inapplicable to the case with which he was dealing.

Some years later, we see the French Commissioners of 1828 reluctantly giving up all hypothesis derived from nature's laws—giving up the curved form for the hachures, excepting when bent to make them perpendicular to contours not parallel on plan, thus sacrificing the pretty idea that a stroke like the curve of beauty is most suitable for the representation of mountains—giving up even the mathematical beauty of the notion of imparting relief on principles of pure geometrical construction, which to the philosophical minds of French savans must have been the sorest trial of all—and yielding to the stern necessities of their task, we see them fall back on a method which is purely conventional. Still, there was left in the empirical formula by which they determined the degree of shade for each slope, just a soupçon of the conflict the minds of the Commissioners had gone through, for they introduced into it the *sine* of the angle of its elevation, and it was only in the latest instructions issued by the "Dépôt de la Guerre," that the French swept away this last shred of pretension to a system of giving relief, based on any thing better than the conventionalism which seemed best to meet the difficulties of the problem.

A history, then, of the progress made in military topographical drawing, since the necessity to represent relief was first felt, to the present day, both in France and Germany, is a history simply of successive refinements in the expedients which the draftsman's increasing knowledge necessitated. He commenced with conventionalisms of the grossest kind, and a strong leaning towards philosophical hypothesis, and natural representation; and as his conventionalisms have improved, he has gradually given up all such pretensions. It is well to be convinced of this, in order that we may approach the subject of a system suitable for the British army without restraint, and without the fear of being reproached with violating "immutable laws," and of "despising nature's pictorial language, which is universally understood."

Nobody can say that hereafter some topographic giant—a Dawson, a Brewster, and a man who could invent contours, combined in one—may not rise and astonish us with a machine which will take and exhibit both vertical and horizontal extension in one plan, so as to allow of measurements being made with equal accuracy in either direction, and, moreover, at the same time, give the true pictorial effect of nature; but we should be unwise to wait for this, and in the meantime we are driven to two distinct methods, though exhibited on one surface, of attaining our end. That is to say, we must obtain our *closer* approximations to the relative altitudes to be depicted, by means of numerous guiding level lines, either themselves all numbered, or admitting of their vertical position being readily ascertained by a reference to a few altitudes marked on the plan; and we must obtain, by shading, the pictorial effect which is to convey to the eye, quickly and vividly, such idea of relief as is necessary to enable us to grasp at a glance the general conformation of the ground, and also, the general character of its slopes. All, who have ever used a contour as a tool, will at once come to a judgment as to the best method hitherto contrived for the first object, and, so long as the contour can be determined *instrumentally*, though only with a reflecting level, will at once give their verdict in favour of the contour; but it has been argued that in reconnoissance and all hasty sketches where instrumental assistance cannot be employed, the draftsman, not finding his contours assume the positions he expected from his detached observations, might be induced to resort to too great license of (to use a mild term) "adaptation." It would be, I think, as reasonable to fear that a surveyor would imperil his honesty by measuring a base of verification. Surely both the surveyor and hill sketcher, since at the best their results only approximate to the truth, would be more likely to fall into error if they neglected to avail themselves of the means at their disposal for comparison and correction. One might as reasonably fear to allow the schoolboy to prove his sums. We have made a long step towards the detection of error when we are brought to suspect its existence.

A second argument against the employment of any continuous contour lines in rough sketches is, that they might lead to the supposition on the part of the person examining the plan, that the sketcher felt more certainty in their truthfulness than his means of attaining accuracy justified; and, indeed, that he himself might be misled by them. I do not think, however, that there is any more force in this argument than in the last. In order to make a sketch the first process must be to picture to the mind what is to be drawn, and in hasty sketching, at least, this must be done with the subject, *as a whole*, before the drawing can have its different features justly subordinated. Practice in the use of contours enables him to form this picture more readily; and conceiving and expressing his ideas by such means, gives them fixedness for his own future comparisons, and conveys to others exactly what he thought. Though there is a strong probability that the contours will put him right if he has fallen into error, it is difficult to conceive how such an aid to the expression of his detached observations can render his notions less trustworthy. If his ideas concerning the relative altitudes of the various portions of his work and their respective horizontal positions will not bear the tests which contour lines afford, there can be no advantage in leaving such errors undetected.

To prevent a wrong impression on the part of the person using the plan, as to the means employed in tracing these lines, a simple note on its margin, stating what they were, is all that is required.

I think, then, there can be no doubt that in all cases the draftsman should be trained to use the contour system as the basis of his shading; and for uniformity of system, it should be prescribed that the contours should be employed at equal intervals, the interval depending on the scale of the plan, and increasing or diminishing proportionally with it. In order also to secure that both the sketcher and he who uses the sketch shall have the full advantage derivable from the contours, these should be shown at intervals on the plan with a line, so far dotted as to indicate its character, but not sufficiently marked to catch the eye unpleasantly. The table hereafter given will show the distances at which I propose the contours shall be marked in dots according to the scale employed and the inclination of the ground; they are so regulated as to allow all slopes to be indicated up to 45°. Should it be required for any special case to indicate such lines on steeper slopes, this must be done by still further increasing the vertical distance between the contours.

Having determined how that portion of the task which is to give accuracy to our interpretations of a drawing may be accomplished,—or that part of it which depends on strict geometrical construction,—we have to consider the pictorial difficulty, or how to give forcible relief to the hill-forms traced out in the first process.

For many years past, the advocates of two systems,—the vertical system and horizontal system,—have waged war; the latter has had its friends among the officers of Engineers, and the Staff of the army have generally espoused the cause of the vertical hachure; and the question of superiority has been debated on four distinct points—resemblance to nature's agencies in producing mountain forms—capabilities for the expression of undulations—pleasing effect—and facility and rapidity of execution.

With reference to the first point, an opinion has already been expressed in the foregoing pages. The champion of one system is not likely to convince his antagonist by geological arguments.

As to the second point, it must be admitted that there are cases in which the horizontal style leaves a momentary doubt as to which parts of the drawing represent valleys and which spurs, whilst with the vertical system, for the most part, no such doubt is produced on the observer's mind for one instant; but, on the other hand, in those very cases in which the vertical system shows a partial superiority,—that is to say, when the ground consists of several rounded spurs and rounded valleys, without any visible watercourses to lead the eye—in those very cases the vertical system fails in another respect, for it causes all valleys to look as if they ran to an angular bottom. The objection to the horizontal system can, I think, be easily removed; the eye merely requires guiding on the first instant; where there are streams, *these* do it, and where there are none, the eye may be led to a correct interpretation by drawing a small arrow in blue in each valley, pointing to the direction in which the water would run if present; or, by so far returning to the old system of introducing light at an angle as to indicate at a glance which are the hills and which the valleys, but not using so dark a scale of shade as in any way to obscure the detail, *nor depending on it at all to convey the relative slopes of the hills represented.* The defect in the representation of rounded valley bottoms by the vertical hachure is not so readily met.

The third point, that of pleasing effect, hardly admits of discussion.

"In matters of taste there is no law."

And on the fourth point, that of facility of execution, I can scarcely venture to express an opinion, as I have never practised the vertical style, nor witnessed the practice of others.* The following considerations, however, have some weight.

If a slight divergence from the proper direction is made with the horizontal strokes, or if they are not quite spaced as the artist intended, the resulting defect is not disagreeable; but if the vertical hachures are not spaced equally, or if their extremities are wanting in perpendicularity to the contours, the effect is most displeasing.

For the higher inclinations the strokes in the vertical style are so short, that the representation of such slopes is most laborious.

If a drawing is commenced by horizontal contours, and the sections of the ground at certain intervals can best be thought out by their assistance, that seems to be a very strong reason for carrying out the same principle for all intermediate levels, but does not seem a valid one for introducing a new principle.

* Major Petley, of the Royal Military College, a very skilful draftsman in both systems, considers that a careful drawing can be executed in the horizontal style, in far less time than in the vertical.

I therefore assume that the horizontal stroke has the more numerous and weighty arguments in its favour, and the system of using them, which I have to propose, is worked out on the following simple principles :—

To convey the idea of relief, it is, of course, necessary to impress on the mind of the observer that the points of the drawing, at which he is looking, represent points at different levels.

It will seem to him a very natural arrangement that for any assumed unit of vertical distance between two points on a slope, whatever its inclination, the horizontal space between them should receive a certain fixed proportion of shade.

He will also readily admit the idea—the whole plan of the ground being covered with the projections of level lines running round the hills, at the assumed vertical unit apart—that the shade is diffused over the wide bases of the gentler slopes, and concentrated on the narrower bases of the steep inclines, corresponding to such unit.

It will not appear a very forced arrangement if he is told that he is to suppose the shading to be laid on in lines at sensible distances apart, in the direction of the projections of imaginary level lines running round the hill, sometimes in numerous fine lines, and sometimes in what may be considered groups of fine lines drawn touching each other, so as to form one or more thicker ones, according to the slope of the ground.

He will, indeed, almost anticipate the last idea, for whatever the reason, the eye readily enables him to conceive that the thicker lines represent the steeper slopes, and that so vividly, that it would be very difficult to dispel the idea when once formed. This is fortunate for the success of such hill shading as I am advocating, for since a considerable number of lines are required to express the minor undulations of gentle slopes falling between two contours, and it would be impossible to draw the same number, per vertical unit, on the projections of steep slopes, there is nothing left to us but to run the lines together for such slopes, either indiscriminately, or so as to form thicker lines with intervals between them. Now, it cannot be doubted that the most pleasing and easiest way of arranging them will be in lines having a thickness proportioned to the increasing slope, the intervals between them being gradually diminished.

This interchangeability of number and thickness in the lines employed to produce relief being granted, we may, without doing further violence to the observer's powers of imagination, arrange the scale of their change so as best to suit our requirements.

A slight variation is made in the thickness of the lines for the steeper slopes according to the scale of the plan, for the obvious reason that the detail of a plan on a small scale will not bear so forcible a shading as can be applied, without destroying the legibility of the detail, on a large scale.

The scale employed in assisting the draftsman to estimate the number and thickness of strokes per unit for scales of $\frac{1}{2500}$, $\frac{1}{5000}$, and $\frac{1}{10000}$ is shown in the diagram, and little need be said in explanation of its use. The draftsman must of course take care not to give his plan a ridgy appearance, by a servile adhesion to the equi-distance of the lines on the scale, when the form of the ground requires that the space between the strokes and their force should be varied ; and he must also, between two diverging contours, be careful to change the number of his strokes, without producing a harsh effect. The dotted lines should be penned in as the shading strokes are executed, or they will stand out

Plate XIX.

Plate XX. too harshly. For the example, Plate XX, drawn on this system, I am indebted to the kindness of Major Petley of the Royal Military College.

Nothing need be said either, beyond the information given in the following tables, of the system on which the number and thickness of these lines have been graduated. The object has been simply to make the weakness inherent in the means of representing relief least felt in the representation of those slopes which are of most importance to the tactical movements of armies.

It may be objected—and I know it will be objected—to the general employment of such a scale for giving relief, that it requires too much care and attention to be of service in ordinary field sketching; but to my mind, it hardly needs proof that if draftsmen are educated to draw with reference to one scale, their early progress will not be retarded; and that when obliged to make rapid sketches, their work will more nearly approximate to one universal language than if they worked, each in his own fashion. A schoolboy is not retarded in his progress in writing, by the copy-slips put before him; and whereas, if he is, as he grows older, free to depart from the forms of letters he was taught, he soon runs into an illegible scrawl which becomes worse and worse with practice; he will, if he adopts the profession of a clerk—whilst he loses little or nothing in celerity—always form his letters, however rapidly he writes, after the perfect type he was first taught.

The scale for shading plans with the pen given in the following tables has been drawn up in accordance with these views, and will not be found materially to differ from that which a good draftsman, in the horizontal style, employs in hill shading.

TABLE showing the number of strokes required for different slopes :—

1	2	3	4
Number of strokes required per vertical unit for the scale employed.*	Approximate slopes for which the number of strokes, shown in column 1, are to be employed.	Approximate angle of inclination of the slope shown in column 2.	REMARKS.
1	$\frac{1}{1}$	45°	The slopes given in column 2 are thus obtained; commencing with the slope $\frac{1}{1}$, the denominators of the fractions representing the other slopes are the approximate numbers derived from the empirical formula :— Denominator $= 1{\cdot}5 + 1({\cdot}5)$ " $= 1{\cdot}5^2 + 2({\cdot}5)$ " $= 1{\cdot}5^3 + 3({\cdot}5)$ " $= 1{\cdot}5^4 + 4({\cdot}5)$ . . . . . " $= 1{\cdot}5^n + n({\cdot}5)$
2	$\frac{1}{2}$	$26\frac{1}{2}$	
3	$\frac{1}{3}$	$18\frac{1}{2}$	
4	$\frac{1}{5}$	$11\frac{1}{4}$	
5	$\frac{1}{7}$	$8\frac{1}{4}$	
6	$\frac{1}{10}$	$5\frac{3}{4}$	
7	$\frac{1}{14}$	4	
8	$\frac{1}{21}$	$2\frac{3}{4}$	
9	$\frac{1}{30}$	2	
10	$\frac{1}{40}$	$1\frac{1}{4}$	

* The vertical unit here referred to is the same as the vertical distances at which the chain dotted contours are to be shown below 5°. (See next table.)

TABLE showing the distances at which dotted contour lines are to be shown on various scales, and for different slopes; and, also, the thickness and number of the lines to be used in expressing the greatest and least slopes:—

1	2					3	4	5		6
Scale of plan.	Vertical distances in feet at which chain-dotted contours are to be shown.					Maximum for 45°.	Minimum for least inclination expressed.	Least inclination expressed.		The greatest number of strokes to be employed on the gentlest slopes expressed, including the dotted contour line.
	For manœuvring slopes.			For slopes which can be ascended singly.	For slopes which may be climbed.					
	Below 5°.	From 5° to 10°.	From 10° to 15°.	From 15° to 30°.	From 30° to 45°.	Thickness of lines to be used for the different slopes in fractions of an inch.		Fractions representing slopes.	Angles of slopes with horizon.	
$\frac{1}{2500}$	5	10	15	25	50	$\frac{1}{50}$	$\frac{1}{500}$	$\frac{1}{40}$	$1\frac{1}{4}$°	10
$\frac{1}{5000}$	10	20	30	50	100	$\frac{1}{60}$	$\frac{1}{600}$	$\frac{1}{40}$	$1\frac{1}{4}$	10
$\frac{1}{10000}$	20	40	60	100	200	$\frac{1}{50}$	$\frac{1}{500}$	$\frac{1}{40}$	$1\frac{1}{4}$	10
$\frac{1}{20000}$	40	80	120	200	400	$\frac{1}{70}$	$\frac{1}{630}$	$\frac{1}{30}$	2	9
$\frac{1}{40000}$	80	160	240	400	800	$\frac{1}{80}$	$\frac{1}{640}$	$\frac{1}{21}$	$2\frac{3}{4}$	8
$\frac{1}{80000}$	160	320	480	800	1600	$\frac{1}{100}$	$\frac{1}{700}$	$\frac{1}{14}$	4	7

The slopes in column 2 have reference to the table given at p. 146.

The greatest thickness for the lines in column 3 has been obtained by micrometric measurement from good specimens of hill sketching. The thickness for intermediate slopes will be obtained by dividing the greatest thickness by the number of strokes corresponding to each slope given in the preceding table. It is not, however, supposed, that in practice, a draftsman can do more than approximate to these thicknesses.

The least thickness in column 4 is obtained by dividing the thicknesses in column 3 by the numbers given in column 6; they agree with the micrometric measurements of the fine lines in good specimens of drawing.

Column 5 has been determined with reference to the slopes which appear to admit of being shown on the scales indicated in column 1, and from existing good drawings.

The numbers in column 6 follow from the slopes in column 5, and are derived from the preceding table.

The scale also as regards the efficient draftsman is intended to be a remembrancer, merely, of the gradations of shade which he, and those who work with him, are to employ; and, though it undoubtedly limits his power to please us, at the expense of truthfulness, it still leaves him plenty of scope for exhibiting his artistic talents. It approximates, indeed, as nearly as possible to those which I have found to be used by our most effective hill sketchers.

It is to be remembered that a defect in shading on the principle recommended only interferes with the proper expression of the pictorial part of the work; it cannot vitiate the general form of the hill which the contours trace out; and these, by the definite language which they speak, check at once very serious inaccuracies.

This, then, is the system which I have to propose; it makes no pretention to originality of conception, or to be supported by any learned argument on mathematical or natural representation. The chief aim has been to adopt the simplest forms of conventionality consistent with that degree of naturalness of representation which is necessary to impart the idea of relief, without strain on the imagination and memory of the observer; consistent also with giving aid to the sketcher in his labours, and enabling him best to delineate those gradations of slope which it is of most importance to a general, in command of an army in the field, to read with some degree of accuracy

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EXPLANATION OF THE PLATES.

Plate I is taken from Layard's "Nineveh and Babylon." It shows the river in plan apparently and the profiles of the hills, not turned over all in one direction, as was practised at a later period in Europe, but in opposite directions, so as to hide no part of the cavalcade in the stream.

Plate II is taken from a map of the country round Pekin, published by the Topographical Department of the War Office, from the Chinese Map of Asia, 1760. It illustrates the extreme conventional mode of representing hills.

Plates III and IV are taken from a work published at Paris in 1636, by the Sieur Tassin. They show the earliest stage of the combination of the profiles of hills with their plan in the same drawing. The point of view for the hills has no command over their reverse slopes.

Plate V is copied from a map of Luxembourg, published at Paris in 1790, and illustrates the next stage of this combination, the hills being represented as they would be seen from a high bird's-eye point of view. In the larger feature one sees the reverse slope of the hill sinking into the bank of the river. Previous to the date of this plan, many topographical draftsmen had adopted the idea of showing hills by vertical strokes in the lines of shortest descent.

Plate VI shows the last improvement upon the old system. Here relief is very cleverly given, without hiding any part of the plan. The point of view is almost vertically over the ground, and one sees the whole of every slope represented. It is from a plan of the neighbourhood of Stockholm, published in 1805.

An examination of the strokes used in these plans, and of the / form of the hachure employed by the draftsmen, from whose work Plates VII, VIII, IX, and X are taken, will, I think, show the true origin of the curved stroke which was supposed most to resemble nature.

Plate VII is from the work of Hogrewe, published at Hanover in 1785. The draftsman intended to abandon the bird's-eye system of representing hills, but the direction of the hachures is in several portions of the sketch very suggestive of it.

Plates VIII and IX are from a French edition of the work of another German engineer, J. H. Hayne, which fell into the hands of its translator in 1798. Figs. 17 and 18, Plate VIII, show the careful manner in which the draftsman was taught the mode of drawing the curved hachures, and in Plate IX are shown the different methods adopted for obviating the stiff appearance given by lines of one length, and for representing steep slopes by crossing the lines.

Plate X exemplifies the difficulties the draftsman had to contend with in representing long slopes by curved hachures. The explanation in the plan that they mean *terrein inegal* appears to show that the artist was not himself quite satisfied with the pictorial truthfulness of his performance. This drawing is part of a plan published at Brussels in 1790.

Plate XI is taken from a translation of the work of Schienert by two officers of the Staff College, G. H. Gordon, 71st Light Infantry, and J. Bedford Smith, of the Carabineers, published in 1812. Schienert's drawings are very harsh and unpleasing; but the hachures are normal to contours traced through some of the points at which the changes of inclination occur, and they indicate in an unmistakeable manner within certain limit, by reference to his scale of shade in Plate XII, the slopes intended to be represented. The preface by the translators of the work contains very just views on the subject of hill sketching.

Plate XII gives Schienert's scale of shade, Major Lehman's scale of shade, and also Sir J. C. Smith's modification of Van Gorkum's normals, which he employs to indicate the slopes in a drawing executed in the old manner. A reference to Plate XVI will at once show the use he proposed to make of them.

In the lower part of the plate is given the scale of shade which resulted from the labours of the French Commission of 1828, and which is still used by the Ecole d'Etat-major and the Ecole Spéciale Militaire. The part M N carries the trapeziums L, L′, L″, &c., in each of which the lines *a*, *b*, *a*′, *b*′, &c., indicate the distance of contours corresponding to the slopes O M Q, O′ O Q′, &c. The intervals comprised between (L L′) (L′ L″), contain the lines *a*, *a*′, &c., which express the distances and the thicknessess of the strokes to be employed for lengths equal to *a b*, *a*′ *b*, &c.

In using the scale, the part comprised between L, L′, &c., is cut away, and lines *a*, *b*, *a*′, *b*′, &c., are looked for, having the same distance between them as that of the contours between which the shading is to be commenced.

Suppose *a* and *b* coincide with two neighbouring contours, the lines *a a*, which are normal to *a* and *b*, are prolonged, so as to fill the space between the contours.

The rectangle R R shows the increasing scale of shade for the slopes of the profile constructed on its lower bounding line.

Plate XIII is introduced to show that there are cases in which the vertical system fails to convey clearly the distinction between hills and valleys, and that it affords a very imperfect means of representing the latter. It is taken from a plan of Mayence, published at Darmstadt in 1815.

Plate XIV is taken from Lieut. Siborne's work on "Military Drawing." It is executed with Lehman's strokes, guided in direction by contours, as recommended by Schienert. It probably affords a fair specimen of the effect which can be produced by Lehman's method and scale of shade.

Plate XVI is from the work of Sir J. C. Smith and shows his application of the normals in Plate XII, to indicate the inclination of the most characteristic slopes.

Plates XV and XVII are drawn according to the scale of shade which resulted from the labours of the French Commission of 1828; Plate XV is from the "*Cours de Topographie*," by E. de Lalobbe, published in 1856; and Plate XVII is from Perrot's "*Modèles de Topographie*," published in 1858.

Plate XVIII is taken from the work of M. Bardin, who published a valuable collection of drawings and models in 1855. It is drawn with Colonel Bonne's modification of the scale given in Plate XII, as that of the Commissioners of 1828. Colonel Bonne's scale of shade was for a long time used by the *Dépôt de la Guerre*. For a scale of $\frac{1}{10000}$ the distance between the hachures is $\frac{1}{12}$th of their length for slopes of 2°, and $\frac{1}{2}$ for that of 30° centigrade. It is considered to give too feeble a shade for gentle slopes, and too strong a shade for steep inclinations.

Plate XIX shows the scale which is proposed in the foregoing paper for use in the horizontal system of shading for plans drawn on scales of $\frac{1}{2500}$, $\frac{1}{5000}$, and $\frac{1}{10000}$, and needs no further explanation than has been given in the text. It shows the intervals at which, according to the scale of the plan and inclination of the slopes, it is intended that the draftsman shall show contours in dots.

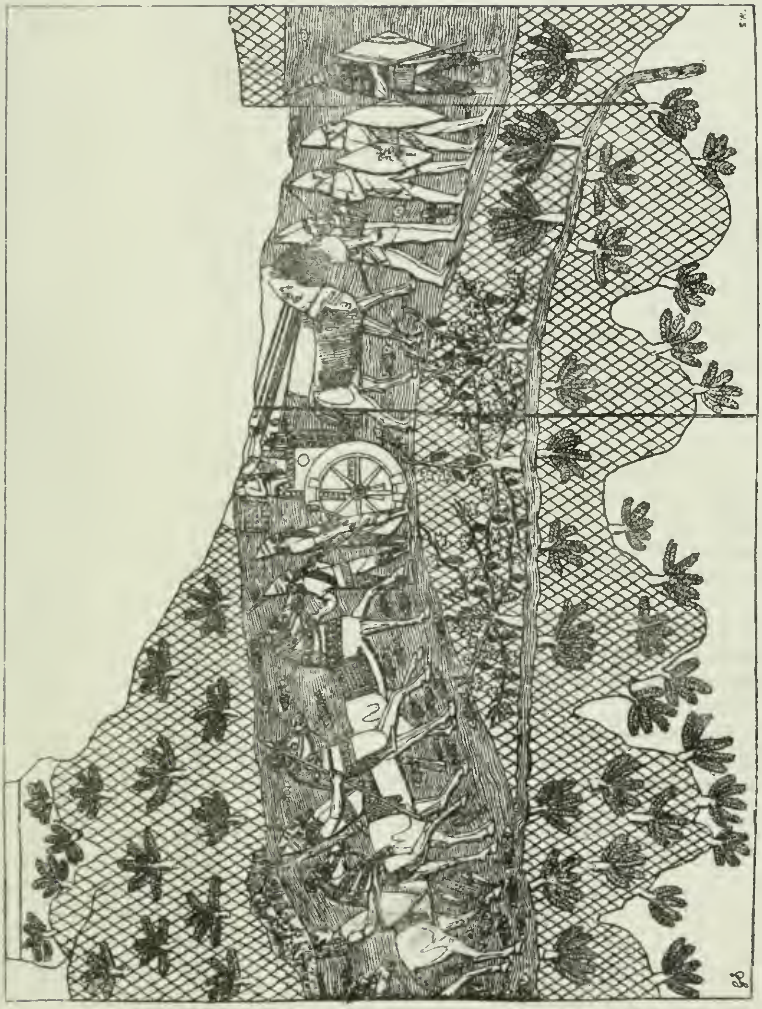
The French scale in the same plate is that which was last engraved by the *Dépôt de la Guerre*. It was found that the scales which resulted from the labours of the French Commission of 1828, though well adapted for gently undulating ground, gave too much shade for such slopes as prevail in mountainous regions, and the scale in this plate was substituted for them.

Plate XX is the representation by Major Petley of a hill near Sandhurst, drawn on a scale of 60 inches to a mile, by means of a scale of shade almost similar to that which is given in the preceding plate. In this instance the dotted lines represent contours instrumentally determined at vertical intervals of 10 feet.

The drawing has lost some of the beauty of Major Petley's handling, through the defects of the Photozincographic process; but all the illustrations have suffered pretty equally in this respect.

HENRY SCOTT,
Capt., R.E., and Major.

Plate I



The King in his Chariot passing through a Stream in a Valley (Kouyunjik)

Plate II

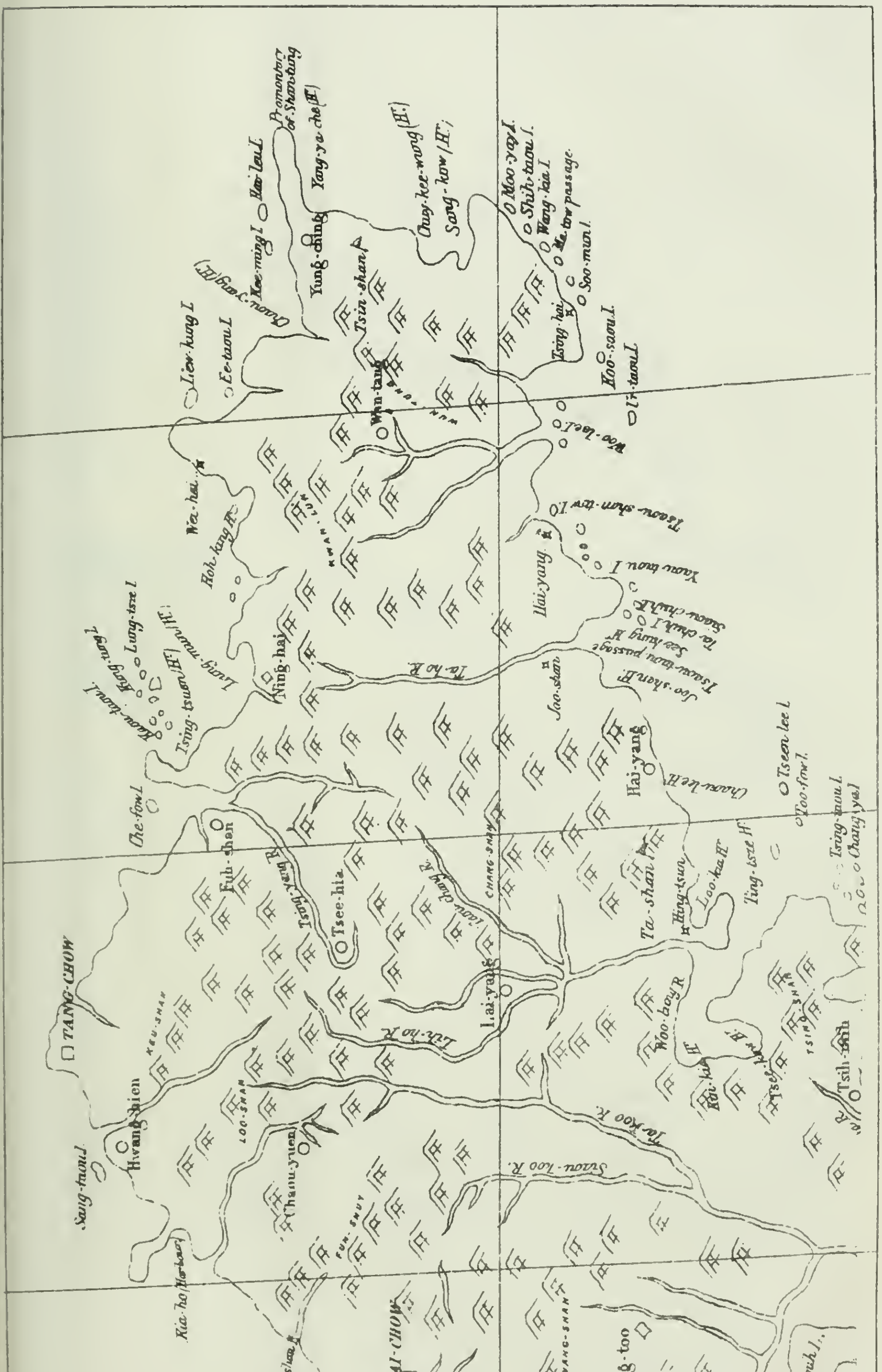

TANG-CHOW
LAI-CHOW
Hwang-hien
Promontory of Shantung
Yung-ching
Tsin-shan
Wan-tang
Ning-hai
Hai-yang
Lai-yang
Tsee-hia
Fuh-shan
Chaou-yuen
Ping-too
Tsih-mih
Ta-ho R.
Ta-koo R.
Siaou-koo R.
Tsing-hai
Che-foo I.
Kia-ho Harbour
Woo-hoy R.

Plate III.

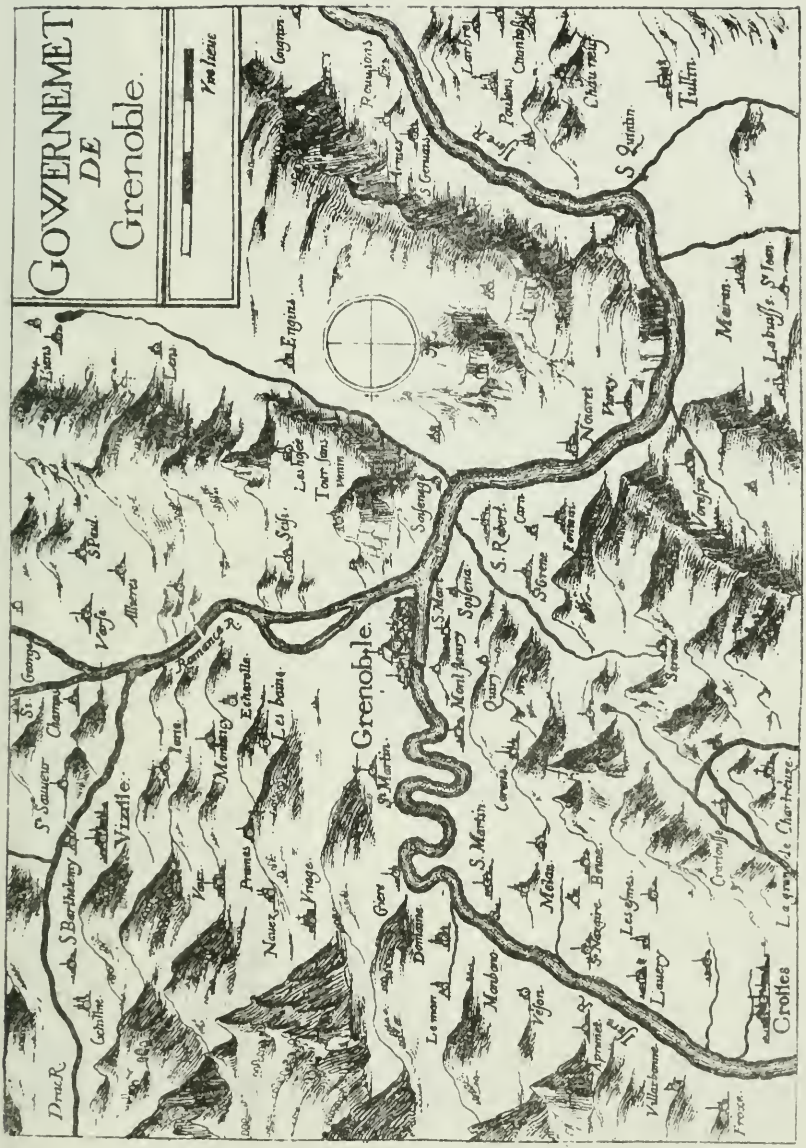

GOWERNEMET
DE
Grenoble.
Grenoble.
Vizille.
Crolles
Engins
Tullin.
S. Quintin.

Plate IV

Plate V

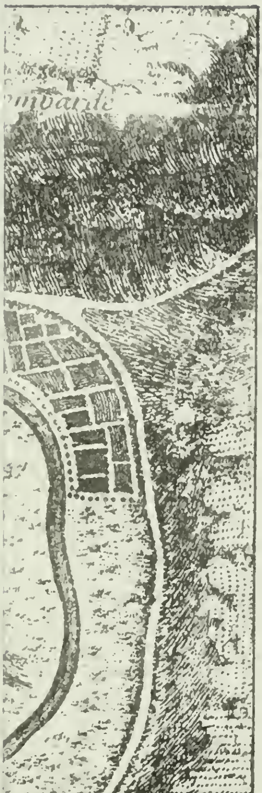


Plate V

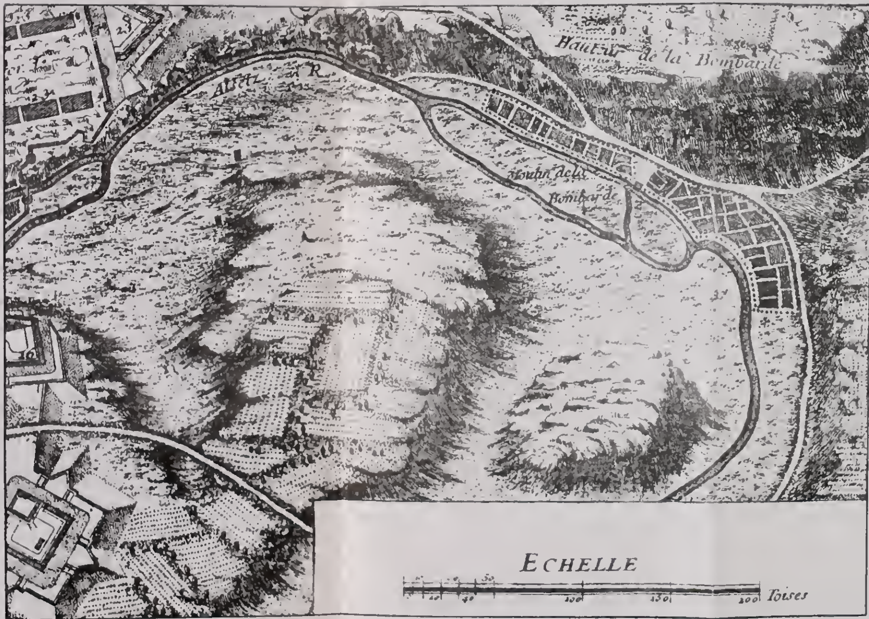

Hauteur de la Bombarde
Allier R.
Moulin de la Bombarde
ECHELLE
Toises

Plate VI

Plate VII

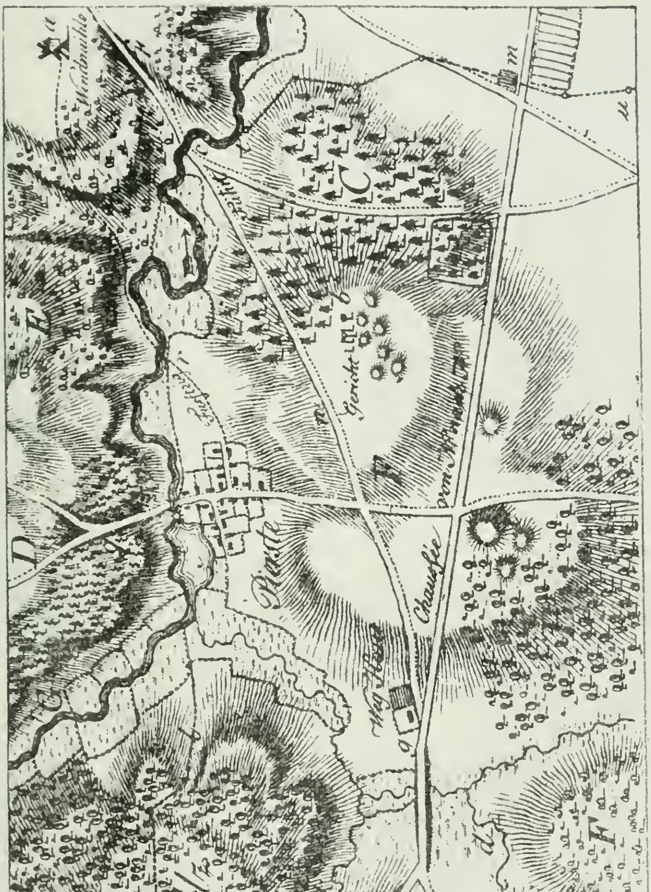


Plate VIII

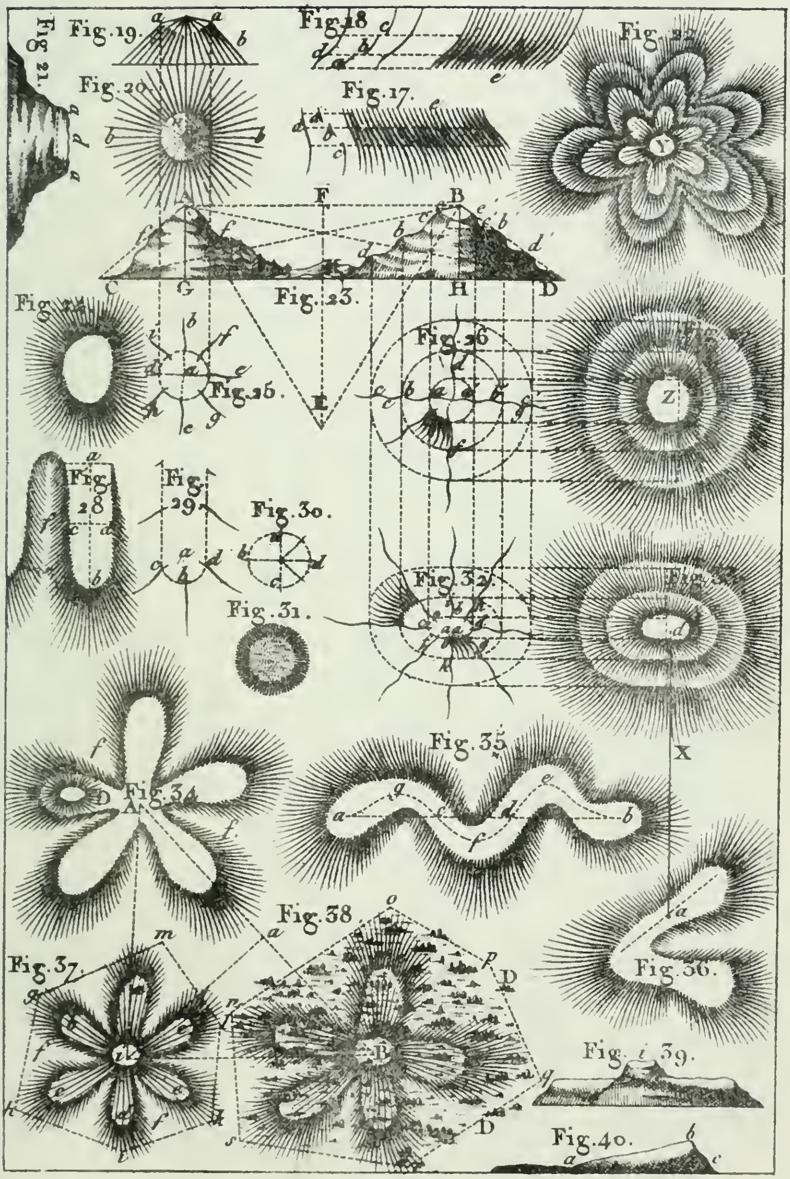


Fig. 17.
Fig. 18
Fig. 19.
Fig. 20.
Fig. 21.
Fig. 23.
Fig. 25.
Fig. 26
Fig. 28
Fig. 29.
Fig. 30.
Fig. 31.
Fig. 32
Fig. 34
Fig. 35
Fig. 36.
Fig. 37.
Fig. 38
Fig. 39.
Fig. 40.

Plate IX

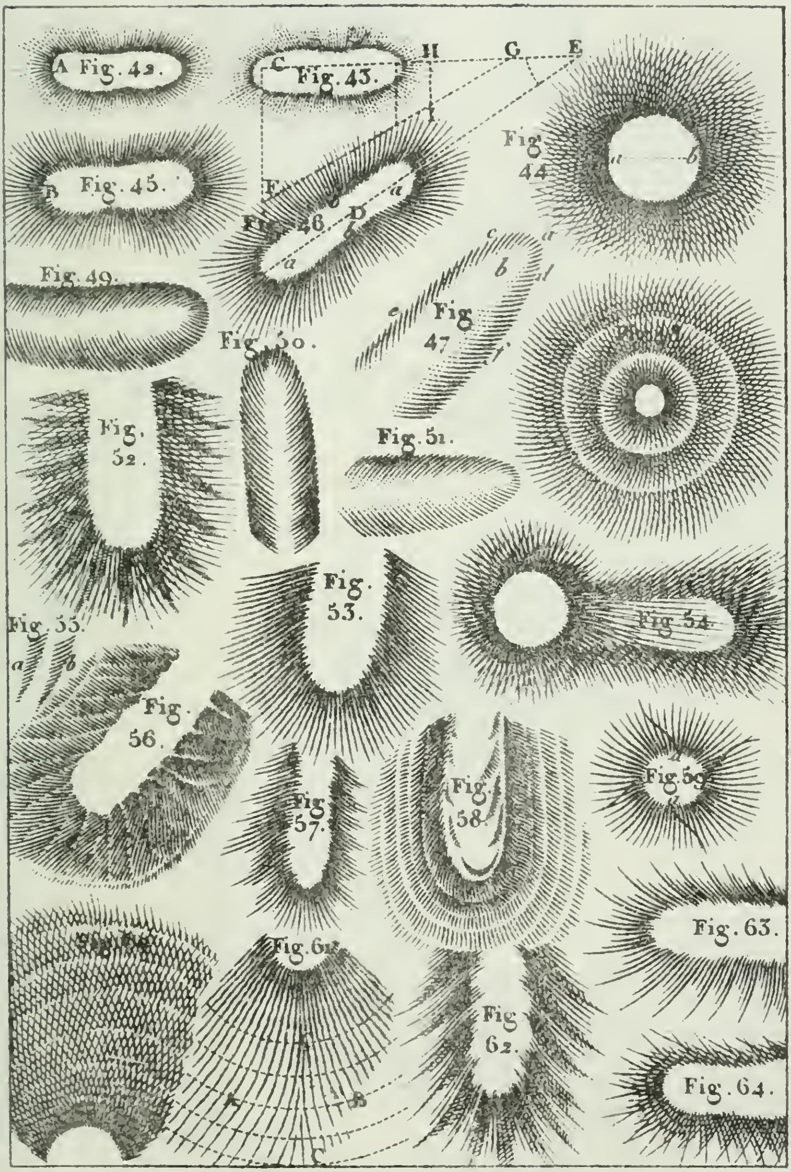


Fig. 42.
Fig. 43.
Fig. 44
Fig. 45.
Fig. 46.
Fig. 47
Fig. 49.
Fig. 50.
Fig. 51.
Fig. 52.
Fig. 53.
Fig. 54
Fig. 55.
Fig. 56.
Fig. 57.
Fig. 58.
Fig. 59
Fig. 61.
Fig. 62.
Fig. 63.
Fig. 64.

Plate X.

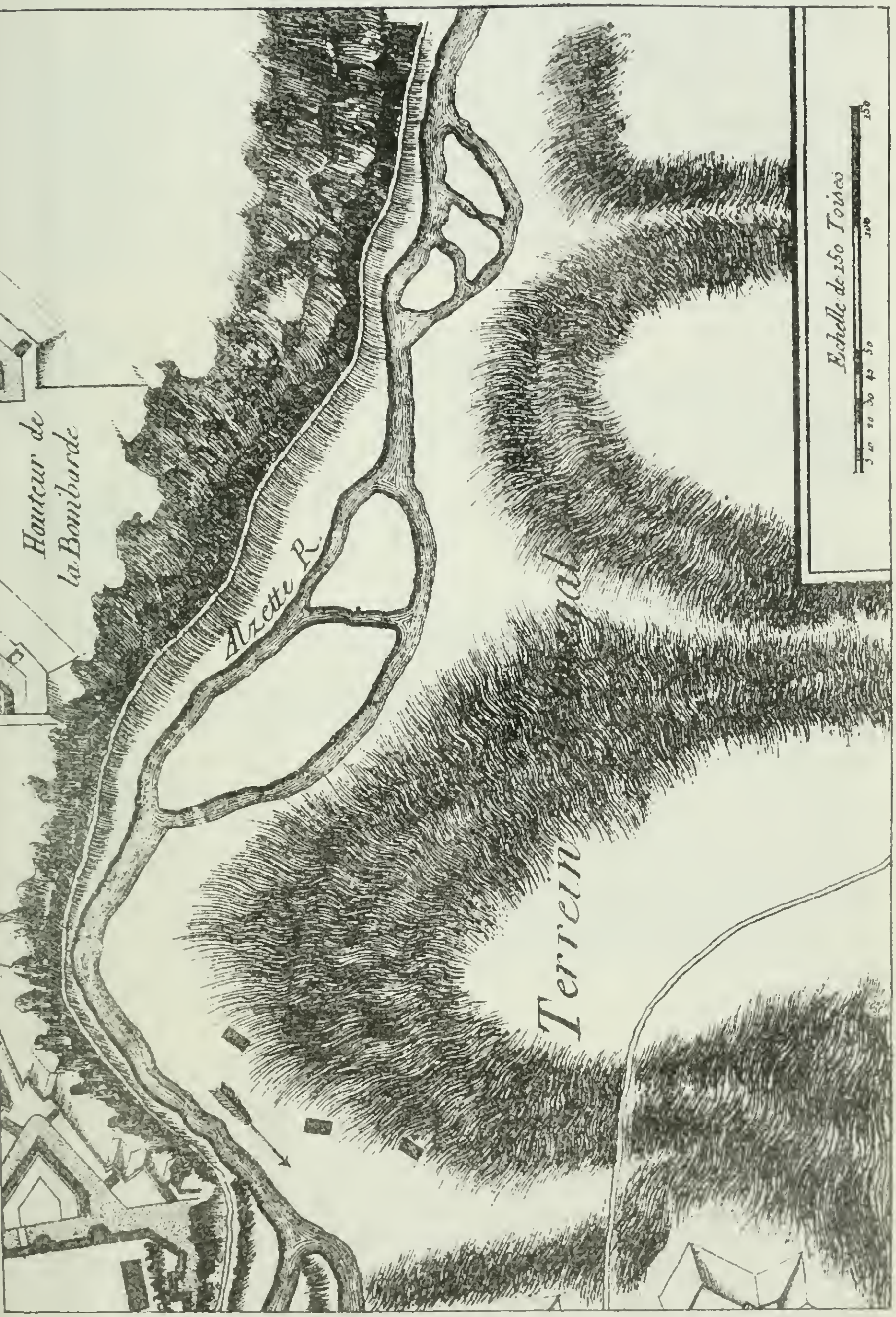

Hauteur de la Bombarde
Alzette R.
Terrein
Echelle de 150 Toises

Plate XI

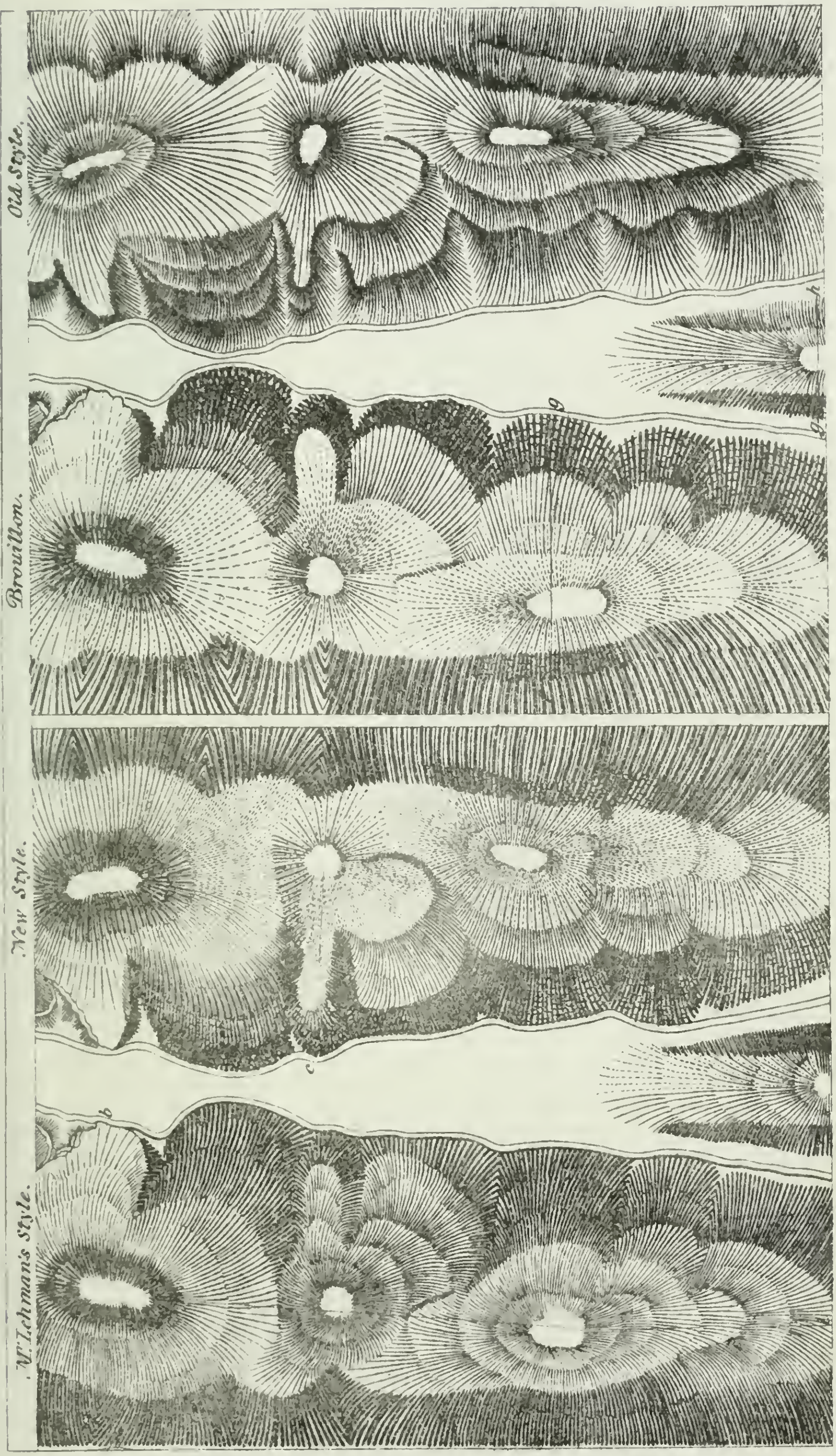
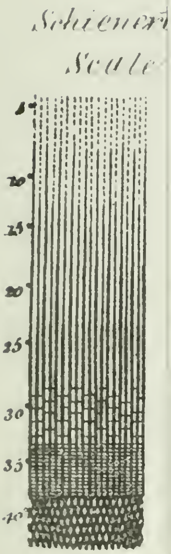
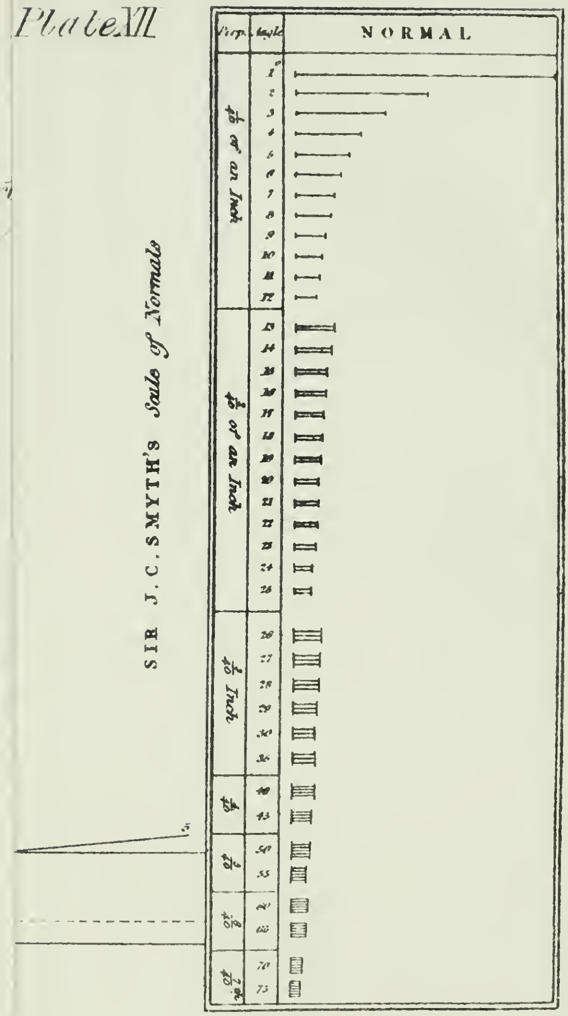


Plate XII





SIR J. C. SMYTH'S Scale of Normals

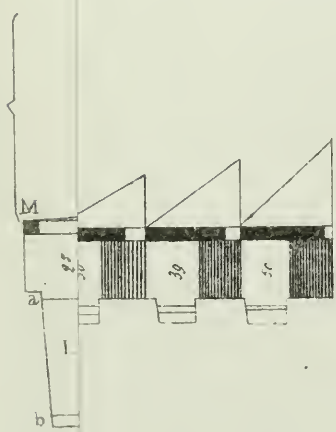


Plate XII

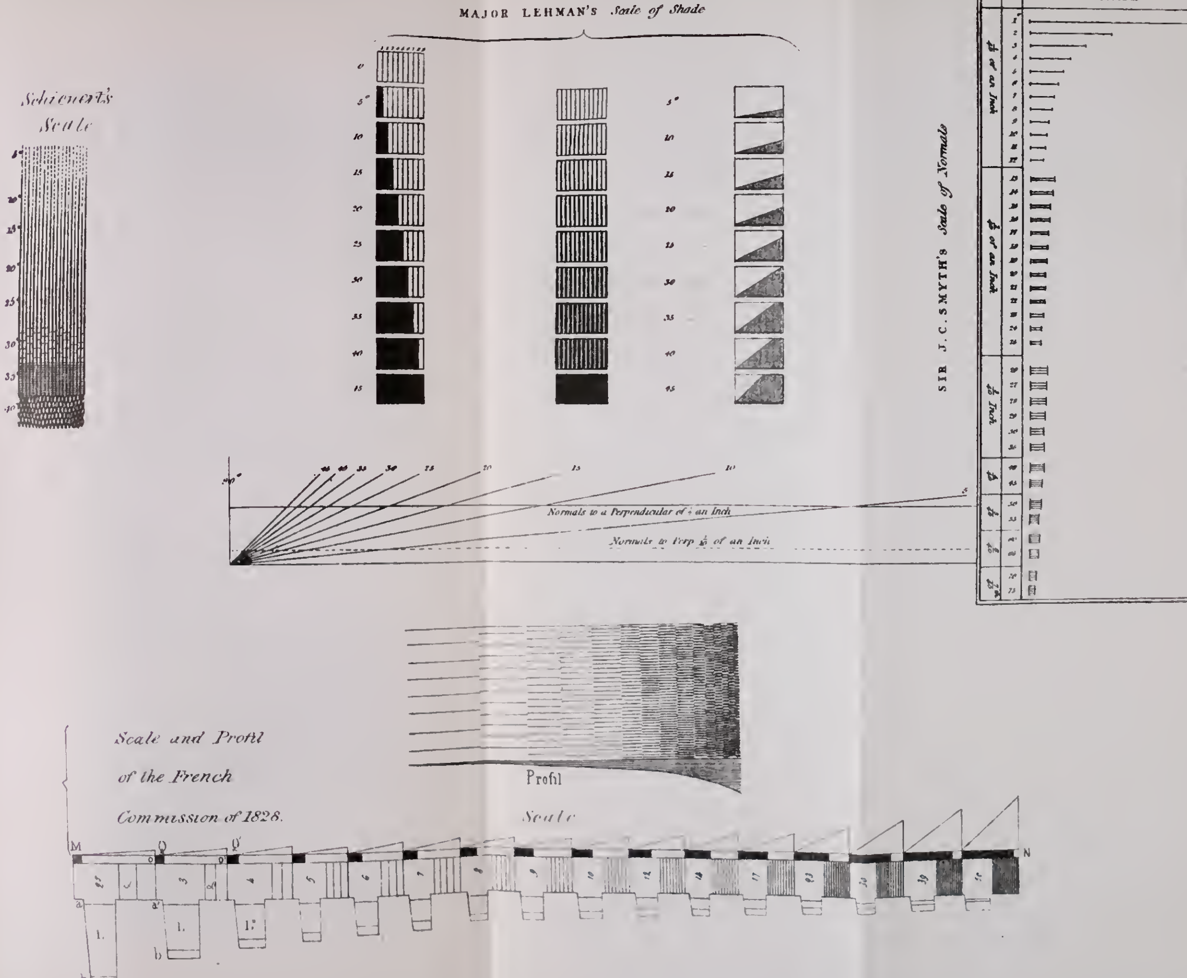

MAJOR LEHMAN'S Scale of Shade
Schienert's Scale
SIR J. C. SMYTH'S Scale of Normals
NORMAL
Normals to a Perpendicular of
Scale and Profil of the French Commission of 1828.
Profil
Scale

Plate XIII

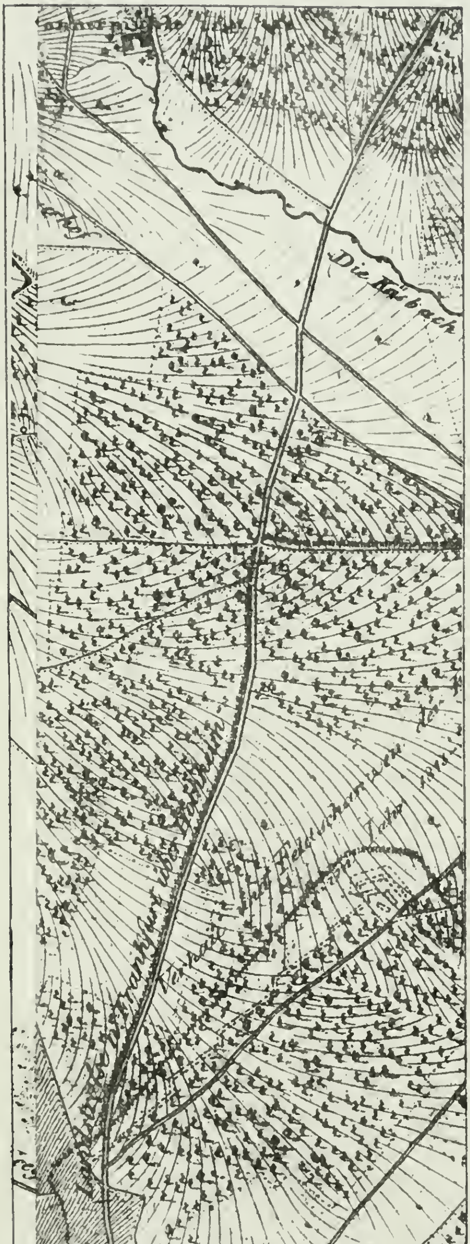


Plate XIII


Ochsenbrunnen
Weg von Nordenstadt
Weg von Diedenbergen
Die Kaibach
Die Drei Quellenbach
Weg von Erbenheim

Plate XIV

Plate XIV

B
A
C
F
D
Q
White House Farm
Farm
The Hill Farm
Quarry
Quarry
North
Ledbury Church

Plate XV

Plate XVI.

Plate XVII

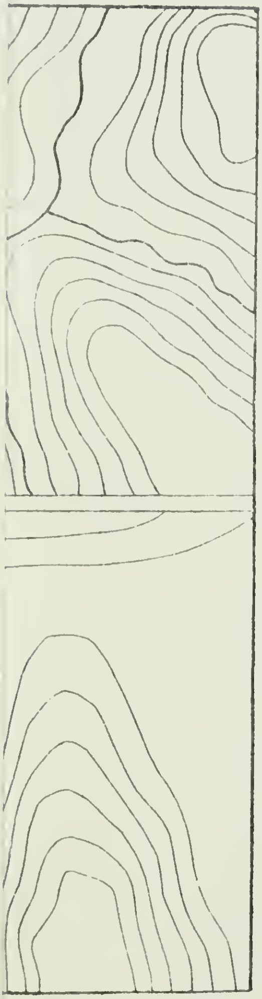


Plate XVII

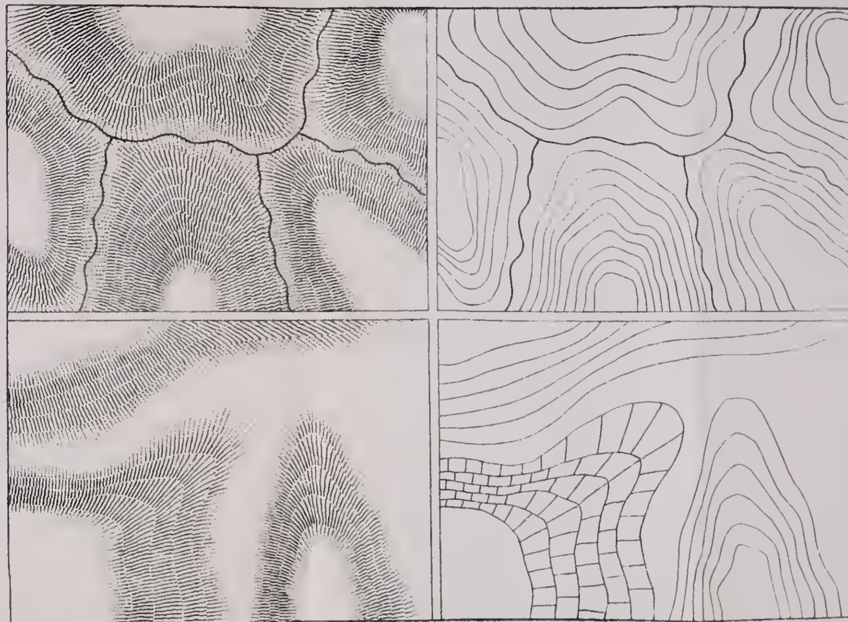
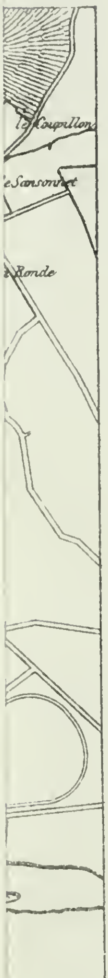


Plate XVIII



FIGURÉ

par lignes de plus grande pente

$\frac{1}{20\,000}$

Fig. 1

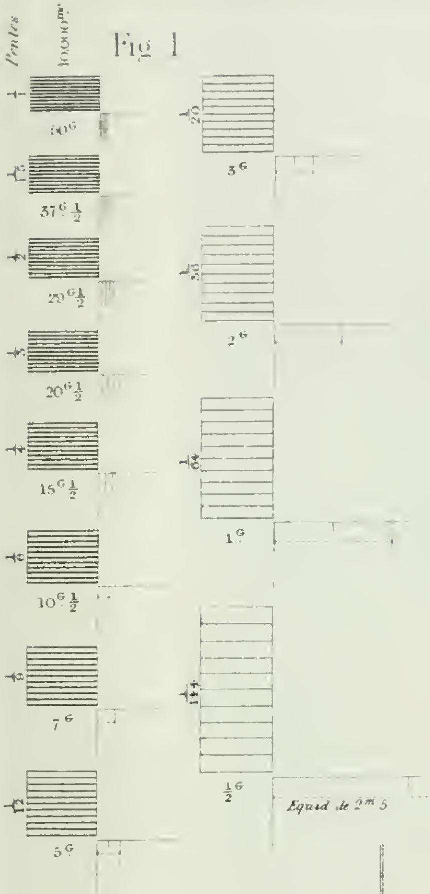
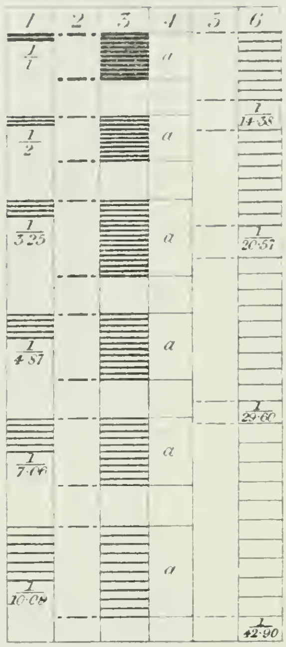


Fig. 2



DIAPASONS DE HACHURES

pour une équidistance graphique* de ¼ de millimètre

Le rapport du noir au blanc est égal à la fraction qui représente la pente, multipliée par 1·5.
L'intervalle i *des hachures d'axe à axe est donné par l'expression* $i = 2\frac{\sqrt{d}}{m} + n^{mm}$ *dans laquelle* d *est la distance en millimètres entre deux courbes horizontales consécutives,* m *et* n *variant avec l'échelle suivant une loi facile à saisir.*

*ou équidistance réduite à l'échelle.

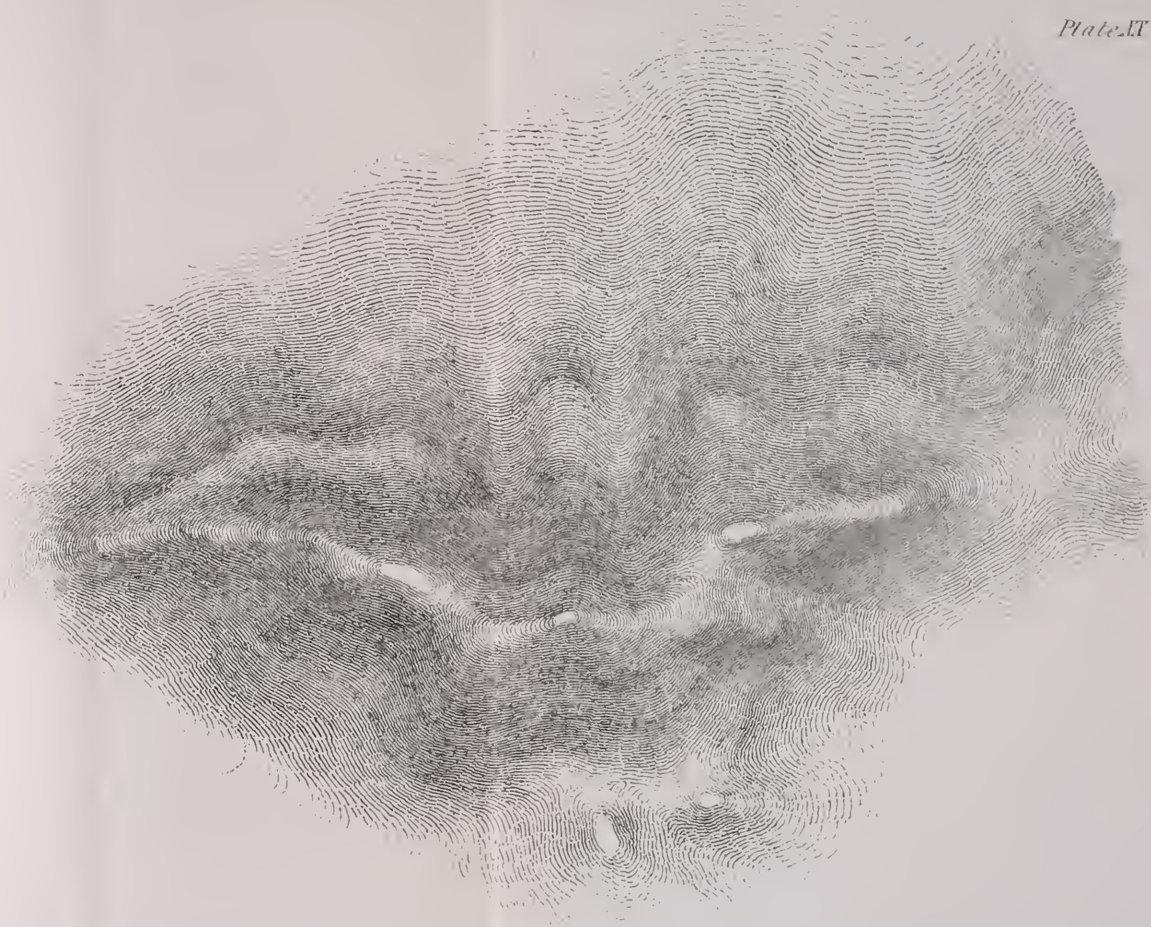
CAPTAIN SCOTT'S

scale of shade for scales $\frac{1}{2500}$, $\frac{1}{5000}$, $\frac{1}{10000}$

In columns 1 & 6 are given the number & thickness of the strokes to be used per vertical unit for the slopes named below them, reckoning from axis to axis of the upper & lower strokes in each case.
In 2 & 5 are given the horizontal distances at which the contours for the said slopes are to be shown in dots.
In 3 & 6 are given the scale of shade that results from the above arrangement for the slopes named.
In 4 the spaces a a are to be cut out in using the scale, so that column 3 may be applied to the sketch sheet.

Plate XV

Plate IV



PAPER XVII.

FORTIFICATION *versus* FORTS,

OR,

Remarks on the Relative Advantages of Continuous and Detached Lines of Works.

By COLONEL CUNLIFFE OWEN, C.B., R.E.

[Read at Chatham on 9th January, 1863, and reprinted with a few verbal alterations.]

"Experience shows that the mode of Fortification is less liable to fluctuation than almost any other element of defence."—*Report of the Royal Commission upon National Defences*, 1861.

An entirely new system of Fortification has of late years been developed among us without any of that professional discussion to which other systems have been subjected, and, as I am one of those who are not yet converts to this new system, I should be glad if the reading of this paper will elicit some facts which will change my opinions, or elicit a more full statement of the reasons why some differ from me. The system to which I allude is that of detached forts as opposed to a continuous ditch and rampart for the defence of a position. Though the detached system has, as I have stated, been newly developed among us, it is not the first time it has been proposed. It was proposed and warmly supported by many able French officers as sufficient for the defence of Paris in the years 1820 to 1840, but after full and free deliberation it was decided that a continuous enceinte to support the detached forts was indispensable, and it was, at an immense national sacrifice, carried out.

We have, like the French Engineers, been called upon to consider extensive schemes of national defence, and have decided differently. It may, therefore, be desirable to reconsider the arguments used on either side by the French, and the supporters of the new system will then have an opportunity of stating what new facts have been discovered to alter the previous decision. Up to this time no such statement has been made, or next to none.

The Royal Commissioners of 1860 upon the defences of our Arsenals, were evidently not converts to these views, for the only material alteration which they recommended in the system of works submitted to them by the War Office, was, that they should be connected by a continuous ditch and rampart. It may be as well to quote *verbatim* the opinions of the Commission on this point. With reference to Portsmouth, they say, par. 79, that "the works between Forts Gomer and Elson and the Hilsea lines, should be completed * * * but that the lines to connect the first-mentioned works, which it was intended to throw up at the time of expected attack, should be of permanent construction." In par. 81, with reference to Portsdown Hill, they recommend "that the works shall be so designed that they may hereafter be connected by lines of ditch and rampart." I believe these works will cross fire with Hilsea lines, and if this be the case the Commission even go beyond me in contemplating a continuous line. At Plymouth, on the North-East, they say—"although, according to the principles usually adopted, and which we ourselves have in other cases recommended, it would be desirable to provide an inner enceinte *to support the outer line of detached works*, circumstances render it necessary in this instance to adopt a different plan. We accordingly recommended that the outer line of works should be connected by lines of ditch and rampart." At Antony, par. 97, "the only suggestion we have to make respecting them" (the works in course of construction) "is that, instead of connecting the works by lines thrown up at a time of expected attack, as was intended, a permanent ditch and rampart should be constructed between them." At Saltash, par. 99, "we consider that these lines should be connected by permanent ditch and rampart." At Staddon, par. 106, the same recommendation. At Pembroke, par. 117, the same.

From these extracts it will be seen that the British Commission of 1860 arrived at the same conclusion as we shall presently see was arrived at by the French Commission of 1840. The French Commission had presented to them designs for continuous and detached works, and adopted both; the British Commission had a detached system only before them, and incorporated the continuous system with it.

Since then, in our Corps Papers of 1860, an officer, who must have known something of the report of the commission, has favoured the corps with a carefully drawn paper upon the works now in course of execution for the defence of our Arsenals and Dockyards, in which he makes very short work of this recommendation of the Commission. He says (par. 11), that "when the extent of the positions now necessary to be occupied is considered, it is evidently impossible to occupy them by continuous lines;" and the reasons given for thus summarily quenching the suggestion, almost the only general professional suggestion of the Commission, are—"because they must be manned throughout their whole extent," and "because they will fall if pierced at any one point."

This assertion is, however, made with considerable reserve, for he still thinks it necessary to consider "whether the detached works shall be connected with lines, or supported by an enceinte, or by other detached works in their rear;" and further on (par. 32), he says, "it cannot be supposed that an enemy would be able to pass between the detached works, either by day or night, accompanied by the guns and supplies of ammunition necessary to bombard the place, or attack the works themselves in the rear," but that "a rush of infantry during the night" is just practicable, and that if such an entrance could lead to admitting the enemy at any other point by sea, a continuous line would be required. He also admits that a continuous line might be required "where the spread of buildings, or the cost of land, renders it more expedient to connect the works by such a line, rather than the more correct principle of forming an enceinte to cover the point to be protected." The continuous ditch and rampart of the Commission is, therefore, not so "evidently impossible," but that it must in many cases be adopted. The author of the paper is clearly not an out-and-out supporter of the detached forts, that is, he does not consider them all-sufficient; he wants an enceinte round the place to make up for the fallibility of the outer line, but not to support or co-operate with it.

The enceinte of old engineers, from the days of Nimrod till now, has been throwing forward outworks, then detached works; and now the detached works challenged by the Armstrong gun, march boldly forward two or three miles to give battle on their own account, and leave their parent enceinte like an old pensioner to do the police of the interior. Its proportions are reduced to "an 18 feet wall hid in a ditch," and it is spoken of so disparagingly, that it will soon vanish altogether from the scene.

The general plan given with the paper shows three forts about a mile apart across an isthmus between the sea and a river. The point to be protected must either be at the end of that peninsula where the river runs into the sea, or near the end, perhaps across some arm of the sea. I should like to know where, in this latter case, the enceinte would be placed, for the arm of the sea would protect the place from "a rush of infantry," but would not protect it from bombardment. I maintain that, except in some very exceptional cases, the whole of the ground within the line may be held by a powerful besieger, the line of forts remaining intact.

The author must excuse me if I attack his paper so closely. He is an old friend and comrade of mine, and I would rather on all accounts agree than differ with him, but he has alone among Englishmen ventured in print to be the apologist of these new works, and I cannot avoid making his paper almost the text of mine. Before giving my own reasons for differing from him, I will collect, as far as I can, the opinions of the French officers upon the fortifications of Paris. I cannot, however, admit, even had they arrived at the conclusion that detached works were the best for Paris, that the reasoning would apply to Portsmouth or Plymouth. Paris is the metropolis, more than the metropolis, of France. With its fall the whole country must fall, and, therefore, in case of a successful invasion, the whole of the remnants of the defeated armies of France would retire, as a matter of course, upon Paris. This force would be supported by a large and warlike population, and a few well chosen detached works would, of course, materially strengthen the ground upon which the last battle had to be fought, even if they did not render the position impregnable. Any powerful and inaccessible battery must be as good, perhaps, as many thousand men on a field of battle, but then there must be an army to fight behind the works, and not a mere garrison such as would be ample for a place regularly fortified. If we could always be sure of having 50,000 men for the defence of each of our dockyards, a few, and not very formidable works, would enable them to fight 100,000 men upon an equality, but 10,000 men would not have a chance though they would form a respectable garrison for a large fortress.

The first man who proposed the fortification of Paris in modern times was Vauban, and he recommended a first continuous line on the site of the ancient works, or "Boulevards," and a second, also continuous, 2,000 or 2,500 yards in advance to prevent bombardment. He proposed to cover the gates by ravelins, and even to carry both enceintes across the Seine on arches! "Afin d'éviter le défaut par lequel Cyrus prit Babylone." Continuous enough in all conscience! The next was Napoleon, and he was also for a continuous line. It was in the midst of his triumphs, when the fall of Vienna followed upon the capitulation of Ulm and prepared the way for Austerlitz, that he looked forward to the time when the strife might be transferred from the valley of the Danube to that of the Seine, and he then gave instructions for studying the question of the fortification of Paris. At St. Helena he gave a general idea that it should consist of from 80 to 100 fronts of fortification, and this is borne out by General Haxo to whom he gave more special personal instructions while in power. Scarcely had the Army of Occupation of the Allies left the French territory, in 1818, before a commission was appointed, of which Marshal St. Cyr was president, to consider the means of fortifying Paris, and place it beyond the reach of the catastrophes to which the reigning dynasty owed the throne. The question submitted to them was, whether it was advisable or possible to fortify Paris? they answered in the affirmative, but added, "Elle" (the commission) "n'admet pas que cette ville doive être défendue comme une place ordinaire par une garnison renfermée dans une enceinte continue. Elle est d'avis que Paris doit être fortifié par des ouvrages établis sur quelques points culminants qui l'environnent; ces ouvrages serviront d'appui aux troupes destinées à la défense de la capitale, et auront en outre pour objet d'éloigner le bombardement et les attaques sur son mur de clôture et les barrières." Then commenced a brisk discussion between the advocates of the "Enceinte continue," and that of the "Forts Détachés," in which soldiers, civilians, and statesmen took part, and which filled magazines, pamphlets, and newspapers for the next 20 years. The advocates of the enceinte most quoted and considered, besides Vauban and Napoleon, were Generals Pelet, Valazé, and Haxo, Thiers, the historian of the wars of the revolution, and Arago, afterwards Minister of War under the Provisional Government of 1848. The principal partizans of the Forts Détachés were Marshal Soult, Generals Rogniat and Bernard. The discussion even took a political turn; the partizans of the forts being charged with wishing to enslave the Parisians, and one of my own earliest recollections was, in 1831, hearing the cries from the ranks of the National Guard, as they passed in review before Louis Philippe, "A bas les Bastilles." At length the year 1840 came. A treaty was signed by four of the Great Powers contrary to the policy of France in the East; and France, fearing she might be again exposed to the attempts of a European coalition on her own soil, determined not to postpone the fortifications of Paris any longer. A committee of the chambers reconsidered the whole question, and all the opinions that had been given, and recommended *both* the enceinte and the forts. The president of this committee was M. Thiers, and had General, afterwards Marshal, Bugeaud for a member.

I will now endeavour to state concisely the arguments used on both sides; and those of my brother officers who wish to judge whether I state them faithfully, or are anxious for a further development of them, may consult the collection of tracts which I have made, and which I present with much pleasure to the Chatham Library. And first it must be understood that Paris had an enceinte already; erected, however, for administrative purposes only. This was the "Mur d'Octroi" which even the partisans of the forts wished to put in a state of defence. It was part of their proposal that it should be raised to a height of 20 feet, that a banquette 6 feet high should be formed within, that it should be loopholed throughout its length, and that flanking towers should be erected. Two thousand metres in advance of this wall, that is, on the line of the present enceinte, a line of outworks was to have been erected, the fire of which would, except so far as the ground was covered by buildings, command the whole of the intervening space. The partisans of the enceinte were for that now erected without forts. Neither party calculated upon the country being willing to pay for both enceinte and forts as was afterwards the case. It is to be observed throughout the discussion that the progress of the art of war is never given as a reason for adopting a new kind of fortification. Detached forts are not advocated as a new system, but rather as an old one, of forming a strong entrenched camp under the existing wall of Paris, instead of making Paris a regular fortress. It is the "défense active" against the "défense passive." The system of manœuvring and fighting the enemy under cover of the works, against that of setting the army free to manœuvre and fight elsewhere if more advisable.

The following extracts from the opinions of the advocates of the forts will abundantly prove it:—"Si l'ennemi osait se livrer à quelque entreprise pour se porter sur Paris, il ne pourrait le faire *qu'en me passant sur le corps*, ce qui ne serait pas facile en raison de la valeur des troupes et des ouvrages de fortification auxquelles elles s'appuieraient."—SOULT.

"Je ne veux pas convertir Paris en une immense place de guerre par une enceinte de siège."—ROGNIAT.

"Or, une bonne défense ne peut sûrement s'obtenir qu'avec des forces actives *proportionnées aux forces de l'ennemi* et appuyées sur de bons ouvrages extérieurs."

"Le system de forts avancés formant un vaste camp retranché, obligerait l'ennemi à se disséminer sur des lignes très étendues, tandis que *notre armée régulière*, maîtresse de tous les débouchés, pourrait constamment prendre l'initiative * * * * dans un rayon de deux et même de trois journées de marche."—BERNARD.

Further, it seems admitted on all hands that the garrisons of the forts, and the troops who meet the enemy in the open between them, must be mainly regular troops, but that the enceinte may be in great measure defended by the National Guards and Volunteers.

I will now set side by side the reasons advanced by both parties.

Arguments for the Forts, and against the Enceinte.	Arguments for the Enceinte, and against the Forts.
1. The enceinte will be no security against bombardment.	1. It will be quite as effective as the forts if traced at the same distance from the town.

2. Bombardment is above all things to be avoided.

Vienna, in 1808, surrendered at once under the fire of 30 field howitzers.

2. The effects of bombardment are much exaggerated. Louis XIV fired in two days (August, 1694), 3,000 shells, and 12,000 red hot shot into Brussels without serious effect. Lille received 6,000 shells and 20,000 shot in six days without much damage. Genoa was bombarded three times without result. 16,000 shells were thrown into Saragossa, and it had, after all, to be taken by regular approaches. In 1757, Frederick the Great bombarded Prague for twenty-two days; the Spaniards, Gibraltar twice in 1782; the English, Havre twice in 1759, without the places falling. In Landau after eighty days' siege there are said to have been no more than five casualties among the citizens.

3. The enceinte will not isolate the garrison from the population, who might compel a garrison to surrender.

3. The enceinte, on the contrary, will be defended by the inhabitants, who would be loath to leave their houses to garrison a detached fort.

4. The escalade of the enceinte in one part would render the whole of the rest useless.

4. Escalades have seldom, if ever, been successful against escarps of a full height. The successful escalade of Bergen-op-Zoom in 1814, and the surprise of Cremona in 1702, ended in disaster to the attacking party.

5. The length of a continuous line round such a capital as Paris is outrageous.

5. The length is 40,000 metres, say 25 English miles. Counting the outworks, covered ways, &c., Lille has 34,000 metres of parapet (before its extension, now in progress), Strasbourg 28,000, Metz 24,000 metres.

6. The expense in land and works of the detached forts will be less than that of the enceinte.

6. Not to any great extent.

The final estimate for the enceinte

was	76,600,000 frs.
for the forts	60,600,000 „
general expenses ..	5,300,000 „
	142,500,000 „

If to the estimate for the forts be added that for strengthening the Mur d'Octroi, the difference will be less than the above figures would show.

7. The enemy could not pass in any numbers under the fire of the detached works.

7. He could. Napoleon, with the army which fought at Marengo, passed under the fire of Fort St. Bard with all his artillery and baggage. It is said the distance was half musket shot.

The only rejoinder to these two facts I find are by Captain Villeneuve, who says, that if the Spanish right flank had been joined by works to Fort Cristoval, the French could not have done what they did, and if the outworks of Schweidnitz were escaladed so would an enceinte have been. The fact, however, remains, that the assailants passed between the works to escalade them in the rear.

Many supporters of the forts admitted that a column could reach the Mur d'Octroi but would be stopped by it.

At the battle of Gevora, in 1811, under the walls of Badajoz, General Girard being ordered to attack the right flank of the Spaniards, marched his division in column to 1,000 metres from Fort Cristoval, and formed line with the fire of that fort in his rear, and that of Badajoz 500 metres further.

At Schweidnitz, in 1761, there were in advance of the place five detached works, with intervals of 500 yards between them, joined by covered ways. Laudon passed over the covered ways, attacked and took the outworks by assault in rear, at the same time that they were attacked in front.

8. The enceinte will prevent sorties.

8. Not if properly constructed. There is no record of sorties having found a difficulty in emerging from and re-entering a fortress even on a large scale. Witness Dufay's sorties from Philipsbourg in 1776. Calvo's from Maestricht in the same year. Wraffler's from Lille in 1706. Those of the Turks from Shoumla in 1810. The garrison of Almeida, in 1811, sallied out in one body during the night, passed through the cantonments of the English army and escaped. They might have added the memorable sortie of Lord Elliott from Gibraltar.

From this discussion I gather that no French officer ever proposed a system of detached forts as a better system of fortification than the old line; that no one thought the position could be defended by a smaller army scattered in detached forts than if guarding a continuous line, but many thought that Paris should be made an intrenched camp, and not a fortress at all; and that as there would be no lack of men to defend the metropolis, detached forts would be better, cheaper, and less in the way than a continuous line. There is also, evidently, an under current of doubt as to the political feelings of the people. Many soldiers remembered with grief the acclamations which greeted the entry of the allies into Paris, they remembered the excesses of the first revolution and preferred removing the defence of the capital as much as possible from the influence of the populace. The other school looked upon this very populace as the greatest element of strength.

And now I come to the proposal to adopt this system of detached works as the means of making an ordinary fortress, or of occupying an extended line in advance of existing works, and leaving ground between not seen from either. I maintain that in the one case the place can be taken at once by superior forces passing through the openings, and that in the second the ground between the inner and the outer line may be occupied.

I will take the author's statements *seriatim*. We are told that—

1st. " It is evidently impossible to occupy positions so extended by continuous lines."

I am precluded in a paper of this kind from discussing particular cases; but the works recommended by the Royal Commission, for Land Defences measure about as follow—

Portsmouth.. ..	12 miles.	Milford..	6 miles.
Plymouth	10 -	Chatham	10 -

There is nothing more impossible in 10 or 12 miles of works than in 10 or 12 works a mile apart, nor would they cost more. The bombproof accommodation may be the same, the caponiers less numerous. The escarp of the detached works is fully equal to cover half the distance, the counterscarp more than half, and much of the expense of Haxos may be saved, as it will no longer be necessary to expose faces to direct enfilade. The interior enceinte, the necessity of which is admitted, is also saved. The continuous enceinte of Antwerp has a development of 12 miles. That of Genoa, 6 miles; and surely the length of a position is no excuse for making it weaker. There are, further, great difficulties on broken ground in getting the whole front of a position seen from a few points along its crest, which are obviated when every point of the line may, at will, be turned into a battery or occupied by musketry. An inseparable condition of detached works is, that not only the ground in front, but that between and behind the works, shall be brought under fire, which calls for heavy cuttings and fillings, from which a continuous line is free. *Impossible* to an engineer means expensive or absurd. The above remarks will show that continuous lines equally long have been executed, are being executed, and are not more expensive than the detached lines proposed.

2nd. " A continuous line must be manned throughout its whole extent."

Who, may I ask, ever proposed to man any work of fortification throughout its whole extent? The fortification is there to stand in the place of men, or to enable few to do the work of many. The stronger the works, the deeper the ditches, the higher the scarps, the fewer troops will be required. To call for more troops because a position is made more defensible, is to admit that the art of the engineer is superfluous, or that the position need not be taken up at all.

The model forts presented to us have a development of 800 yards, measured on the escarp, and are each flanked from five points, with an average range of 120 yards. In former times, when the effective range of fire arms was one-fourth of what it is now, 300 yards was considered the distance which should not be exceeded for an efficient flank. Supposing a caponier front, this would give 600 yards, which could be flanked from one efficient caponier. Three such caponiers would secure a line one mile long, and with a good scarp and counterscarp, if those three caponiers are manned, there can be no access to the lines except by a regular siege. The caponier fronts of Antwerp, now in course of construction are, I am told, each 1,000 metres long.

We are given as a specimen a line two miles and a quarter in extent, the forts of which require being watched at 15 points. The same ground might be covered by a continuous line, thoroughly flanked from seven, if not from five points. A single battalion and a company of artillery would, on a pinch, make the continuous line secure from surprise or escalade, whereas the same number of men would be scarcely sufficient to look after the three detached works, and must leave the intervals to take care of themselves.

Supposing two armies in presence, works or no works, the least precaution which can be taken is to have a line of sentries in the night upon, or in front of, the works, within call of each other; that is to say, 65 yards apart, or allowing for sinuosities 30 per mile—67 sentries for the line under discussion—which would therefore require a guard of 200 privates. It would require a strong battalion to furnish that guard day after day, and the garrison could not be less therefore than a battalion. With this minimum garrison and a 30-foot scarp, the continuous line gives fair security against escalade. The detached forts, to be of any use, require besides a strong manœuvring force in their rear, ready to meet the enemy in the open and nearly upon equal terms. Of the two, most decidedly the detached line requires most "manning."

Bousmard gives 600 men and 10 guns as a sufficient guard for one league of a continuous line on a field profile! (See Book v, Chap. 8). In fact all that Bousmard says in that chapter is well worthy of attention, and bears directly on the question before us.

3rd. "A continuous line will fall if pierced at any one point."

So will any line, and the detached line has this disadvantage, that it is pierced already at all points. The paper in question makes merry at the expense of another projector, for omitting his escarp, and depending entirely upon his counterscarp, and says it makes a "permanent and continuous breach, so that when the counterscarp is blown in, an assaulting party may walk up an easy slope and sit down on the rampart." Advocates of detached lines are the last persons who should make this a reproach. To blow in a counterscarp requires an enemy to have effected a lodgment upon the top of it; and according to our present information, to effect such a lodgment requires much ceremony and time. No breach can be so easy as a piece of open country.

4th. It is stated that "an enemy could not pass between the forts with guns and ammunition sufficient to bombard the place or batter the forts in rear"—but that infantry might penetrate.

If infantry can enter they can do so in any numbers. Columns of infantry have attacked and carried lines of intrenchment fully manned and armed, and surely can march by such a fire for a short distance, as the instances quoted above will prove; and when they have gained the unoccupied ground behind they can remain there, intrench themselves if they will, and cut off all communication between the forts and the inner line, if there be one. The next night they can in all safety bring in guns and open a fire on the gorge of the forts, or on the inner line. Guns, be it remembered, are generally brought into battery during the night, over ground commanded by the fire of the works.

Besides, practically, there must be a flank to these lines. The cases are very few where a covered parallel may not be formed between the extremity of the line and the sea, or round the flank of the lines, on which there will be fire only from one side, and from that moment the communication between the inside and outside of the lines is complete and constant. You all here practice double saps and half double saps perched on the crest of the glacis, and exposed to the cross-fire of two adjacent ravelins, and I cannot doubt but that double lines of communication might be formed, even between two adjacent works if it were necessary.

5th. It is admitted that an exterior enceinte is necessary where an interior one cannot be obtained.

I think the part played by an enceinte in a combination of continuous and detached works, such as that of Paris or Antwerp, is here lost sight of. The enceinte has not only to cover the fortress from being run into, but to command the intervals between the forts and the whole of the intervening space. With such an enceinte the forts can only be regularly attacked in front. In case of an attempt to pass between the forts, such troops of the garrison, as may be observing the besiegers outside the works, have only to fall back leisurely upon the forts and enceinte, the cross-fire of which must render all permanent lodgments impossible. The same would be the case, if, as proposed by Montalembert, there were two or more lines of detached forts in advance of the enceinte, the inner forts flanking the openings between the outer ones, and the inner forts supported by an enceinte; but to place an isolated line of forts a mile apart, 8,000 yards or so from the place, and to expect any real use from them is quite a novel idea, and I think I have shown as false as it is novel. In only one case could it be right, and that is in a case where the command of the enceinte is so great or the country so flat, that with our new artillery no cover would be left to an enemy within the line of forts.*

In speaking of the cost of the works, I have alluded to the saving in Haxo casemates in a continuous line. This point deserves more attention. It is a necessity of the proposed system of works that they should have powerful flanks, not only as in a bastioned enceinte to flank the ditches of the collateral bastions, but to sweep the ground between the works. These faces must therefore, by their nature, be subject to enfilade, and must, moreover, be constantly armed, whether the enemy are attacking on that side or not, for everything depends upon them, not only against siege but against surprise. The model fort shown would mount 10 guns on each flank, and that would be a very moderate battery to perform the marvels expected from it. We have, therefore, 20 guns a fort diverted from the general defence of the fortress to form an "armement de sûreté," and for these, besides the guns in caponiers, powder, projectiles, and those still more precious articles—gunners—must be provided and always ready. In fact when these forts are not bristling with artillery they are quite powerless. Now the artillery resources of most places are limited, and will be required upon the fronts of attack. From 200 to 300 guns, and the means of working them, is the most that practically we could make available for the defence of one of our fortresses; bear in mind that all the resources of the empire were required to bring that number of guns into battery before Sevastopol, and not more could be

* Or, as I have before stated, when you can calculate on having a very large force to defend them.

done by a mere garrison however strong. Your whole armament will, therefore, be required for the flanks of your works, whereas two light guns in each flank of a bastioned enceinte are considered sufficient against an escalade, and say 6 guns per caponier in the Antwerp fronts.

Then great store is laid upon the keeps of these forts. Well, keeps are in their way excellent things, if we can afford them, but they are after all mere adjuncts. To have a keep in a bastion of a work from which the summit of the breach can be commanded, and into which the guard may retreat in case of an escalade, is very valuable; but it cannot be compared in importance with the curtain which connects the bastions.

I have been reminded of Torres Vedras, but Torres Vedras was an intrenched camp and not a fortress; it was garrisoned by 45,000 men, and the French army was little superior to the garrison in numbers. And hear what Sir John Jones says about these lines (Prof. Papers, 4-to. Series, Vol. III, p. 28). "A successful defence of the lines hinged altogether upon the unremitting vigilance, able disposition, and rapid movements of the defenders. One single error of judgment, or one single miscalculation of time or distance, might have rendered the whole line of works useless; for field redoubts left to their own garrisons, even when thickly studded, can only be expected to impede, turn, or disorganise a column of march with its artillery, *but never to oppose an impenetrable barrier to the advance of a powerful and determined army*."

Then the Venetian Quadrilateral is quoted, and I am asked to accept a redoubt as a representation of a fortress! But even if the comparison were just, the Venetian Quadrilateral is nothing without a manœuvring army in the field. With an army numerically strong enough to fight a battle so nearly drawn as Solferino, the Quadrilateral was impregnable. Even had the Austrians been more thoroughly beaten they would have found great use from their fortresses, but had they merely had small garrisons for the four places a powerful army could have marched through and left them behind. A single fortress has often made a long and heroic defence against very great odds, but what system of isolated works ever did? It was because the invaders of France in 1813, and again in 1815, marched through the lines of frontier fortresses almost as if they had not existed, that the French determined on making a great national sacrifice to fortify Paris itself.

Again, why should we English Engineers, who have had less opportunity of constructing large works than those of any other country, strike out a new line? Officers of great experience may adopt the views I venture to condemn, but they do so in the face of all the great engineers of the past, and against the present practice of all Europe. The Belgians on the Scheldt, the Russians on the Vistula, the French at Lille and Toulon, are now building continuous lines of works. I have heard that something in the way of detached works is being done at Warsaw, at Nicolaieff, and at Havre, but have not been able to learn any particulars. There is nothing in the nature of rifles, or rifled cannon, to excuse or explain it. They may allow of flanked lines or lines of defence being made longer, and of advanced works being pushed farther forward than before; but they upset no one principle in fortification. Jomini foretold—and the campaign in Italy proved—that they upset no one principle in tactics.

The above are the objections of the engineer, but there are one or two more general considerations which I have to urge against this system of works, of which officers of other branches of the service can judge as well, if not better, than we can. Beyond works, or stores, or guns, or anything else, the defence of a place depends upon the Governor. He is the spirit, while the rest is mere matter. Upon the skill, vigour, and above all, the courage of the Governor, must depend the defence of a fortress. His voice, his looks, his very gait, will give the tone to the whole defence. The general feeling of mankind will endorse this opinion. If the defence of Grave is spoken of, it is connected with the name of Chamilly more than with the ramparts he fought upon. Lord Heathfield has left a name as imperishable as the Rock of Gibraltar. It appears to me impossible that a governor can exercise the same active control over the defence when the garrison is split up into countless detachments, as when it is managed as a whole. In a line of works, the regiments for duty, generally about one-third of the whole, are paraded together and marched to their posts or works to relieve the previous guard, under the superintendence of the superior officers of the garrison. When off duty they mix freely together, and even the humblest member will learn something of the state of affairs and of the objects for which the contending armies are fighting. There will be a public opinion in the garrison into which a brave governor may infuse some of his own determined spirit. But the garrison of each detached work must remain there, with little or no communication with the garrison of other works, and will take its tone from the senior officer on the spot. On the fronts of attack they will be exposed to constant fire, and though bombproofs may shelter them from actual hurt, the very sound and excitement of a constant fire falling on a limited space makes all, but a very few, wish for intervals of repose. Besides each must be in command of the senior officer present, and the security of the whole line will depend upon the will of perhaps the least resolute among many. A flag of truce may be brought to the gate of any of these forts at early dawn. The commanding officer, apprised truly or falsely that the line has been broken and the besieger in possession of the place, may be urged to save further bloodshed, and surrender his command, or submit to an instant and combined onslaught from the whole victorious army. The same game might be played all round the place at the same hour. How can we secure that one of perhaps twenty commanders will not falter.

As was said by the writer of a very interesting article in the *Spectateur Militaire* of May, 1833, "The Commander-in-Chief will have to break up his command, to delegate it to the commandants of the forts, who can be at times cut off from him, and to the officers commanding the troops in the intervals between the forts, who not having between them and the enemy any serious obstacle to impede the march of the latter, will be often obliged to judge according to circumstances. Is it probable that so many different wills should concur exactly in the general object of the defence?"

Another consideration arises out of this new system. I have said that each of the forts has to be guarded from five points. In practice it is far more, and I could point to instances in which no less than eight separate flanks have to be manned to secure the enceinte of one fort from escalade—not open flanks like those of a bastioned work, but caponiers, reverse fires, counterscarp galleries, in fact *caves* of one kind or another from which alone the ditch can be seen.

These posts are reached by tunnels, staircases, and other passages,—dark even during the day—and the commanding officer will always, with the best arrangements, be in doubt of the conduct and vigilance of the guards immured in these places. It will be practically impossible for him to give that constant superintendence to every point which can alone secure efficiency, and the security of the fort will depend, not altogether upon him, but upon the conduct and judgment of perhaps a corporal's guard. Roused from their beds during the dead of night, in darkness and doubt as to the points of attack, panic and false reports are only too likely to take place even amongst the best troops.

In a bastioned enceinte a strong guard can be mounted in each bastion which may direct its fire from either flank as may be most wanted. The commanding officer can mount his horse and assure himself in a few minutes of the security of the works entrusted to him, he can bring up his reserve to the points most menaced, and surprise becomes almost impossible. Caponiers have not yet stood the test of actual war. I do not, on that account, condemn them, but they should be few and large. At Antwerp there will be one to every 1,000 metres of enceinte ; an officer's guard may, therefore, be placed in each, and the rest of the troops on duty kept in hand on the ramparts. The troops will know that the enemy can come from only one side. They will see their officers and be seen by them, and will have what light there is in the heavens above them instead of a dark vault. The opportunities for skulking, which our *hole and corner* flanks afford, always give me great uneasiness. I only once saw troops in a counterscarp gallery, and then not in earnest, but that one instance has left an indelible impression on my mind of the difficulty that would be found in getting them all out again and posting them on an open rampart, and the same idea occurred at the time to other officers present. Perhaps some officers here this evening may give us their experience of the same sort of thing at night. You must in these forts, and, in fact, in the German system generally, have men on the ramparts as well as in the caponiers. The bastioned system, with all its faults, has this advantage, that the men in the flanks are ready to repel an assailant at any point of the rampart, which they can reach in a few seconds.

It will be seen that objections were made to the detached forts round Paris because the National Guard would not take the same interest in their defence, and this I can find no where contradicted by the other party who counted upon regular troops to garrison the forts. I think it quite as clear that we must not count upon Volunteers to garrison our detached works. Many brave men in every large town will be found to co-operate in the defence of the walls of their native town, but few will be found to compose permanent garrisons for detached works. Neither are Volunteer troops or Volunteer Officers the best fitted to manœuvre against an enterprising and well trained army between the forts, and the defence will virtually be left to such regular troops as are available. Bear in mind, also, that we are fortifying our dockyards in order that the bulk of our regular troops may be available for the defence of the metropolis, and even of regulars, only the newest levies can be spared to garrison the dockyards. For them, therefore, and for their officers, the simplest form of works should be selected, and it is not treating them fairly to expect them to take up an utterly new and untried system of defence.

This is not a question solely for Engineers, but for the general and staff officers of our army, with whom, after all, the actual defence of our fortresses will rest, and I would ask them whether they would undertake to fight an open line of works against numbers greatly superior.

One of the bravest soldiers in our army commanded the garrison at Malta when I visited it a few years since, and he did me the honour to consult me upon one or two points in the works which he considered weak and liable to surprise. One of them was the junction between the ditch of an outwork and that of the bastioned enceinte upon which it depended. He thought that an enemy could advance along the ditch, flanked by artillery and musketry in front and rear, enter the ditch of the enceinte, and thence gain the gate in the centre of a curtain, covered by the fire of the flanks of two adjacent bastions and a double-palisaded caponier. He wanted what he called a *material obstacle* between the two ditches. I pointed out that, as they were on the same level, no obstacle could be interposed which would not mask the flank fire; but I am afraid I did not succeed in convincing the General that there really was no fear of an open assault by such a dangerous route. I thought, and still think, the General's fears were exaggerated, but he urged his objections so strongly, and gave such a graphic description of the assaults he had seen, and the impetuosity which well trained troops attain in an attack, that I was almost induced to throw principles to the winds, and recommend that, at all hazards, some sort of dam should be erected to check the advancing Zouaves. Should he hear this statement repeated, I trust he will excuse me for making it, but I cannot adduce a stronger proof of the soundness of my objections to a detached line of works than that an old officer, who had seen and fought on so many fields, should think such an enterprise possible.

I have been fortunate enough to find an interesting opinion of the late Duke of Wellington, bearing upon this question, in the valuable papers recently printed by Sir Harry Jones upon the defences of the Netherlands. Among these you will find the following remark made by the Inspector General of Fortifications of the Netherlands, after a conference with the Duke upon many different questions, among which was the restoration of Namur. "Son Altesse (the duke) persistant à désapprouver le système des ouvrages détachés pour la première ligne en avant du Château, il a été convenu qu'on adopterait pour ce qui est de la dite première ligne *le système fermé* proposé par les Ingénieurs Anglais." Opinions of the same kind are given with reference to Menin and Nieuport, and I can find nowhere anything in favour of open lines.

This shows that not only the Duke, but our own officers, with the Peninsula and Waterloo campaigns fresh in their recollections, insisted upon continuous lines of works against very strong opposition. Was it a continuous or detached line which our officers constructed to cover Balaklava, or that the French Engineers constructed to cover Kamiesh and Kasatch, or that both together made at Gallipoli? Depend upon it, when war becomes a reality with any of us, no one will make a detached line unless he is almost strong enough to fight without works at all; unless he is able to feel the same confidence as Marshal Soult, that the enemy cannot come on *sans me passer sur le corps.*

Guibert cites the battles of Fontenoy, Rocoux, and Lauffelt, as instances in which columns of attack have penetrated between detached works armed with artillery. You can trace the battle of Fontenoy step by step in Kausler and see how the Duke of Cumberland's column, 14,000 strong, passed quite unbroken between two works 750 yards apart, and to which a hollow way formed a sort of curtain, and were only repulsed because they could not manœuvre when they got in. I cannot make out Rocoux quite as well, but it would appear certain that Marshal Saxe turned the left of the allied army, though resting upon the Citadel of Liége. Lauffelt or Lawfeld I have not been able to find any particulars about. I trust that the question I have started may lead to further research, for it is clear that the effect of artillery may be as well studied in the case of field as of permanent works, so long as the works themselves are not carried by assault.

Every Engineer, and, I hope, every soldier in the British army, must revere the memory of Sir William Reid. Well, Sir William Reid, when Governor of Malta, was more anxious about the security of the gates than any other point. What is a gate to a gap nearly a mile wide?

Another advantage incidental to the enceinte is that it is an obstacle to desertion and to spies.

Civilians often say that they cannot understand a word about our fortifications. Now this ought not to be. We do not trust a medical man who cannot give some reason for his recommendations. A judge has to bring the most abstruse questions of law within the comprehension of a jury, and we all form our opinions, and pretty strong opinions too, on Theology and Politics. Because this is the case, it is no reason that we should set ourselves up as physicians, or lawyers, or divines, or politicians. We can, or ought to be able to, understand the bearing or purpose of every science, and so ought all intelligent men to understand the bearing and purpose of ours. There is no *glamour* about fortification. When a farmer puts up a fence or a wall round his garden he erects a fortification; and so long as fortification is a development of that one simple idea every one can understand it. When you put up a row of forts and say the enemy cannot pass through, it is asking the farmer to believe that the posts of his fence will keep out cattle without the rails; he does not "see" it, nor, I confess, do I. A good wholesome wall and ditch which the enemy has to get through or over, before he reaches his object, will commend itself to the understanding of any man of sense, soldier or civilian, however much it may be complicated or strengthened by the art and experience of the engineer.

Since I compiled this paper the report of the American Commission who visited Europe during the Russian War has fallen into my hands; it states the arguments for and against the detached works much more clearly than I have found them elsewhere. What the Americans discuss is not, however, any work they have seen, but the ideas towards which the German school of fortification tends, but which they might, had they waited long enough, seen adopted in their extremest sense in "the old country." As this valuable report may not be fully known to the present meeting I will venture to read some extracts from it.

"An *extensive continuous enceinte*, whatever may be the composition of the system of its fronts, presents in all parts an equal resistance, or rather the same weakness, that the garrison is under the necessity of protecting on every point of the fronts of attack and collateral fronts with a determinate force. These fronts cannot be reinforced without doing so on the whole extent at the same time, to make the reinforcement of any value; and the line overcome at one point, the position is taken without the other parts having contributed to increase the resistance of the point attacked."

"These enceintes may be compared to extended lines of battle with slight depth, abandoned in modern tactics, and replaced by great masses, or lines held in hand by the commander, to be thrown suddenly into masses, supporting lesser ones in front of battalions; or, in place of the latter, by bodies of tirailleurs. It appears consistent that fortification should also be made to accord, as far as practicable, with this principle."

"Thus the main idea is to '*enclose the polygon*,' or to compose the line to be fortified of STRONG POINTS, which, while bearing to each other a reciprocal relation of defence, may each possess the independent means which their immediate defence calls for; each one becoming one of the works we have given the denomination of 'independent defensive.' The spaces between the works are closed by curtains or simple lines, which may be denominated *unattackable*, either on account of their re-entering position, and the immediate protection they receive from the collateral independent work, or for the more important reason, that when one of these lines is taken, the enemy has gained little or nothing, since the strong points still remain intact, their fires from the gorge making it impossible for the besieger to hold the position. This is a merit claimed for the German system that will receive further elucidation."

"The immediate inference from this principle is, that the enceinte of a place may be one of great extension, without increasing in a corresponding proportion the garrison strictly necessary for its defence. The place may be considered secure against any sudden or unexpected attack, if it be garrisoned by a force sufficient to defend the POINTS which we have already stated to constitute the real strength of the position; while at the same time the place admits of a strong division of troops to serve as a support for the army in the field, or to enter into the defence to contest the enemy's main object, by the most vigorous efforts, combined with powerful sorties."

"The natural consequence of this mode of fortifying places, is to make the fronts susceptible of the most active defence at the proper time; and by placing the communications near and under the strong points, they offer all desirable width and facilities without the defects attributed to other systems. Such is what is claimed for this system, and that by this means the field of fortification is enlarged, the object of fortresses is completely changed, and instead of being restricted to the protection of a point, is enabled to extend the sphere of its operations to a great distance, and have an important influence in the progress of a campaign, rather than at the time of its investment, offering a prolonged resistance against the powerful means that may be at the disposal of the attack. These considerations have induced intelligent engineers and military men to look upon fortresses rather as impediments in the way of actual operations of armies in the field, absorbing so much of their moveable strength, and given rise to doubts concerning their necessity or utility. Let them once more be given the relation they should bear with the strength of armies, and auxiliary thereto, occupying strategic points, (and not merely encircling cities to *fence in* their wealth), either as great entrenched camps, depots for resources, or closing, as barriers, defiles leading into a country, they will again fulfil the great objects for which they were intended; and the equilibrium so long sought for between the attack and the defence will again be restored. To such results do the German engineers contend their peculiar application of the principles of fortification will lead."

"Their principles, however, have been much opposed. A place composed of strong points or independent works is objected to, for the reason it would require as many officers, possessing all the qualities indispensable for the direction of its defence, as there were separate works; and to the difficulty of finding such is added the objection that the general defence of the place cannot be carried on with the unity which should be vested in one superior head, who, with many points under his command, would be unable to judge at a glance of the state of the defence; and that the garrison at each point will act independently of each other, without the vigour resulting from united and simultaneous action."

"We can but think these objections are equally applicable to any place, the garrison of which exceeds the number a commander can have within sound of his voice, and that they increase with the strength of the garrison, and all easily overcome by DISCIPLINE, without which neither army or fortress is a reliable security to a nation."

"The partisans of the bastioned system have enumerated under the following heads the general defects of the German system:—

1st.—The construction of German fortresses must be expensive on account of the numerous works of masonry requiring nice workmanship, and the excess in cost, if expended upon some other systems, would produce fronts of greater defensive value.

2nd.—Troops and material of war are distributed throughout the independent works of the place. Thus, the defence loses the strength which union and concerted action imparts to all operations of war, and which can only exist under the immediate direction of one single commander.

3rd.—There will be difficulty in finding for each independent work an officer capable of directing the defence in perfect unison with the plan, more or less active, which the commander of the place may have adopted.

4th.—The numerous works of masonry in this system are liable to be destroyed by curved fires at slight elevations and by heavy projectiles.

5th.—The inconveniences of various kinds attributed to casemates are also inherent in this system.

6th, and finally, that it is imprudent to abandon the existing systems of fortification before the sanction of experience has placed beyond doubt the advantage of the modern systems."

"With respect to the first point, '*the greater cost of their fortresses*,' the answer of the German engineers is, that experience has proved the contrary. The meagre data we possess on this point and which we present, if insufficient to decide the question, will nevertheless have some explanatory bearing."

"The second and third objections to the German system have undoubtedly more foundation. In effect, the commander of the fortress cannot, as in continuous systems, direct alone the operations of the defence, nor can he at a single glance take in the progress of the siege. Each work has allotted to it a determinate garrison, requiring the officer in command to act independently at a given time, in accordance with the true spirit of the orders of his commander; nor can the latter reinforce him opportunely, either for the purpose of repelling an attack or making sorties, as occasion may call for."

"While we admit the existence of these inconveniences to be of a serious nature in a general sense, yet in special cases we find their importance much diminished, and consider they are more than counterbalanced by the advantages otherwise accruing from this very objectionable system, as shown from the disposition of those isolated commands. Much of the objection may hereafter be overcome by the use of a telegraph wire, a most simple and effectual means of communicating with the general head-quarters."

"Let us suppose the fortress of Posen to be invested; it is undeniable that against any irregular attack it will be easier to defend it than a continuous system. Each isolated point is provided with secure means of defence. Nor are these points of so complicated a nature as to prevent an officer in command from directing the defence against any such attack, while the commander would direct his attention to the curtains, which the enemy might attempt to escalade. The critical situation of the one would give greater freedom of action to the other. We cannot either believe that this difficulty of commanding the whole defence exists in the case of a regular investment of three fronts, the other being secure. The artillery of the redoubts and casemated batteries is alone out of sight of the commander; but the offensive movements of the garrison, their retreat, and every material circumstance connected with the siege, passes under the commander's eyes. If we turn to the defence of Rastadt, the numerous artillery that would be required to operate against Fort Leopold, the probable field of attack, renders it almost certain that two of those "independent forts" could not be attacked simultaneously. The most to be attempted would be to make a false attack; and the true point being once ascertained, the commander of the place may then give his personal attention to the main attack."

"In some fortresses *repaired* according to the German system, these principles have been exaggerated, and a pernicious use made of subterranean communications, which, while complicating the interior of the works, conceal the movements of the troops from the commanding officer, and have an influence on the *morale* of the soldier, who becomes reluctant to leave the cover and protection they afford. This abuse, springing from the very latitude of the system, and of which many remarkable examples could be cited, has contributed to give more weight to the defects under consideration than they really possess. The objections can only be truly established after some vigorous siege and resolute defence of one of these new fortresses."

"With respect to the fourth objection, we will bring together the considerations previously stated; and first, as a general principle, the masonry in this system is covered by earthen works, as well as in the bastioned system, and they cannot be systematically battered by direct fire."

"2nd.—The position of the caponiers, casemated redoubts, &c., guards against, as a general rule, destruction by curved fires, as experimented with at Woolwich, in a normal direction, or approximating thereto, the only case in which we may say their effect would be certain. Their arches, covered with earth, are calculated to resist the usual shell. Twenty-four inch mortars, if such could be brought against them, would produce very destructive effects on this system, nevertheless, the practice with such mortars at the siege of Antwerp would seem to remove all fear in this respect."

"The defensive barracks, by their position and the great mark they present, are the works most liable to be injured from slightly curved fires; still we think we have shown that, as redoubts, they are far superior to the uncovered redoubts of the bastioned system, and this, in reality, is the material question, *which is the best;* and to which, in devising a plan for a locality, should we give the preference? In a matter as yet undetermined by the experience of actual sieges, we may cite in favour of these casemated barracks the opinion of officers of the French school, as Bousmard, Choumara, and Fleury, the latter the director of the works at Lyons."

The American officers seem inclined to favour the direction in which these German views tend, but I would observe that, in no one instance, do the Germans seem to have carried them out. They have made their bastions defensible to the rear, but they have not abandoned their curtains. I cannot even find that they have satisfied themselves with an escarp lower or less covered on the curtains than on the salients of their works.

1st.—Rastadt, Posen, Ingoldstadt, Coblenz, are closed works in the fullest sense of the term.

2nd.—Most of the questions under discussion are between open and casemated flanks, between a bastioned or caponier trace which scarcely affects the main question at issue.

3rd.—The difficulty arising from a want of unity in the defence is almost admitted, and discipline is invoked as a palliation, but the most difficult quality to obtain in new levies or irregular forces.

4th.—The abuse of subterranean communications, and their effect on the *morale* of the soldiers is also admitted.

5th.—No reply is given to the objection they themselves started, "That it is imprudent to abandon existing systems of fortification before the sanction of experience has placed beyond doubt the advantage of the modern systems."

6th.—The Prussians, with all their science, all their ability, and all their glorious traditions, have known less of war in its reality than any European power during the last half century.

7th.—The analogy drawn from the progress of tactics is striking. Puységur said, long ago, that an army was a moveable fortification, and certainly a fortification is a fixed army, and many principles are common to both fortifications and tactics, but has the change of tactics in question taken place? Have we or any other nation given up the line as the order for receiving an attack? To facilitate manœuvres it may be broken into battalions in close column at deploying distance, but the object of this is only to form line the more readily, or squares when necessary; the line itself has, on the contrary, become more and more slender. It was at one time six deep, then four, then three, and we English had the honour of leading the way in reducing it to two deep.

8th.—Neither the experience of the three officers who made this report, nor the achievements of the army of which they are members, can make us attach undue importance to their opinions, any more than to the criticism upon our operations in the Crimea, by which one of their volumes is prefaced.

I urge, therefore, in conclusion, that a continuous line is as cheap as a line of detached works; that it can be defended by fewer men, and those men far less trained; that its defence is simpler and easier understood by generals, by officers, and by men; that it appeals most to the patriotism of the citizens; that it has been well and fully tried for thousands of years; and that nothing in the art of war has been discovered to supersede the old-fashioned ditch, rampart, and parapet, not only as a battery upon which to mount guns, but as a means of keeping the stronger from closing with the weaker.

If detached works can be afforded, by all means let us have them to delay the approach of the enemy to the enceinte. If we can add keeps to assailable portions of the line let us do so; but to depend upon keeps and forts without the fortification itself, is to depend on the masts of a ship without the hull, on the limbs of an animal without its body, upon the skirmishers of an army without the line of battle.

If I do not carry my brother officers with me, I am ready patiently to hear their objections, and if I cannot answer them, to repent from my errors, but without some such conversion I cannot admit that mere Fort-building is Fortification.

H. C. OWEN,

Lieut. Col. R.E., and Colonel.

…ARITIME FORTRESS.

…ENCES BEING CLOSED BY CONTINUOUS LINES

… CLOSED BY DETACHED FORTS.

IMAGINARY MARITIME FORTRESS.

THREE SECTIONS OF THE DEFENCES BEING CLOSED BY CONTINUOUS LINES & ONE SECTION CLOSED BY DETACHED FORTS

PAPER XVIII.

ON DETACHED WORKS *versus* CONTINUOUS LINES,

Applied for the Permanent Defence of an Advanced Position.

By CAPTAIN J. J. WILSON, R.E.

[Read at Chatham on 20th March, 1863, and reprinted with a few alterations.]

In January last a paper was read in this room by Colonel Owen, before a numerous meeting, advocating the superior merits of continuous lines as compared with a line of detached works, for the permanent defence of a position such as that of a dockyard or arsenal, and containing some severe criticisms upon the works lately proposed, and in some cases executed, for the defence of our own great dockyards. The paper was very forcibly written, as I am sure all will allow who had the pleasure of hearing it read; but inasmuch as I think that many of the arguments advanced by the writer, as well as the illustrations on which they were based, are of a fallacious description, I have been induced to take up the consideration of the subject from a somewhat different point of view, and to endeavour to combat or disprove the conclusions arrived at. Those conclusions were :—

First—" That a continuous line is as cheap as a line of detached works."

Secondly—" That it can be defended by fewer men, and those far less trained."

Thirdly—" That its defence is simpler, and easier understood by generals, by officers, and by men."

Fourthly—" That it appeals most to the patriotism of the citizens."

Fifthly—" That it has been well and fully tried for thousands of years, and that nothing in the art of war has been discovered to supersede the old fashioned ditch, rampart, and parapet, not only as a battery upon which to mount guns, but as a means of keeping the stronger from closing with the weaker."

I propose to take these conclusions one by one, and to discuss their merits freely; and as in doing so I shall have to look closely into Colonel Owen's arguments, I take this opportunity of declaring my desire to keep within proper limits, as well as to examine the subject in an impartial spirit.

The first of the general conclusions urged upon our attention is, " That a continuous line is as cheap as a line of detached works."

I must begin my remarks on this point by recording my protest against the elastic properties with which Colonel Owen endows his continued lines. At one time,* when seeking to impress upon us the defensive merits of such lines as compared with detached works, he enlarges upon the advantages afforded by the bastioned enceinte; at another, when endeavouring to reduce the number of the defenders to a minimum,† the line is pulled out, as it were, till it becomes perfectly straight, and flanked by caponiers; and in the case before us some such feat is accomplished, for I cannot make out otherwise how the escarp of the model fort shown in the 9th volume of our "Professional Papers" can cover half a mile of ground when applied to the continuous line. Neither can I admit that by substituting a continuous line for the line of detached works, it would be possible to save the construction of an inner enceinte. It could not, with propriety, be left out in either case. The absolute destruction of a dockyard, which must ensue if once an enemy got possession of it, is more to be dreaded than a bombardment, and it would not be wise to leave its safety dependent upon the defence of a simple continuous line of works; once that line was broken through, which might be effected even by surprise, there would be nothing to stop the tide of destruction, both defences and dockyard becoming involved in one general disaster.

Again, when estimating the expenses likely to be incurred by the adoption of detached works, Col. Owen states, "That in order to bring the ground in front and rear under fire, heavy cuttings and fillings must be executed, an objection from which a continuous line is free." But this is altogether a question of site; and while on the one hand it would be easy to imagine a site where the cost of excavating the long ditch of the continuous line would be so excessive as to render the job impracticable, on the other hand it would be difficult to imagine a site other than a perfect plain, where cuttings and fillings would not be required, even if we elected to fortify it with a continuous line.

I might settle this question of expense at once by referring to page 170 of the paper under discussion, where the final estimate of the cost of the fortifications of Paris is given—the enceinte at 76 millions of francs, and the forts at 60 millions, making a difference of more than one-fourth in favour of the latter. And if the forts here spoken of be, as I apprehend, those which have been actually constructed at the average distance of a mile and a half in front of the enceinte, this difference will be largely increased. The perimeter of the enceinte being about 21 miles, its ratio to the outer circle will be about as 7 to 10, so that the cost of the detached works to be compared with that of the continuous line would be 42 millions of francs, in place of 60. This certainly appears conclusive, but a brief comparison of the length of the walls and parapets required for the lines shown upon the diagram attached to Colonel Owen's paper will make the question still more clear.

In that diagram there are two descriptions of continuous lines, one simply bastioned, the other of similar form apparently, but with the addition of caponiers in the ditch, flanked in front and rear by the short flanks of the line itself. The detached works are, I presume, intended for exact representations of the forts shown in the plates attached to Paper XIX, Vol. IX, "Professional

* Pages 176 and 177. † Page 172.

Papers." Now it will be manifestly best to take the same data, so far as is possible, in comparing the cost of these systems of defence, so as to eliminate all chances of misunderstanding in that respect; I will, therefore, assume that the general profile of the lines will be similar to that of the detached works along the faces and flanks of the latter. It will be presumed, also, that the forts are one mile from centre to centre; so that, if a line of detached works were required to make the complete circuit of a position—say 12 miles round—there would be required for it 12 forts, *i.e.*, one fort to one mile of the continuous line, exclusive of the sinuosities given to the trace of the latter for the sake of flank defence.

In the bastioned trace laid down in the above mentioned diagram, I find that $2\frac{1}{2}$ fronts just cover one mile. Each front will therefore have an exterior side 704 yards long, its faces, flanks, and curtain being respectively 204, 85, and 230 yards in length. The total length of escarp wall of the five flanks required for one mile of the line will then be 5 × 85, or 425 yards. Now, presuming that the flanks will be casemated, both for the purpose of giving effective fire along the bottom of the ditch, and of providing safe accommodation for a portion of the garrison, we shall not be far wrong in estimating their cost per yard lineal of escarp as the same as that of the keep of the fort, measured by the same standard; especially when we consider that on account of the polygonal or circular trace given to the keep, its inner dimensions are very much less than its exterior, the crest being actually 48 yards shorter than its escarp. Far less earth will, therefore, be required for its parapet; moreover its ditch, not being nearly so deep, will be less costly to excavate. Now, on referring to the plans in the 9th volume of "Professional Papers," it will be found that the total length of escarp of the keep is 200 yards. Between the escarp of the flanks and that of the keep there will then be a difference of 225 yards, a quantity more than enough to place against the three caponiers required for the ditches of the detached work.*

Next, as to the counterscarp and covered way. In the bastioned enceinte the length of the counterscarp for one mile of the line is 1,830 yards. The counterscarp in front of the faces and flanks of the forts measures, when developed, 662 yards, that of the keep 187 yards, making together 849 yards; and if to this we add the length of the escarp wall, built along the gorge of the work, viz., 294 yards, overlooking the absence of covered way in the two last instances, we have a total length of 1,143 yards to set against the above-mentioned 1,830 yards, showing an excess of 687 yards length of counterscarp, per mile, on the side of the continuous line.

Again, the total length of escarp of the faces and flanks of the fort, including the gorges of the caponiers, is 500 yards; whereas the total length of the faces and curtains of the bastioned line required for the space of one mile is 1,595 yards. So that we may conclude that to construct the continuous bastioned line shown in the diagram, supposing the flanks to be casemated, and bomb-proof accommodation provided for the garrison, there will be required about 1,100

* This assertion is based upon a careful comparison of the quantity of masonry required for the three caponiers with that required for the counter-arched escarp wall, as shown in the plans and sections referred to. As to earthwork there can be no doubt that a very much smaller quantity will be required for the caponiers.

yards lineal of escarp and parapet, and 687 yards of counterscarp and covered way per mile in excess of the quantity required for the detached works, occasioning an increase in the total outlay of at least one-third—a result not very different from that given in the estimate for the works at Paris.

On turning again to the diagram, it will be found that in the continued line defended by caponiers the fronts are about 900 yards in length, so that two caponiers only are required to defend the ditches along one mile of the line. Here Colonel Owen at once claims an advantage, but it is one which, on consideration, cannot be fairly allowed him. The lines of defence being so long, upwards of 400 yards, there is no doubt that a more powerful work will be required to flank them than in the case of the detached works, where the extreme length defended by the fire of a single flank is under 150 yards. If three guns be necessary in the latter case, four will be required in the former. I think it is a mistake to increase the length of our ditches in accordance with the superior ranges afforded by modern artillery, unless we at the same time increase the number of guns from which the defence is derived. As the line increases in length, so increases its liability to be assailed at more points than one, and the work expected from the guns is in a like proportion augmented.

Again, the detached works exhibited in the 9th volume of our "Professional Papers" are very elaborate and complete in their construction, and I contend that it is not at all reasonable to compare their cost with that of a line planned without regard to the same careful principles. Two caponiers would have flanked the ditches of the faces and flanks of the forts, whereas three have been employed. Now there can be no doubt that the increase of cost so incurred has resulted in a much more perfect and secure system of providing flank defence for the ditches; but the fact of there being three in this particular case does not arise of necessity from the works forming part of a line of detached forts. From these remarks it will be evident that we may assume the cost of the caponiers for the two fronts of the continuous line to be pretty much the same as that required for the caponiers of the fort.

The length of the faces and flanks of the fort we have seen to be 500 yards, and supposing that we make the same comparison as in the former case with regard to the counterscarp, there will remain about 1,300 yards of escarp, and 550 yards of counterscarp and covered way to be covered by the cost of the keep; a result quite as unfavourable to the continuous line as that arrived at in the case of the bastioned line, when we consider that in using the cost of the keep to cover the expense of part of the surplus line, we omit to provide a corresponding amount of bomb-proof accommodation for the troops, which they could not do without.

But it may be said, "In the above comparison, you have taken no notice of the saving in Haxo casemates, which it will be unnecessary to construct in continuous lines." I have taken no notice of them, and for these reasons—I consider that they will be required in one case as well as the other, and even if saved they would cover but a fraction of the expense left unprovided for. They would be necessary, because it would be impossible, except in very rare instances, to make flanks without exposing them to enfilade fire, on account of the very great choice of position afforded to besiegers by the long range of rifled guns; the only way to avoid having to build them would be to do without flanking fire above ground altogether, a principle of construction which would certainly cheapen your line, but which would as certainly cripple its capabilities of defence.

In the foregoing remarks I have considered these systems of defence, as applied solely to a site which is tolerably level, conditions of comparison manifestly most favourable for continuous lines: for as soon as we have to deal with an uneven broken site, the trace of these lines will be much increased in length, as they will have to advance or recede according to the accidents of the ground; the fronts will have to be more numerous, and the lines of defence much shorter. It is true that such a site would occasion an increase in the number of forts required, and therefore augment the cost of a line of detached works, but not to nearly so great an extent as in the construction of a continued line.

The next point urged upon our attention is that a continuous line "can be defended by fewer men, and those men far less trained."

Now, if "defended" means anything, it must be taken to mean "defended under all circumstances." There is no limit in the terms of the proposition; but when I examine the arguments upon which it is based, I find considerable limitation. The only case gone into is that of security against surprise, the most favourable one possible for continuous lines. If they are of any use at all, it will be for presenting a continuous obstacle against sudden assault; but these are not the only conditions under which we expect fortifications to fulfil their functions of protecting an important post, or of keeping the stronger from closing with the weaker. In the case of a siege by a powerful army, provided with abundant means of attack, the comparison must be very much in favour of the detached works. The number of points of attack is considerably reduced, and there may be a corresponding reduction in the number of defenders. There is not nearly the same extent of escarp to watch. Each work is as strong and secure in itself as any part of the continuous line, and would certainly require no more men to defend it than ought to be allotted to each of the fronts of the latter; and as the detached works are a mile asunder, while the fronts of a bastioned line would be at least two and a half to a mile, it may be fairly concluded that the garrison of the latter would have to be more than double that of the former.

But even in the case supposed by the author of the paper under discussion, I think it may be shown that he has not just grounds for the conclusion he arrives at. His remarks at first take the form of a reply to the common opinion that continuous lines require to be manned throughout their whole length, an opinion which cannot be upset, so long as it is applied to lines possessing only a field profile liable to be stormed at any point, and presenting nowhere an impassable obstacle; but if you increase the depth of your ditch, revet both sides, and raise your escarp to an unassailable height, you are no longer in the same danger of surprise, and may expect to reduce the number of defenders accordingly. Up to this point I quite go with Colonel Owen, and what he says about it is undoubtedly true, but when he goes on to apply this reasoning to the case of "Detached Works *versus* Continuous Lines," he has evidently got upon the wrong road. He says, "To call for more troops because a position is made more defensible is to admit that the art of the engineer is superfluous, or that the position need not be taken up at all." No one calls for more troops because a position is made more defensible.

To assume that a continuous line is more defensible than a line of detached works, is to assume the whole point contended for, and we should be justified in retorting with the latter part of the sentence quoted, and in saying that to make a long continuous line when a line of detached works will do, is taking up a position unnecessarily, and making a superfluous use of the art of the engineer.

Colonel Owen next seeks to avail himself of the fact that the polygonal outline of the detached work renders necessary a greater number of flanking points than will be required for the ditch of a continuous line. He reckons those of the former to be five in number for each fort, while for the latter he places three caponiers to one mile. Now, apart from the fact that the ditches of each fort may be flanked thoroughly from four in place of five points, it may be remarked that two of these caponiers fire from one face only, while all the caponiers of the continuous line fire from both faces; also, that the length of the line flanked being less, the work will be more efficiently done, and in each case by a smaller number of men. However, the difference is not really so great as Colonel Owen makes it appear when he proceeds to apply his estimate. He takes three forts to two miles and a quarter, placing one fort at one end of the line; whereas, when dealing with the caponiers of the continuous line, he places each extreme one 300 yards, the full length of his line of defence, within the ends of the line; so that in place of 15 to 7, as he states it, the proportion should be 10 to 6, even according to his own estimate. Again, with regard to the actual guard required for the parapet, who, with the proper reliefs, are dignified with the title of a minimum garrison,* it will, I think, be scarcely necessary to prove that the fort, forming a continuous enclosure less than 800 yards in perimeter, will require no more than half as many men to guard it as will be necessary for a continuous line one mile long. Or, taking the garrison as limited in number, say, to 300 men per mile, will not the duty of watching and guarding the shorter length of scarp be of the two the more efficiently performed? Colonel Owen says† the fortification is to do instead of men, but you will have to execute your work on a scale most gigantic, and to build your escarps with dimensions most stupendous before you can do without defenders.

But, we are told,‡ the intervals are left to take care of themselves; "the detached forts, to be of any use, require a strong manœuvring army in their rear." Here, I think, we are getting upon different ground, and mooting quite a different question, and one which I will presently discuss. What we are concerned with now is simply the garrisons required for the works in each case.

With regard to the assertion that the amount of training required for the defenders is less in the case of continuous lines, I must confess that some authorities lay it down as a rule that detached works ought to be defended by well disciplined troops; but so ought all works of defence, if possible. And I think when we consider the heroic defence of Arab Tabia, at Silistria, against the Russians in 1854, it must be allowed that there is nothing in the nature of a detached work which renders it unsuitable for defence by comparatively untrained troops. The most heroic defences on record are those where powerful moral forces have been brought into play, and the patriotic feelings of the besieged have not only converted every man into a finished soldier, but have

* Page 173. † Page 172. ‡ Page 173.

endued him with a spirit of self-sacrifice and resolution which must be often wanting even among the best disciplined troops; besides, the rule which I have mentioned is not exactly applicable in this case, for the comparison is here to be made between a simple continuous line and one of detached forts, both some 8,000 yards in front of the inner enceinte, and not between detached forts and the main enclosure of a fortress.

On the other hand, it may be reasonably argued that the defenders of the simple continuous line are subject to an adverse influence from which the garrisons of detached works are entirely free; and that is the uncomfortable feeling that all their efforts, however determined, to keep the enemy out of their position on one side, may be rendered entirely fruitless from his forcing his way in at another, as the moment a simple continuous line is forced at any point the whole must fall; the defenders, guns, ammunition, and stores of every description, being at the mercy of the assailants. It is true that, in the paper under discussion, an attempt is made to dispose of this objection by the assertion that a line of detached works is pierced already; but, surely, this is confounding the piercing a line in a military sense with marching troops into the intervals purposely left between detached forts. Until those forts are taken their garrisons must be deemed secure from the assailants, and the occupation of the ground between them and the inner line would be, as I hope presently to show, impossible for an enemy without the previous capture of at least one of the forts.

The third conclusion urged upon our attention is, that "the defence of a continuous line is simpler and easier understood by generals, by officers, and by men."

This conclusion seems to be based, so far as the general is concerned, upon the difficulty which it is supposed he will have in communicating with the commandants of the several forts. This is pressed upon us as likely to embarrass the general, and to lead both to mistakes and to an absence of unity in the efforts of the defenders. This source of weakness, however, may now be considered as almost totally removed by the introduction of the electric telegraph; by its aid constant communication can be kept up between the governor and those in command of the outer works, and by its aid will be rendered fruitless even the hypothetical summons by the besiegers at early dawn, conceived and put forward* as likely to lead to the surrender of at least one of the forts.

As to the commandants of the forts, I presume that every officer placed in command of a post makes it his business to study the course of action which he ought to pursue when the hour of trial arrives, and I do not see why in this case it is to be supposed that there are any difficulties to be mastered which he would not have to contend with, if in charge of a portion of a continuous line. Detached works are no novelties. We have felt their influence ourselves in conducting siege operations in former wars, and the instance given above of the defence of Arab Tabia by the Turks, to which others might be easily added, will suffice to show that detached works have been and can be successfully defended, without producing any extraordinary strain upon the military capacities of those responsible for their defence.

Additional difficulties for the defenders will, in Colonel Owen's opinion, arise from the arrangements made for providing flank defence for the ditches of each

* Page 176.

fort, and no doubt the freest access possible ought to be afforded to the caponiers and galleries constructed for this purpose. But provided there is that free and ready access—and there is no reason for the contrary, except perhaps in the case of counterscarp galleries—is it wise to condemn such defences for giving (for it really comes to this) too much security to those who are making use of them? Has the art of the engineer become at last too perfect? And because we protect brave men from the effect of an enemy's fire, are those men likely to become skulkers?* In the paper before us the comparative darkness of these "hole and corner flanks" is contrasted with the light streaming down from the heavens above upon the defenders of an open flank, but we must add the stream of enemy's shells, to complete the picture.

Moreover, underground or casemated flank defences will have to be provided in the case of continuous lines on the German trace. The salients of the caponiers will have to be defended either by counterscarp galleries or casemates in the escarp of the line itself, and these latter works, equally with the flanks of the bastioned line, may be battered and breached from a distance unless faced with iron. It is better to have a little difficulty in getting to a flank than to have a flank so placed that, in a day's firing, the enemy may render it useless.

In the 5th conclusion, it is asserted that continuous lines appeal most to the patriotism of the citizen; and it is argued that volunteer defenders will be easily found to co-operate in the defence of the walls of their native town, but not easily to compose garrisons for detached works. The former part of this argument may be quite true, but it is not much to the purpose; for a continuous line of defences 8,000 yards in front of the main enclosure is not exactly analogous to the walls of a town. The patriotic feeling which would be called into action by an invasion, should we unhappily become subject to one, would certainly bring forth defenders for the advanced line of works, whether they are detached or continuous. Both lines are on an equal footing as to their distance from the main enclosure, and there is no doubt that the garrisons of the detached works could be either relieved or reinforced when necessary, for, as will be presently shown, the ground within the outer line could not be occupied by the besieger's army, while that outer line remains intact.

The final deduction is commenced with the statement, "that continuous lines have been well and fully tried for thousands of years."

Now, it is perfectly true that continuous lines have been from the earliest days of fortification applied to form the main enclosure of a town or military position, but so far as I know, this is the first time that they have been proposed for application to an extended position, some 8,000 yards in front of the main enclosure, upon a permanent scale. The history of former wars tells us that for a long period it was the custom to defend military positions by extended continuous lines; but history also tells us that such lines were almost invariably broken through with ease by their assailants; and in practice, as well as theory, modern engineers show a decided preference for detached works alone where the defenders are very numerous, and for detached works connected by lines when the contrary is the case; rightly rejecting the simple continuous line on the ground that, for want of independent defensive points, it effects no economy in the number of defenders, and must fall throughout if pierced at any one spot.

* Page 177.

Colonel Owen claims the lines of Gallipoli and Balaklava as examples of continuous lines, but they form combinations, in each case, of the two principles of construction.

It is true that the positions referred to are fortified only with fieldworks, but in dealing with permanent defences, the reasoning which leads to the rejection of the simple continuous line only gains force and weight when we consider that the position to be fortified is a long distance in advance of an inner line. And on examining the different fortresses of Europe we find that such advanced positions are invariably occupied by detached works. We are told in the paper under discussion,* that it is not wise in English engineers to strike out a new line, and that in building detached works in such positions we are acting in opposition to the practice of all Europe, that "the Belgians on the Scheldt, the Russians on the Vistula, and the French at Lille and Toulon, are now building continuous lines of works." But this is a very imperfect statement of the real facts. If dependence can be placed on plans, the continuous works now being built at Toulon form but a moderate extension of the original enceinte; in fact to give more room for docks. The old enceinte, I presume, will be removed, and the new works will nowhere be more than 1,000 yards from the point protected, while on the heights around are detached works, built, no doubt, for the purpose of preventing the approach of an enemy within bombarding range of the dockyard.

Again, at Modlen, on the Vistula, which I imagine to be the Russian fortress alluded to, there is an inner line or citadel immediately covering the barracks and stores, and about 1,600 yards in advance is a second continuous line of works, the fronts of which are strengthened by ravelins. Surely, in neither of these cases are the new continuous works analogous to the lines which Colonel Owen recommends us to build 8,000 yards in front of our dockyards. One would suppose from his statement that detached works were never built by Continental engineers; but what is the fact? They form a very considerable part of the fortifications of nearly all the most important places, while in some, as at Lyons, for instance, they constitute almost the whole system of defence. At Cherbourg the land defences consist of an enceinte in close propinquity to the docks and buildings, with detached works about a mile in advance. In Austria, we are told by Colonel Delafield,† the general system of defence "for harbours and cities is to surround them with detached forts or redoubts encompassing a great surface, within which the city is beyond the reach of an enemy's guns." "The redoubts are for garrisons of from 60 to 200 men, and in some few instances for 1,000 men:" "the gorge having a masonry circular redoubt." "The old enceintes are preserved as interior lines of defence in some instances."

Colonel Owen goes on to say, "that nothing in the art of war has been discovered to supersede the old fashioned ditch, rampart, and parapet, not only as a battery upon which to mount guns, but as a means of keeping the stronger from closing with the weaker:" but surely he will allow that detached works can have ditches, and ramparts, and parapets, as effective for the protection of the troops within them as were ever applied in the form of continuous lines. And think a little consideration would serve to show that the guns placed on their

* Page 175.

† "The Art of War in Europe," by Colonel Delafield, U.S., Engineer.

terrepleins, though certainly fewer in number than can be mounted along the ramparts of continuous lines, will exercise proportionately a greater influence upon the efforts of a besieger, and be quite as difficult to silence.

The mention of these points opens up the whole question as to which of the two systems offers the most effective opposition to an army desirous either of forcing its way in for the purpose of gaining complete possession of the dockyard, or of attaining a point from whence it may be bombarded. In the paper before us it is alleged that the forts being a mile apart, and affording therefore perfectly open intervals of about 1,500 yards, the enemy may pass between them, either to attack them at the gorge, or to entrench themselves on the ground beyond, within bombarding range of the dockyard. In fact it is asserted that,* "except in some very exceptional cases, the whole of the ground within the line (of forts) may be held by a powerful besieger, the line of forts remaining intact." If this were possible, there would indeed be no protection from bombardment afforded to the dockyard, and the forts might as well have never been constructed. But is it possible?

To discuss the question on the ground selected, and subject to the same limitation, I will presume the case to be as supposed, and leave out of sight, all accessory defences and obstacles, as well as the possible existence of other detached works between the inner and outer line.

That a body of infantry might rush through the intervals is taken for granted, and I will not deny that they could, subject, however, to the necessity which they would be under of executing the movement by night. The attempt to march up to works, such as these model forts, in broad daylight, subject to the fire of numerous and powerful artillery along the whole route, and finally to pass within 750 yards of their flanks, mounting each 10 or 11 guns so placed that they could not be silenced, would certainly be too hazardous to attempt, and if attempted not likely to succeed. However, having got in, these troops, we are told, are to intrench themselves on the unoccupied ground beyond, and "the next night they can, in all safety, bring in guns, and open a fire on the gorge of the forts or on the inner line."† Mark the rapid sequence of the events, and how all difficulties seem to vanish under the vigorous treatment of this imaginary foe! The infantry had to make a rush of it, but the guns and trains get by next night "in all safety." Unoccupied ground is presumed to be safe from the fire of both forts and inner line, though the distance between them must be under 8,000 yards, and our rifled guns have ranged 9,000. But their troubles have not yet been all got over. Having to remain where they are for some few days at any rate, communication must be kept up with the interior, provisions and supplies of all sorts brought in, sick and wounded taken out, in fact, the thousand and one journeys that caused us such trouble and labour at the siege of Sevastopol. But what of that? A communication is soon made leading from the inner to the outer position. It will have to be some 8,000 yards long, it is true, and will have to pass between the flanks of two adjacent forts; but does that matter? Do we not all learn to make saps and double saps on the crest of the glacis, much nearer to the defender's works? We certainly do; but not until the artillery fire is silenced; and the guns in these flanks until silenced would quite prevent the formation of any sap in the position proposed.

* Page 167. † Page 173.

But I may ask, is not this project of attack quite contrary to all our received opinions upon the subject? The difficulty of communicating with the front at the siege of Sevastopol was excessive on account of the distance and the bad state of the roads, but would not those difficulties have been insuperable if the Russians had possessed a couple of forts such as these we are discussing, one on each side of the road within 750 yards? And would not the capture of both those forts have been a necessity before any attempt was made to occupy ground beyond them, unless some other and secure route had been open to us? And if necessary then, would not that necessity be threefold more urgent now, when forts are armed with rifled guns such as we possess? Or, to take another illustration from the same siege, the redoubts, thrown up by the Russians in front of the Careening Bay, were more than 1,000 yards distant on the right from the line along which approaches were being pushed forward against the Mamelon, and from thence against the Malakhoff Tower; but those approaches could not have been made had not the Russians been driven out of the redoubts above mentioned. If these redoubts exerted such influence in 1855, will forts have less influence now?

However, an instance is quoted of the inability of a fort to prevent the passage of artillery by it in the night. Napoleon passed his guns and trains under the fire of Fort St. Barre. What has been done once may be done again.

Let us look a little more closely at this illustration. On reaching the Fort St. Barre, in his famous passage of the Alps, and finding that it thoroughly commanded the road that he was traversing, Napoleon directed every effort to be made to take possession of it. Its outer defences fell into his hands by a successful surprise, but the fort itself resisted all his attacks, many lives being lost in the fruitless assaults made upon it. Finding himself baulked in his first project, Napoleon set all his staff to work to discover another route; but, though they succeeded in finding a passage for infantry secure from the fire of the fort, they could discover no pass practicable for artillery. Then it was, while the garrison were amused by these efforts and researches which were being carried on all round them, that Napoleon directed the road through the village, under the very embrasures of the fort, to be covered with dung and other soft material, and succeeded in, at last, getting his guns and train through, but not without some loss. So we find that Napoleon, though the boldest of generals, thought it necessary to take this fort before attempting to steal by it, and expended time, as well as the lives of many men, in the effort. But, after all, there is no real analogy between Napoleon's passing this fort and the attack imagined in the paper under discussion. Napoleon's army was not cut in two, as would be the case with these hypothetical besiegers; and he had no need for communication backwards and forwards along the road, which he had once successfully traversed.

I contend, therefore, that taking these forts even subject to the limitations assumed, they would not prove the total failure which is alleged, but would exercise such an influence upon the invaders as to compel them to sit down and besiege them in the ordinary manner. But it is not fair to take up the question in this way. There is no room for supposing the possibility of an attack in the manner proposed, as the following considerations will show:—

First—No invasion could be so sudden, and no surprise so complete, that the commandants of our naval ports would not have at least some days' warning, during which each could look to and strengthen the land defences of his post. And when we remember the numerous populations which surround our dock-yards, as well as the military labour at command, we may safely grant that there would be abundant time to create such obstacles across the intervals between the forts as would deny to a besieger the possibility of traversing them, subject as he would be to the fire from the flanks. Fieldworks might be thrown up, forming a continuous line between the forts, but retiring well back from them, and strengthened at the re-entering angle by an enclosed work.

Second—It will be seen that the feasibility of the proposed attack is in a great measure dependent upon the assumption that there is unoccupied ground between the inner and outer line, but which is seen from neither. This is altogether a question of site; and the probability is either that such ground would be defended by some intermediate work, or that the line of outer works would, at that point, recoil as it were upon the inner defences, the position taken up being such as to screen the point protected from the view of an enemy's batteries. It is admitted* that in the case of a perfectly level site, by giving the works a good command, the whole space between the inner and outer line may be brought under fire with rifled ordnance, so that the occupation of any part of it by an enemy would be rendered impossible; and from what has been shown with regard to the comparative cost of continuous and detached lines of works, there is no doubt that where it is considered advisable to construct intermediate works, that plan may be adopted without any fear of increasing the total outlay beyond what would have been required for a continuous line.

Putting aside then, as chimerical, the notion that an enemy could hold the ground within the forts, the line of forts remaining intact, I will proceed to say a few words on the respective qualifications of these two systems of defence when attacked in front by a powerful besieger.

For centuries, all engineers have concurred in the propriety of thrusting out, as it were, in front of the main defences, strongly marked salients, for the purpose of reducing the points of attack, and of massing upon these points all available means of defence, so as to neutralise as much as possible the superiority in numbers which a besieger is presumed to possess. Now, this most important principle receives its very fullest application in a line of detached works, but is totally neglected in the continuous line. On the latter, the enemy can advance with a broad front, and on numerous points. Along the great extent of line attacked, the besieged will be thinly scattered; and, distracted by having to defend simultaneously so many different spots, all equally fatal should the enemy once break in, it would be unreasonable to expect from them a successful defence. Here I claim a very decided superiority on the part of the detached works; and it may be remarked that the smaller the number of troops available for the defence, the more decided will this superiority be.

And if we presume that the garrisons are sufficiently numerous to resort to more active measures of defence, the comparison will again be immensely in favour of the detached works. The facilities they afford for sorties, of which a strong garrison might be expected to make a good use, will give them a great advantage over continuous lines. It is all very well to say that sorties are not

* Page 174.

difficult from properly constructed fortresses, but if that be the case, why have engineers, in the desire to give free egress from the works, proposed, and in actual practice ventured, to suppress counterscarps altogether? But whatever difficulties have been experienced in sallying from a fortress, these difficulties will exist in tenfold force when the line defended is a simple continuous enceinte, owing to the absence of ravelins or projecting salients of any description.

Or supposing that an enemy were besieging one of our naval stations on one side only, and that our forces in the interior of the country moved down to relieve the place. The general in command of this relieving army might be desirous of strengthening his chance of success by combining, with his own attack from without, a powerful movement from the fortress; and a few thousand men having been thrown into the place for this purpose, I contend that they, in addition to the regular garrison, might sally out between the detached works, their advance being supported and covered by the forts, with an ease and force which would be altogether denied them in the case of continuous lines.

Affording such advantages as these, and affording them, too, at the most moderate cost, it is no wonder that engineers, when seeking to prevent an enemy from closing with the main defences, have invariably built detached works at suitable distances in advance. And I may ask, is not the expediency of adopting such a course, greatly increased by the improvements which have taken place in artillery? While, on the one hand, the position to be taken up is much further in advance, and therefore more extended in length, on the other the longer ranges attained by rifled guns enable us to cover the ground with a smaller number of works, and thereby diminish the total outlay. And if with the shorter line it was deemed advisable, on the score of economy, to build detached works rather than continuous defences, surely, in dealing with the longer, we ought to follow the same course.

Cases might occur in which (as is stated in the article in the 9th volume of "Professional Papers," before alluded to) it might be deemed necessary to suppress the inner defences; and in which therefore it would be better to connect the detached works so as to close the interval between them; but this would effect no alteration in the principle on which detached works were applied to the position. Advocates of the continuous lines may perhaps say, "why, here is a continuous line after all, the very thing we were contending for;" and at first sight it might, perhaps, appear that the point has been reached at which the opposing parties may shake hands, and consider that an amalgamation has taken place. But in looking more closely at the matter it must be acknowledged that the independent system is still there, the original detached works, secure in themselves and denying the occupation of the lines between them by their perfect flanking fire both within and without, an element which is, I apprehend, altogether wanting in the simple continuous line. But, it may be said, "we will create defensive works along our line, which it will be possible to maintain after the enemy has taken possession of the curtain between them." And now, at last, I will grant that there is a chance of cementing our alliance. Our lines are certainly growing alike now; and if these entrenched positions are made equally as strong and self-defensive as the detached works, I am ready to allow that one line will be as good as the other. But what an expensive way to go about it! The curtains between the detached works need not cost half so much as the same length of the continuous line. Would it not have been much better to have taken up the principal positions first, and occupied them with powerful, well constructed forts? In case of threatened invasion, the intervals might have been secured through the aid of the many thousand hands which would work in such a cause both willingly and well, and as years rolled on, according to the peculiar exigencies of each case, if money could be spared, permanent lines might have been substituted for those of a temporary character.

Having now brought the examination of my subject to a close, I will sum up what I have been urging as follows:—

Independently of the exigencies of site, which will often dictate the course which can with most propriety be pursued, the system of detached works seems the most advantageous we can employ as an advanced line of defence.

1st.—On the score of economy, both in the expense incurred, and in the number of defenders.

2nd.—Whether the garrison be numerous or the reverse, it may be, relatively, used with the maximum effect.

3rd.—Though perfect in themselves, detached works can be easily added to, should the necessity occur, without any alteration of the general scheme of defence, or any departure from the principles on which they were constructed.

JOHN J. WILSON,
Captain, Royal Engineers.

PAPER XIX.

SIEGE OPERATIONS AT GRAUDENZ.

1862.

Communicated by COLONEL NELSON, R.E.,*

Accompanied by Extracts from a Report on the same subject by Major General F. W. Hamilton, C.B.

The fortress of Graudenz lies on a commanding height, insulated from the surrounding country by the low ground between the Ossa and Trienke, while its gorge rests upon a steep bank of the Vistula.

The immediate proximity of the fortress is free from buildings, and on the north side, at the foot of the glacis, there exists a piece of ground 618 yards by 412 yards, belonging to the Government, formerly a sappers' practice ground, upon which the contemplated works of attack could be undertaken, as far as it would be necessary to break ground.

The enceinte, built after the designs of Frederic the Great, is very strong in trace and profile, and its defensive capabilities are little, if at all, affected by the introduction of rifled cannon.

In its front are situated detached works, which, although small, would serve as useful points of support for the occupation of the ground outside the fortress by an active defender. There is, besides, an extensive system of countermines on each front, and this would admit of such experiments in mining, (which will probably play a most important part in future sieges) as would be possible at no other place.

The union of the above-mentioned favourable circumstances decided the selection in favour of Graudenz as the theatre for the proposed operations.

General scheme.

The general plan of the operations was adapted to the form of the piece of Government ground. An army on the east, on the right bank of the Vistula, was supposed to detach an infantry division, a regiment of cavalry, and four field batteries towards Graudenz, in order to secure a safe passage across the river by the capture of the fortress, under the supposition that the railway bridge near Marienburg and Dirschau was destroyed. This was presumed to be followed by the despatch of the siege equipment from Marienburg, one part by the Vistula and the remainder by the way of Marien-

* Translated from the German manuscript by the editor, Colonel Nelson's sight being at present too weak to allow him to undertake much writing.

werder. Simultaneously with these operations on the right bank, others were supposed to be carried on against the works on the left bank of the Vistula. The fortress was assumed to have its proper equipment and garrison.

The actual attack was to be carried on against bastions Nos. IV and V, and after the capture of the detached lunettes Nos. III and IV (which command the field of attack), No. IV ravelin and bastion were to be chosen as the special points of attack.

Duration of the practice.

The duration of the practice was limited to 6 weeks, of which 2 were allotted to the preparations, and 4 to the actual siege works. As the discharge of the reserve* was to take place on the 1st September, the practice commenced on the 12th July and ended on the 23rd August. In the last week of August the levelling and disarming of the works took place.

Personnel.

Three Sapper Battalions of the 1st Sapper Inspection—total 36 officers, 128 non-commissioned officers, and 780 Sappers, were ordered up to Graudenz to take part in the operations.

There were, in addition to the number of officers just stated, those on the staff of the Sapper Inspection, making with some others a total of 53 officers, the distribution of whom and of the troops was as follows:—

a. For the attack, 29 officers and 7 Companies of Sappers.
b. „ defence, 14 „ 3 „ „
c. „ a committee to direct experiments and record results, 7 officers.

The chief command, especially of all practice in connection with the Infantry, was given to Lieut. General von Wasserschleben, Inspector of the 1st Engineer Inspection.

The technical portion fell to the charge of Colonel von Schweinitz.

Lieut. Colonel Clausius (Commanding 1st Battalion of the East Prussian Sappers) was Commanding Engineer of the attack; and Major Braun (Commanding the Battalion of Sappers of the Guards) was Commanding Engineer of the defence; Major Weber (Commanding 2nd Battalion Pomeranian Sappers) was President of the Committee of Experiment.

The military attachés of the English, Austrian, and French embassies were permitted also to be present.

Materiel.

A sum of £1,050 was allowed for the purchase of siege materiel; the equipments of the three sapper battalions, 14,745 lbs.† of mining powder, and (by special permission) 2,268 lbs. of gun cotton were also available.

Preparations for the practice. *a.* Defence.

By authority from the Minister of War the fortress was placed in a state of defence on the fronts of attack, whereby much instruction was afforded both to the Engineers and Artillery.

The glacis on the fronts of attack were cleared of brushwood, so that there might be an uninterrupted view from the ramparts; the brushwood thus obtained being made into gabions and fascines. The covered way was palisaded,

* This refers to an essential feature in the constitution of the Prussian army, in which the Landwehr of the 1st Ban is recruited every year by those who have served their 3 years in the Line.—(See *United Service Journal*, September, 1839, p. 15.)—R. J. N.

† All weights and measures have been reduced to the English standards.—Ed.

the entrances provided with barriers, the places of arms with blockhouses, and other weak points strengthened with palisades.

The guardhouses at the gates were provided with regulations suitable to a state of war.

The detached lunette No. IV., which had a redoubt but no revetment, was made secure against assault by a palisade at the bottom of the ditch and at the gorge; a tambour was also constructed to cover the entrance.

The countermines were likewise made ready for service, the masonry galleries being extended with frames, mine-chambers formed, and all necessary preparations made for subterranean warfare.

Guns were mounted on the ramparts to oppose any attack by main force, and provided with the necessary materiel for their service.

Everything presented the appearance of the front of a fortress regularly armed.

b. Attack.

On the part of the attack, immediately after the arrival of the besieger's forces, the fortress was reconnoitred by the officers, and the front of attack determined on; part of the Sappers were moved into cantonments, and 2 companies were encamped, changing weekly.

Positions were selected for the depôts, the depôts themselves arranged, brushwood and mining timber prepared, and tools provided according to regulation.

The artillery park and the principal materiel depôt were placed on the same plain as the camp of the Siege Corps, 2,470 to 2,880 yards from the fortress, concealed from it by the nature of the ground. The laboratory and principal powder magazine were however farther off, 4,940 to 5,760 yards distant east and west of the Marienwerder Road. 3,000 gabions and 1,900 fascines were collected in the Engineers' depôt.

These preparations occupied two weeks, a period which, in an actual siege, is also requisite between the arrival of the Investing Corps and the opening of the trenches. The supply of the various siege materials afforded much practical instruction to the officers.

Proceedings of the siege. Trench operations.

The commencement of the siege by tracing the distant batteries, such as the long ranges of rifled cannon now render admissible, had been arranged in consultation with the Artillery, and the discussion called forth on this occasion has contributed to make manifest the changes which rifled cannon will introduce into the tactics of sieges, and to diminish as much as possible the number of points which must be reserved for the actual experience of war. The position of these batteries,* and the progress of the attack are shown on the plan.

The trace of the 1st parallel was determined by the form of the ground, and occupied a position 620 to 660 yards from the fortress, the same as was selected at the siege of 1807. The actual excavation of the 1st parallel was not undertaken, because as the fields were not reaped, the compensation money would have been out of proportion to the funds available for the operations. To advance from the first parallel, it was necessary to capture lunettes Nos. III and IV. The storming of the armed lunette No. IV formed therefore the commencement of the operations. The front of attack and No. IV lunette were occupied on the 25th July by eleven companies of infantry. The troops told off for the attack were

* The position of the whole of these batteries is not shewn on the plan attached to this paper. They were most of them behind the first parallel, at a distance from it varying from 450 to 35 yards, according to the nature of the ground.—Ed.

formed in order of assault. Detachments of sappers removed the obstacles before and in the ditch of the lunette, and made a partial opening in the palisades by exploding a powder bag, through which, after repulsing a sortie of the garrison, the infantry immediately rushed, and, with the aid of the sappers, entrenched themselves in the lunette.

On the following evening, 26th July, the 2nd parallel was opened by common trench work, its right flank resting on the steep bank of the Vistula. As on the day before, part of the infantry were deployed opposite the fronts of attack, part were employed in the construction of the parallel, and another portion in covering these working parties from sorties.

After the 2nd parallel had been widened and prepared for the reception of the guard of the trenches, the execution of the demi-parallel, by flying sap, was carried out during the evening and night of the 29th July. In spite of difficult soil the workmen soon succeeded in obtaining cover, and in excavating the trench to the necessary depth.

As the demi-parallel was within effective range of small arms, the approaches were now made by single sap, and the flying sap was used only occasionally during the night. From this time forward the military duties were performed by reliefs, so that the work progressed uninterruptedly night and day.

The authorised method of executing common trench work and flying sap will not in future require any essential change, since they will be carried out under cover of darkness at a greater distance from the fortress. As regards the single sap, on the other hand, by means of which the approaches have to be constructed up to the crest of the glacis, it becomes necessary carefully to consider whether, owing to the improvements in fire-arms, the rules respecting it can be carried out as heretofore. Before Sevastopol an entire change had to be made in the construction of the single sap; and the artillery experiments carried on at Magdeburg in the present year have proved that the ordinary sap parapets will be pierced by shot from rifled cannon and must therefore be strengthened. The more difficult question however is, as to how the sap roller, under the protection of which the single sap advances, is to be kept in its place as a moveable means of cover, since its remaining stationary is hardly to be depended on. These two questions, the solutions of which will be the foundation for the proposed revision of the rules for sapping, have been already considered in executing the approaches in front of the demi-parallel, and the lodgments on the glacis. It was proved that, as a general rule, the strengthening of the parapet must be attained by deepening the trench, and that instead of the single sap, that called "Erd-walze" or Turkish sap must be used. The more detailed investigation of these ascertained results must however be reserved for further experiment.

An additional and much discussed subject of experiment was that of endeavouring to determine the most suitable form of "embuscades" or rifle pits. Since these had proved to be of use to both sides at the siege of Sevastopol, it did not seem out of place to try a series of different proposals for the best form to be given them, and to ascertain that which could be most quickly constructed, and which, by giving good cover to the rifleman, would facilitate his aim. These experiments have led to good results.

On the 11th August the execution of the 3rd parallel and the construction of the mine lodgment were completed, while on the right flank the mining operations commenced, a more detailed description of which will be found further on; on the left flank the double sap was advanced to the crowning of tho glacis.

At this stage of progress of the works of attack, the commandant of the fortress executed an interesting defensive operation on the 16th August. At dusk tho besieger endeavoured to crown the covered way by assault, and to open the postern gates. Six companies of infantry advanced rapidly from the trenches, rushed into the covered way and down into the ditch. They were however observed, and the garrison lit up the ditch with light balls, threw shells and hand grenades into it, and opened fire from the flanks. The assailants were obliged to retire; they had however succeeded, under cover of this manœuvre, in commencing to crown, by flying sap, the covered way in front of the salient of No. IV ravelin.

The crowning was continued on the following day, and widened for tho assembling of the columns of assault, a breaching battery constructed in it, and the descent into the ditch commenced. The length of time—10 days—occupied in the construction of this descent is worthy of note. It was owing to the great depth of the ditch, to the tenacity of the ground, and to the strength of tho masonry of the counterscarp, which was so great that it could be overthrown only by gunpowder.

As soon as the breaching battery was finished, it was armed with a short and long 24-pdr.; the bringing of the short one through the narrow winding passage of the lodgment occasioned no difficulty; the transport of the long one, on tho other hand, required the exertion of great strength and very skilful management of the thickly crowded detachment. It plainly showed how great an advantage it would be to facilitate this difficult operation by the substitution of the 12-pdr. rifled gun for the long 24-pdr.

After breaking through the counterscarp, the passage of the ditch to the supposed breach in the right face of No. IV ravelin was effected, and preparations made for storming the main escarp, which was to terminate the practice, as the mining operations on the right flank were drawing to a close.

Mining operations.

The preparations for the mining operations on the part of tho defence were commenced at the time of mounting the guns, and continued until the opening of the trenches. On the ground allotted to the attack, a space 82 yards wide was set apart for the mining practice; its boundaries were not allowed to be encroached on either by the attack or defence. These limits were imposed, partly with regard to the means available, and partly with a view to the greatest possible preservation of the galleries of the countermines.

Within the mining ground there were three principal galleries issuing from the revetted counterscarp, and provided with branches and listeners according to Lahrsch's system. These having been lengthened and completed with wooden frames, were ready to oppose the besieger's progress above ground, and to compel him to resort to subterranean warfare. They were from 18 to 31 feet below the surface, and were 105 yards long. In consequence of their great length, much care was requisite in regulating the communication, in the renewal of the air, and in every part of the arrangements, which precautions would not be needed in mining operations conducted on a smaller scale. The present opportunity was therefore of great value for the instruction of both officers and men; and so far as could be managed in time of peace, in order to give them still further practice, the work was continued without intermission night and day, and secrecy on both sides carefully preserved.

Captain Bogun von Wangenheim, with the miners of the battalion of Sappers of the Guard, conducted the defensive mining operations, Captain Kurtzrock, with the Prussian and Pomeranian miners, those of the attack. The superintendence of the operations on both sides was entrusted to Majors Braun and Weber, who relieved each other every 24 hours.

The besieger had excavated a separate lodgment in front of the 3rd parallel along the whole breadth of the mining ground. The left flank of this lodgment was slightly thrown forward, so that the heads of all the countermine galleries should be at an equal distance of 45 ft. from it.

The plan of attack was to advance from eight galleries at a distance of from 25 to 30 ft. apart, to mislead the defenders and induce them to make premature explosions; then to push forward as quickly as possible, and spring an overcharged mine; and afterwards, from the crater of this mine, to drive new galleries in different directions.

While therefore the defenders were preparing listening stations at the head of their galleries, the underground work of the besieger was commenced on the 11th August. He did not long remain undiscovered. As early as the 13th August the listening apparatus announced that the besieger's miners were plainly to be heard, and at midnight of the same day, the defenders considering that the besieger had come within their reach on the right flank, determined to spring their first mine loaded with 257 lbs. of powder. The distance had however been underrated; the gallery of attack (No. VIII) was uninjured, and the charge produced a small crater, which the besieger occupied, with the view of entrenching himself there during the night and forming a lodgment from which he might push on so as to get closer to the countermines. The defenders, immediately perceiving the danger which threatened them in this direction, quickly removed part of the tamping, introduced a 2nd charge of 41 lbs. of gun cotton, and destroyed No. IX gallery of the attack just commenced. This charge produced a considerable effect; notwithstanding which the besieger again endeavoured to advance from the same point, particularly as he thought the defenders had injured themselves by the explosion. As soon as the effects of the explosion became evident, he commenced a new gallery, No. X, and worked forward energetically. But hardly had the work advanced any distance than it was again destroyed, the defenders having succeeded in removing part of the tamping of their previous charge, and in loading and firing another almost in the same spot.

Equal energy was displayed in the defence in the centre of the mining ground, where a gallery (No. IV) 10 feet distant, was completely destroyed, and another (No. VI) 6 feet distant, was rendered unserviceable.

Meanwhile the besieger succeeded on the 4th day of the mining operations in driving (unknown to the garrison) No. III gallery 42 ft. long, and in loading it with a charge of 2,710 lbs. of powder. The springing of this mine opened a crater 72 feet in diameter and 15 feet deep, and destroyed two of the defenders' listening galleries, as well as his own galleries to the right and left of it.

The besieger had, by the effect of this mine, gained possession of 72 feet of ground, and he lost no time in following up his advantage, for immediately after the crater had been formed into a lodgment and occupied by riflemen, three new galleries, Nos. XI, XII, and XIII, were commenced. His active adversary, however, surrounded him with fresh countermines, formed almost underneath the crater, and by a series of well placed charges, prevented all his attempts to advance from this crater up to the end of the operations.

The besieger now perceiving that he must provide himself with a larger base for his future advances, attempted to lodge two over-charged mines, one on each flank. The end of No. I gallery on the right, which would have been suitable for this purpose, had been destroyed by the garrison. He succeeded, however, in again establishing himself in it, and as the defenders were prevented by bad weather, from exploding another charge in their counter-galleries, the besieger, on the 7th day of the mining operations, hurriedly prepared a charge of 1,031 lbs. of gun cotton, for the purpose of producing a second large crater. This charge of gun cotton corresponded, according to Austrian data, to 3,093 lbs. of gunpowder; from experiments made at Berlin, with gun cotton prepared at Spandau, it would be equivalent to only 2,577 lbs. of gunpowder, and at this latter rate, the present charge corresponded about to that which the besieger had first exploded. The result of the explosion did not equal the anticipated results, the diameter of the crater being only 62 feet, 10 feet less than that of the first over-charged mine.

After the besieger had, by this means pushed forward on his right flank, he made every effort to advance on his left, from the small crater formed by the first mine of the defenders, which had been since gradually enlarged. But all his efforts failed. No sooner was a gallery, by dint of great effort, commenced, than the defenders blew it up. The besieger was consequently obliged to retire to the original lodgment, and operate from thence through gallery No. VIII, which was still standing. As its direct prolongation would fall on ground completely honeycombed by previous explosions, it was turned to the left, and a charge of 1,700 lbs. of powder lodged and exploded at its end. The crater produced had a diameter of from 54 to 61 feet, and a depth of 18 feet. The distance from it to the first crater was too great to allow the besieger to suppose that the defenders had no uninjured galleries between. To drive them out of these, a flying sap was formed to connect the two craters, a shaft sunk in its centre, and an untamped charge of 1,031 lbs. of powder placed at the bottom of it.

An additional object of this proceeding was to ascertain whether it was possible in one night to prepare an untamped shaft mine, and to explode it the next morning. The experiment was successful, and the explosion produced a crater with a diameter of from 31 to 36 feet, and 8½ feet deep, and sufficient effect was produced to drive the defenders out of any galleries they might have had in the interval.

As a parallel experiment to the preceding one, an untamped shaft mine of similar dimensions to the last, was prepared on the following night, loaded with 412 lbs. of gun cotton, and fired next morning. The result was a crater 29 feet in diameter and 7½ feet deep, considerably smaller than the effects of an equivalent charge of powder. On the other hand, the under-ground effect extended to a much greater distance. The difference of action of the two kinds of charge could be clearly distinguished; while the explosion of the powder was of a quieter nature, the earth was ejected in a conical form, and the crater was of a symmetrical shape—the action of the gun cotton was unequal and violent, the earth was thrown up vertically, and fell back into the crater, the sides of which were irregular and jagged.

During these proceedings of the besieger, the defenders were not idle. They attentively watched every advance of the galleries of attack, contrived to destroy them by a repetition of small charges, and to produce such an effect upon the earth in the immediate neighbourhood of the craters, that it lost all consistency, and the execution of any new galleries thus became more and more difficult for the besieger.

On one occasion, when, after the customary purification of the air, the miners advanced into a counter-gallery, close to which a charge of gun cotton had been fired, an explosion of fire-damp took place, and three miners were more or less burnt. The wounds healed after a few days, but this accident shewed that on occasions of this kind, safety lamps ought to be provided.*

After eleven days' uninterrupted exertions, the besieger had succeeded in advancing a third of the distance to the crest of the glacis, with the view of establishing a new position by means of five over-charged mines. He had driven 31 galleries, of which the greater part had been destroyed by the defenders. The latter had sprung 16 camouflets, and lost their advanced position; but their second one being uninjured, they would be enabled from it to continue an obstinate resistance. It was, however, undeniable that their strength was beginning to be exhausted, and this was to be accounted for by the unwearied and active zeal, both day and night, of a comparatively small body of men, and from the occasional, but constantly recurring, illness arising from the foul air in the mines.

At the conclusion of the mining practice, a still larger overcharged mine than any of the preceding ones was exploded, for the purpose of ascertaining the surface and subterranean effects of large charges in undisturbed ground. At the bottom of a shaft prepared for the purpose, a charge of 4,950 lbs. of powder was loaded and fired. The explosion produced a crater 82 ft. in diameter and 22½ ft. deep; the earth was thrown to a height of 409 ft., and spread over the ground in a circular form with a diameter of from 620 to 825 ft. The subterranean effects extended as far as 101 ft. from the charge.

The mining operations thus brought to a conclusion, conducted as they were with so much zeal and intelligence, have not only supplied practical lessons to those immediately engaged in them, but will by their recorded results be of lasting value.

* I do not know how far our experiments in mining with gun cotton have gone, nor what has been thus given to the Corps; but it would appear from these Graudenz records, that the subject invites further attention, and demands decision; especially in these days of Long-Range, in which we may have to resort somewhat more to subterranean warfare than hitherto.

"Fire-damp" (carburetted hydrogen) thus ignited, yields "choke-damp" (chiefly carbonic-acid gas), though there are other sources in coal mines for this last. I learned at the Sydney mines in Cape Breton, that about 1 part of fire-damp and 9 of common air gave the most violently explosive mixture; and that the miners continue to work and breathe for some short time in a mixture of 2, 3, or perhaps 4 parts of gas diffused through the galleries, even though they have all lamps stuck in their hats.—R. J. N.

The results of the operations may now be summed up by the following observations:

1. That practice in an extensive system of countermines, long discontinued, has been again revived.

2. That the renewal of the air in long galleries, so important a matter in mining, has been, by the introduction of a new apparatus, effected better than heretofore.

3. That the problem of the certainty of the explosion of mines, unsolved up to the present time, has been, by the careful use of different preparations, so far determined, that no charge missed fire.

4. That listening experiments for the determination of an enemy's position should be extensively tried.

5. That the operations of mining warfare might be further improved and understood, particularly as to the value to be placed upon a simultaneous action with overcharged mines, their number being determined by the locality.

6. That the existing tables of charges for overcharged mines and camouflets have been tested and corrected.

7. That finally an opportunity has been afforded of putting to the proof, the Austrian assertion of the superiority of gun-cotton for mining purposes.

With regard to the last observation, it must be remarked that the gun-cotton for the present operations, made at the Spandau Powder Mills, has produced, in large charges, inferior results to gunpowder, while, on the other hand, in small charges, as in camouflets, an at least equally powerful subterranean effect has been obtained with it as with powder. It has been also observed that the gases resulting from the explosion of gun-cotton produce more violent and lasting illness than those arising from that of gunpowder. As a means for breaching palisades and stockades, and for petards, gun-cotton has established its superiority here equally as in Austria.

On the evening of the 23rd August, the final manœuvres, in which the infantry joined, took place.

On the supposition that the right face of No. IV ravelin had been breached, that the fire from the fortress had been completely silenced by the superiority of that of the batteries of attack, that the flank defences of the ditch had been destroyed, and that the energy of the diminished garrison was beginning to be exhausted, an assault on the ravelin and an escalade of the body of the place were attempted simultaneously. The columns assault of were assembled in the lodgments on the glacis and adjacent trenches. The formation of these columns for the passage of the gallery of descent, and the arrangement of the requisite time were made subjects of previous careful consideration.

On the appointed signal the first column advanced through the gallery of descent and deployed at the foot of the supposed breach; the succeeding columns, provided with scaling ladders, advanced along the ditch of the ravelin, placed them side by side in the ditch, raised them up against the escarp (28 feet high), mounted to the top of it, thence rushed up the parapet, formed upon the crest, and drove back the hastily assembled garrison.

The Artillery then dragged through the gallery of the descent a short 24-pr., in order to place it, if necessary, upon the breach, and thence make an opening in the retrenchment.

These siege operations, so valuable in their results, and so interesting from the experiments connected with them, were thus brought to a close.

EXTRACTS FROM A REPORT BY

MAJOR GENERAL FREDERICK W. HAMILTON, C.B.,

ON THE SIEGE AND MINING OPERATIONS AT GRAUDENZ, ON THE VISTULA,

COMMENCED 23rd JULY AND ENDED 23rd AUGUST, 1862.

On the 23rd of July the operations commenced by the enemy driving the outposts of the garrison across the river Ossa, and taking possession of the town of Graudenz, thereby restricting the besieged to the plateau. The Artillery and Engineers at the same time commenced the establishment of their parks of artillery and stores of materials for the siege.

On the 24th, the besiegers formed a line of circumvallation, driving the besieged behind their most advanced works.

On the 25th July an intermediate depôt of tools for sappers was formed, and at night the 1st parallel was opened, and the construction of the enfilading batteries was commenced.*

These were completed the following day (26th), when a fire was opened from all of them. Some of the advanced works, including lunette No. IV, were stormed; the besiegers established themselves in it (see Plan I), and at night opened the 2nd parallel and constructed approaches to it. The batteries in the 2nd parallel were also commenced.

The 27th was a day of rest.

On the 28th, the 2nd parallel, and the approaches leading to it, were widened; at night the batteries were armed, and a line of rifle pits dug on the alignment of the future half-parallel; the approaches to these were made by the flying sap.

The following two days (29th and 30th) were spent in completing these works, and during the night of the 30th rifle pits were dug where the 3rd parallel was to be made, and approaches to the 3rd parallel were commenced by the single sap. These works were continued on the 31st July and 1st August; the heads of the approaches were connected with the 3rd parallel, and the approaches themselves were widened on the 2nd August.

On the 5th, the 3rd parallel was completed. Bomb-proofs and other covered places were constructed in it; and the approaches to the crowning of the glacis by the double-sap with sap rollers were commenced. Preparations were also made for the commencement of the mining operations. A trench or mining lodgment, 100 yards long, out of which the several mining galleries of the besieger were to be driven, was constructed 12 to 15 yards in front of, and communicating at both ends with, the 3rd parallel.

It will be observed (see Plan I) that the attack, as far as the 3rd parallel, had been carried on against all the threatened parts of the fortress in a similar manner. From this period, however, while the attack against the right face of No. IV ravelin and left face of its adjoining No. IV bastion was carried on by the direct sap to the crowning of the glacis; the attack against the left face

* These works do not appear to have been actually constructed, but only traced.—See Page 201, and Plate I,—Ed.

of the ravelin, and the counterguard in front of it, owing to the extent of defensive mines constructed under the glacis in front of those works, was carried on by the besieger by a system of mining operations.

From the lodgment in front of the third parallel, the besieger drove eight galleries to distances varying from 28 to 40 feet, and at an inclination of from 1 in $2\frac{1}{2}$ to 1 in 3. It may here be remarked, that all the mining operations were carried on on both sides as they would be in a regular siege, the Commanding Engineer on each side having no further knowledge of the operations of his adversary, than what could be gained by listening to the progress of the miners under ground. When either party was ready to spring a mine, he reported the fact to an independent committee of three officers, who superintended the whole work, and who gave orders, by sound of bugle, for all parties to quit the trenches and mines. After each mine was sprung a detailed report of its effect, and of its success or failure was drawn up, and operations were immediately resumed.

The first mine sprung by the besieged was on the 11th August, in the left branch of the right direct gallery, when suspecting that the enemy's miners were nearer than they actually were, the former sprang a fougass charged with 41 lbs. of powder at a depth of $17\frac{1}{2}$ feet. It did not, however, interrupt the besieger's progress, and as soon as their gallery was clear of smoke, the besieged during the next two days advanced 10 feet, when hearing the enemy's miners approaching very close, they charged a mine with 257 lbs. of powder at a depth of 19 feet. (See No. 1, Plate II.) This was sprung on the 13th, by which about 8 feet of the besieger's gallery, No. 8, was destroyed; the surrounding ground below the surface was disturbed to the extent shewn by the dotted circle; the dimensions of the crater, 12 by 16 feet are also indicated. The besieger immediately took advantage of this crater and occupied it, driving forward a gallery from its southern side.

On the 14th, the besieged having prolonged their centre direct gallery to within a few feet of the enemy's inclined gallery No. 4, charged a mine with 227 lbs. of powder, at a depth of 22 feet, the explosion of which destroyed 9 feet of the besieger's gallery.

On the same day, and again on the 16th, two fougasses, charged with 41 lbs. of gun cotton each, were exploded near the entrances to the inclined galleries Nos. 1 and 3; the lines of least resistance were 6 feet. The effect was to destroy a small part of the parapet of the "lodgment of the mines," which was shortly repaired.

On the 15th, the besieged sprung two mines, Nos. 4 and 5. No. 4, of 227 lbs. of powder, at the extremity of one of the right branches of the centre direct gallery, (the line of least resistance being 22 feet,) by which 7 feet of No. 6 inclined gallery of the enemy were destroyed. No. 5, of 103 lbs. of powder, was laid in the left branch of the right gallery, and was sprung with the view of interrupting any progress the enemy might be making in the gallery which he was driving from the crater of No. 1 mine; the result was quite successful, the whole gallery being destroyed. *

* This gallery on the right of No. 5 countermine, as well as two small portions on the left of it, should have been shaded *dark* to denote that they were destroyed.—Ed.

In the meantime, however, the enemy had worked uninterruptedly in No. 3 inclined gallery, to a distance of 46 feet, and had there prepared a surcharged mine of 2,710 lbs. of powder, at a depth of 22½ feet. This was sprung on the 15th with very successful results, producing a crater 72 feet in diameter, with a depth of 15 feet. The earth was shot out to a perpendicular height of 263 feet, and the cone of dispersion of the ejected soil averaged from 140 to 159 feet radius. The underground effect was to destroy the whole of their own No. 3 inclined gallery, as well as part of the permanent countermines, and 26 feet of the prolongation of the centre direct gallery of the besieged. No sooner had the smoke cleared away from the crater, and the effects of the explosion been ascertained, than the besiegers commenced establishing themselves in the crater, converting the side towards the fortress into a parapet, and completing the communication with the trench in rear. They also commenced driving 3 inclined shafts from the bottom of the crater, against the permanent galleries of the besieged.

On the 16th, the besieged had advanced in their left direct gallery to within a few feet of No. 1 inclined gallery of the enemy; when hearing the enemy's miners, they sprang a mine, No. 7, charged with 324 lbs. of gunpowder, at a depth of 18 feet. The explosion destroyed about 8 feet of the extremity of No. 1 inclined gallery, as well as about 12 feet of their own. On the same day they had advanced in the extreme right branch of the centre gallery, when, under the impression that the enemy was mining in the immediate neighbourhood, they charged a mine, No. 6, with 227 lbs. of powder; the effects of the explosion however did not reach any of the enemy's mines, but destroyed a portion of their own. The crater of No. 6 was small, but the enemy occupied it and commenced driving galleries from the bottom of it towards the fortress.

As soon as the smoke of No. 7 mine had cleared away, the enemy commenced the requisite repairs in their No. 1 inclined gallery.

On the 18th the besieged sprang another mine, No. 9, with 216 lbs. of powder, in the left branch of the right direct gallery.

On the same day the besiegers having completed the surcharged mine at the extremity of No. 1 inclined gallery, sprang it, destroying thereby two of the most advanced right branches of the left direct gallery. This mine was charged with 1,031 lbs. of gun-cotton, the line of least resistance was 23 feet from the original surface of the ground; but No. 7 mine of the besieged having been previously sprung near the same spot, that line was somewhat reduced. It was calculated that the effect would be equal to that produced by 2½ times the amount, or 2,577 lbs. of powder. The following however were the results:—The depth of the crater was 16 feet, or 1 foot more; the extreme height to which the masses were thrown was 272 feet, or 8 feet more, while the diameter of the crater was only 62 feet, or 10 feet less. The cone of dispersion was from 108 to 150 feet of radius.

As soon as the smoke had cleared away a lodgment was made in the crater; and a communication was effected with the adjoining crater No. 1.

At a later period, on the same day, the besieged sprang three mines, charged with gun cotton, with the view of destroying the cover the enemy had made for themselves in No. I crater, and of damaging the galleries they were pushing forward from it. For this purpose, they had repaired part of the direct branch in continuation of the centre direct gallery, and laid No. 10 mine, charged with

82 lbs. of gun cotton. They placed No. 11 mine, charged with 124 lbs. of the same material at the extremity of the right and most advanced branch of the left direct gallery, and No. 12 mine charged with 82 lbs. of the same, at the extremity of the left permanent branch of the centre direct gallery. Several of the galleries were destroyed by the explosion, and the cover of the enemy in crater No. I in part weakened, but the latter was restored during the following night.

On the 19th, the enemy, with the view of completing a more advanced lodgment, had been preparing a surcharged mine at the extremity of their No. 8 inclined gallery, which they had repaired since the explosion of No. 1 mine of the besieged had checked their progress. This mine, with a line of least resistance of from 23½ to 24½ ft., was charged with 1,700 lbs. of powder; the effect of the explosion was great, destroying the advanced galleries of the besieged, and affording immediate cover to the enemy for driving two galleries, forward. The masses of earth were thrown to a height of 305 feet, the dimensions of the crater were 54 to 61 feet in diameter, its depth 17 to 18 feet deep, the average diameter of the cone of dispersion was from 105 to 161 feet radius: small masses were thrown by the explosion in the direction of the wind to a distance of 438 feet. A communication about 51 feet long, forming a salient angle in the centre, was completed between the crest of this crater and that of No. 1.

On the 20th, the besieged had been preparing a mine, No. 13, charged with 216 lbs. of powder in the left branch of the right direct gallery; it was exploded at the same time as the besieger's surcharged mine, and the effects could not be estimated separately.

On the completion of the communication between Nos. I and III craters, the besieger sunk a shaft in its salient angle to the depth of 10 feet, and lodged 1,031 lbs. of powder in a chamber at the bottom, marked No. IV, Plate II. There was no tamping in the shaft, nor was the chamber formed in a return, the consequence of which was that when the mine was ignited the masses of earth were thrown to a much greater perpendicular height than from larger mines well tamped, viz., 338 feet, while the diameter of the crater was only 31 feet. Some splinters of wood were thrown to a distance of 400 feet, the cone of dispersion however was very small, the masses of earth falling within a radius of from 40 to 42 feet.

A more advanced communication was now effected between the new-formed crater and No. III crater, and at its salient and most central part another shaft was sunk with the object of lodging a charge of gun-cotton; this operation was continued during the night of the 20th August, and was completed by the following morning; the shaft was 10 feet deep as before, without any return for the chamber. The mine was charged with 412 lbs. of gun-cotton instead of 1,031 lbs. of powder. The effect of the explosion was what might have been anticipated from the more sudden ignition of the gun-cotton and the non-tamping of the mine. Some masses of earth were thrown to a height of 383 feet; the diameter of the crater was from 27 to 29 feet, and the cone of dispersion from 50 to 75 feet radius. Splinters of wood were thrown to a distance of 149 feet.

21st.—In the meantime the besieged had been preparing three more mines to resist the progress of the enemy, of which two, Nos. 14 and 15, were charged with 324 lbs. each of gun-powder, and No. 16 with 154 lbs. of the same.* No. 15 was placed in the extreme right advanced listening gallery of the right branch of the left direct gallery, with the view to checking the advance of the enemy in the gallery which he was driving from No. II crater. The galleries were however getting so choked with the fumes of the exploded cotton and powder as to render any further working in them injurious to the health of the troops. Nearly 5,150 lbs. of powder however remained unexpended, with which it was determined to charge one mine, to judge of the effect produced by so unusually large an explosion. As the soil in continuation of most of the existing galleries had been much shaken and loosened by successive previous explosions, it was determined in this instance to select a spot between the left and centre direct galleries, and in the centre of this spot to sink a shaft.

This was commenced on the 22nd of August; a chamber was excavated on one side at a depth of 20 feet below the surface of the soil, and the mine was charged with 4,950 lbs. of powder. The powder was contained in bags weighing 20 lbs. each, three bags occupying about one cubic foot.† The effect of the explosion was truly magnificent: the whole earth shook, and the eruption of large masses of tenacious clay produced a scene rarely witnessed in military mining operations. Many huge masses were hurled 412 feet perpendicularly into the air; the cone of dispersion was from 313 to 375 feet radius. The crater, 22½ feet deep, was from 80 to 85 feet in diameter.

The effect of the falling of these large masses of tenacious clay on the surface of the ground was remarkable. First entering the soil as a solid mass, they spread out till their upper surfaces were flat and nearly level with the surrounding soil. In the act of spreading out they turned up the edges of the surface turf, thus presenting the appearance as if it were produced by an upheaval of the ground from below; indeed some spectators for a moment imagined that parts of this great charge had forced their way through underground channels, and had produced so many small craters, but they were soon undeceived.

The springing of this mine concluded the operations of the siege; various other experiments were made however, at different periods, to which I will refer in due course.

Gun Cotton underWater.

With the view of testing the force of gun cotton under water, 41 lbs. of that material, calculated to produce the same effect as 103 lbs. of gun powder, were enclosed in a waterproof case and fastened at a depth of 10 feet below the surface of the Vistula. Upon this mine being ignited by means of a galvanic battery, a thin column of water rose to a height of 307 feet, far above the heads of the spectators, who were standing at the gorge of the fortress, 215 feet above the river, and formed a strong contrast to the previous explosion of 4,950 lbs. of powder.

The amount of powder allowed for the foregoing experiments, is equal to 20,400 lbs. of gunpowder; that is 14,730 lbs. of gunpowder, and 2,268 lbs. of gun cotton, which being equal in effect to two and a-half times by weight the force of gun powder, is equal to 5,670 lbs. of gunpowder; total, 20,400 lbs.

* The position of charges Nos. 14 and 16 could not be ascertained on the original plan.—Ed.

† The mine was tamped with sods of earth from the chamber to the level of the ground.

The cotton used was manufactured by the Prussians, but according to the Austrian system; whereas, however, the Austrian gun cotton produces three times the effect of powder, the Prussian produces only two and a-half times the effect. The Austrian gun cotton cost 60 dollars, or £9 per cwt. The Prussian cotton which is not so effective, cost 120 dollars, or £18 per cwt.

It was remarked during all these mining operations, that the fumes generated in the galleries by the explosion of gun cotton, were much more prejudicial to the men's health than those of the common gunpowder, and the surgeons were always enabled, after a man had described his sufferings, to say, whether he had been brought out of a gallery where gunpowder or gun cotton had been exploded. The headaches produced by the fumes of gunpowder, were always felt across the forehead, and were removed after three or four hours spent in the open air. Those produced by the fumes of gun cotton were always felt across the top of the head, and were much more severe as well as of longer duration.

The following table, No. 1, shews in a tabular form the amount of powder and cotton expended each day in the several mines during the operations. Tables 2 and 3 give the dimensions of the craters, and other details connected with the explosions of the several surcharged mines.

TABLE I.

Expenditure of Gunpowder and Gun Cotton during the Siege Operations at Graudenz. August, 1862.

			Defenders.		In the Attack.		Select Committee.	
	No.	Date.	Powder.	Cotton.	Powder.	Cotton.	Powder.	Cotton.
Fougasse.		11	41	.. ..	.. ..	.. ..	26	.. ..
Camouflet.	1	13	257	.. ..	.. ..	.. ..	.. ..	.. ..
"	2	14	227	.. ..	.. ..	.. ..	.. ..	.. ..
"	3	14	.. ..	41	.. ..	.. ..	.. ..	.. ..
"	4	15	227	.. ..	.. ..	.. ..	.. ..	.. ..
"	5	15	103	.. ..	.. ..	.. ..	.. ..	.. ..
Surcharged mine.	I	15	.. ..	.. ..	2,710	.. ..	.. ..	.. ..
Camouflet.	6	16	227	.. ..	.. ..	.. ..	.. ..	.. ..
"	7	16	324	.. ..	.. ..	.. ..	.. ..	.. ..
"	8	16	.. ..	41	.. ..	.. ..	.. ..	.. ..
"	9	18	216	.. ..	.. ..	.. ..	.. ..	.. ..
Surcharged mine.	II	18	.. ..	.. ..	.. ..	1,031	.. ..	.. ..
Camouflet.	10	18	.. ..	82	.. ..	.. ..	.. ..	.. ..
"	11	18	.. ..	124	.. ..	.. ..	.. ..	.. ..
"	12	19	.. ..	82	.. ..	.. ..	.. ..	.. ..
Surcharged mine.	III	19	.. ..	.. ..	1,700	.. ..	.. ..	.. ..
Camouflet.	13	20	216	.. ..	.. ..	.. ..	.. ..	.. ..
Surcharged mine.	IV	20	.. ..	.. ..	1,031	.. ..	.. ..	.. ..
Camouflet.	14	21	324	.. ..	.. ..	.. ..	.. ..	.. ..
"	15	21	324	.. ..	.. ..	.. ..	.. ..	52
Surcharged mine.	V	21	.. ..	.. ..	.. ..	412	.. ..	.. ..
Camouflet.	16	21	154	.. ..	.. ..	.. ..	.. ..	.. ..
Surcharged mine.	VI	23	.. ..	.. ..	4,950	.. ..	.. ..	.. ..
Descent of ditch.	Wall.	21	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Submarine mine.	Water.	23	.. ..	.. ..	.. ..	.. ..	.. ..	41

TABLE II.

MEMORANDUM RELATING TO THE SURCHARGED MINES DURING THE SIEGE OPERATIONS AT GRAUDENZ.

No.	Charge.	Powder or Cotton.	Line of least Resistance.	Diameter of Crater.	Height to which stones were thrown.	Depth of Crater.
	lbs.		ft.	ft.	ft.	ft.
No. I.	2,710	Powder.	22½	72	263	15
No. II.	1,031	Gun Cotton.	23	62	272	16
No. III.	1,700	Powder.	23½—24½	54—61	305	17—18
No. IV.	1,031	Powder, not tamped in perpendicular shaft.	10	31	338	10
No. V.	412	Gun Cotton, in perpendicnlar shaft not tamped.	10	27—29	383	10
No. VI.	4,950	Powder.	20	80—85	412	22½
No. VII.	41	Gun Cotton under water in Vistula.	10		307 about.	

TABLE III.

The cones of dispersion of the masses of earth and stone thrown into the air by these explosions, had the following dimensions:—

No. I. 140 to 159 feet radius.

No. II. 108 to 150 feet radius.

No. III. 105 to 161 feet radius. Small masses of earth were thrown in the direction of the wind, to the distance of 438 feet.

No. IV. 40 to 42 feet radius. N.B.—Splinters of wood were thrown to the distance of 400 feet; while the earth, as shown by the small circle of dispersion, appears to have fallen down again nearly perpendicularly.

No. V. 50 to 75 feet radius. Splinters of wood as far as 149 feet,

No. VI. 313 to 375 feet.

The following is a short account of the three systems of ventilators used in the galleries during the siege operations.

Ventilators for mines.

Ventilators used during the siege operations at Graudenz for ventilating the countermines, &c.

1. The cylinder blowing machine (brought from Stettin by the Pomeranian Battalion of Sappers).

It consists of a double bellows with a receptacle for air. It has produced by far the best effects. It extinguished at the end of a leaden pipe, 300 feet in length, a lighted candle placed 6 feet from its embouchure.

2. The miner's ventilator, by R. W. Dumendahl, near Steele.

It is made entirely of iron, generally upon the old system; not with a simple shovel wheel, but with a fan wheel, so that the air cannot escape sideways, but only at the periphery of the wheel in the direction of the tangent.

There is a tin case, 2 feet 3 inches in diameter, in which the fan wheel turns. The air enters freely on one side of this case and is driven out at the top. By means of suitable pipes or tubing, this machine can also be applied to the purpose of drawing out the bad air from the mines. It has many advantages over the old ventilator.

3. The old ventilator.

This machine has met with very little success, and will no longer be used.

4. The simple field forge bellows, which was exclusively used by the besieger, belongs properly to the pontoon train.

The first and second of the ventilators above referred to were used by the defenders; the first proved to be the most efficient. They were placed in the ditches near the entrances to the countermine galleries, and they were protected from the fire of the enemy by bomb-proofs.

The following memoranda show the relative qualities of the three kinds of fuzes used, viz. of

1. Bickford's patent quickmatch.*
2. The Austrian gun cotton fuze.
3. The American patent electric safety fuze.

The Austrian Gun-Cotton Fuze.

A plaited wick of gun cotton enclosed in a linen tube steeped in caoutchouk.

Its tested properties:—

1. It is easily ignited.
2. If it has been kept perfectly dry and is laid upon the ground, it will burn quickly through without ceasing, however much it may have been pressed, or however it may have been handled.
3. If it becomes damp it burns much slower, and by fits and starts.
4. All breakages are quickly repaired by simply tying the two ends together.
5. It is very easily affected by moisture, and must therefore be preserved in the driest possible places.
6. If it has become damp, it can be made serviceable again by drying in the sun.

* The description of Bickford's fuze is omitted, being the same as that used in our own service.—Ed.

7. The caoutchouk tubing is not water-tight, but it preserves the fuze to a certain degree from the dampness of the earth.

8. A length of 50 feet of this fuze when perfectly dry, burns in 1½ to 2 seconds; when it is damp, in from 10 to 20 seconds.

9. It is very light and easily handled, 1 foot in length weighs 0·3 ounces.

10. It does not deteriorate by transport.

Patent Electric Safety Fuze of Gomez in Washington.

A tube or covering of gutta percha covers an internal tube of paper, in which the composition is placed. This composition consists in equal parts of

Blei eisen cyanür and
Chlorsaurem kali—chlorate of potash.

There are two kinds of fuzes:

1. The land fuze.
2. The submarine fuze.

The submarine fuze is protected by another resinous covering in addition to the gutta percha tube.

Their tested properties:—

1. It burns through very rapidly. In a length of 50 feet no appreciable difference was observed between the commencement and termination of the ignition.

2. It is very easily ignited, and the progress of combustion is certain.

3. The rapidity of combustion ensures the simultaneity of the explosion of several mines.

4. The branching off of several trains is easily effected by splitting the fuze up the middle for a distance of half an inch, and by placing the two ends that are to be fastened together in such a manner that the composition in them may lie in contact, their surfaces having been first roughened. The junction is then secured by crossties.

5. The composition is not easily affected by damp.

6. It is very light, the foot weighing about 0·3 ounces.

7. It is easily handled and protected from external injuries.

8. One foot of it costs sixpence English.

9. The Berlin imitation fuze costs only threepence English, *i.e.* but little more than half as much.

10. The submarine fuze has not always proved itself water-tight when placed under water.

From the foregoing observations it will be remarked that the American patent electric fuze possesses greater advantages than the other fuzes.

The Prussians have adopted three different methods for igniting the charge.

1. By galvanism (the voltaic battery).
2. By Electricity.
3. By the safety fuze.

1. The galvanic battery employed consists of 36 cells enclosed in a wooden case 10 inches square and 5 inches deep. The lid, to which the plates are fixed, is supported a little above the top of the box by four spiral springs at the corners, and the battery is made to act by the simple action of pressing the lid down, by which operation the plates become immersed in the acid.

The apparatus for igniting the charge is thus constructed :—

The extremities of the two copper wires from the battery are brought into a conical plug, made of three pieces of wood; the central part is a flat piece of wood; the two sides are half cones, or nearly so, truncated, and they have cut out of them on their inner flat surfaces a furrow, into which the wires are securely fastened, so that they cannot slip out. The points project beyond the plug, and to these is fastened a small platinum wire. The three component parts of the plug are bound together by two bands of wire, and for security in travelling, a wooden stopper is fitted on to the small end where the platinum wire is fastened. When required for use, this stopper is taken off, and before inserting the plug into the charge of powder, a composition of sulphur, antimony, and another ingredient, is placed over the platinum wire. This composition ignites more freely than gunpowder, and secures the discharge of the mine with greater certainty, than when the plug is charged with powder only.

2ndly. By Electricity. A copper wire passes through as many charges as it is required to ignite. This wire is cut in two in each charge, and the two extremities are brought near to each other. The electric spark, passing from one to the other extremity, ignites each charge simultaneously. The electricity is produced in the usual way by the friction of a wheel. Less wire is required by this method than by the former, but it is not so certain in its results.

3rd. The third method is the American safety fuze, referred to in a previous page, when treating of fuzes.

Ventilating tubes.

The tubes now in use for conveying the air forced into the galleries by the ventilator, are lengths of caoutchouked linen pipes, 2 inches in diameter, with tin mouth pieces 6 inches long, to fit one to the other. They cost sixpence per foot. A new kind of tube is recommended, made of zinc, 3 inches in diameter, and to cost but little more than 8½d. per foot; 600 feet would cost 150 dollars or £22 10s. It has been proposed to lay down permanent pipes of this kind under the floors of the galleries, these pipes being furnished with screws at each end, to fasten other lengths to them, with knees for turning the angles of the branches.

Lighting up the main ditch.

On the evening of the 17th August, a feigned attempt was made to carry the fortress by storm; an operation which, considering there was no breach and the scarp revetments were everywhere 30 feet high, would have been in reality impracticable. The besiegers were supposed to take advantage of the moment after springing a large mine, to descend the counterscarp of the redoubt of the covered way, to run along and across the main ditch, and force an entrance from the lower gate in curtain No. 4. The ramparts were manned, guns placed to defend the gate, and other preparations were made to resist an attack. The principal object of interest was the method adopted by the garrison for lighting up the main ditch on a dark night, as soon as the first alarm of a night attack might be given. This consisted in igniting large balls of fire fastened to a small truck on two wheels, which was let down the exterior slope of the rampart, until it rested on the berm or top of the scarp revetment. One of these placed in the middle of the curtain, and two on each of the adjoining bastion faces, were sufficient to allow the garrison to see every movement of the attacking party, while they remained themselves in comparative darkness.

Arming the breaching batteries.

On the night of the 21st August, two guns were brought up the double sap from the rear of the third parallel, to the breaching battery on the crest of the glacis, a distance of 247 yards.

The first gun brought in was a short 24-pr., weighing—Gun, 2,692 lbs.
Carriage, 1,650 „

Total .. 4,342 lbs.

20 men were employed, and the operation was completed in 14½ minutes.

The second gun was a heavy 24-pr., weighing 54·6 cwt., the carriage weighed in addition 26·3 cwt., total weight 80·9 cwt. During the first part of the operation 24 men were employed; this number was found insufficient, and at a later period 40 men were put on, and the operation was completed in 2¾ hours, but about half-an-hour was lost by the wheels in one place sinking and becoming firmly imbedded in the sand, and much difficulty was experienced in raising them again. When in the battery, the guns were placed 16 feet from each other, measuring from centre to centre.

Descent of the ditch.

The descent into the ditch was effected opposite the right face of the ravelin No. 4, and presented no remarkable features, while working through the soil, which was of a very tenacious character. The stancheons and capsills were placed as usual, and the work was finished in good style; the progress averaged to be 6 feet in the 24 hours. On reaching the back of the counterscarp wall, the work progressed much slower, owing to the stone-work and hardness of the mortar; but it was facilitated by the use of small charges of gunpowder, which were so regulated as not to disturb the remaining parts of the counterscarp.

Blowing up palisades.

Several experiments were made on the 22nd August with the view to testing the relative efficiency of gunpowder and guncotton in making breaches in palisades.

The first series of experiments was made against strong palisades of the covered way, (dimensions not given.) A charge of 26 lbs. of cotton destroyed 9 palisades, making an opening of 9 feet 8 inches.

45 lbs. of powder similarly placed, destroyed 8 palisades, making a breach 8 feet 6 inches wide.

15 lbs. of cotton blew up 4 palisades, opening 6 feet 6 inches; and

46 lbs. of powder destroyed 7 palisades, opening a breach of 7 feet 6 inches.

The second series of experiments was made against a strong palisade, 8 feet high, strengthened by a second row of palisades 6 feet high, the palisades varied from 12 to 15 inches broad, and from 11 to 12 inches thick. 26 lbs. of cotton were placed at the foot of the front of the palisade; the explosion of the charge opened a breach 4 ft. 3 in. broad, breaking off the palisades flush with the ground.

The second experiment was with 77 lbs. of powder similarly placed, the result of which was a clear breach of 6 ft. 6 in.; the adjoining palisades not thrown down were all forced slightly out of the perpendicular.

The third series of experiments was against a row of fraises fixed on the top of the counterscarp of a ditch. No. 1 experiment was with 15 lbs. of cotton, laid on the upper surface, the explosion of which destroyed 5 fraises, making a breach 6 ft. 9 in. broad. The second experiment was with 46 lbs. of powder, which destroyed 2½ fraises, opening a breach of only 3 ft. 4 in. wide. On another occasion 27 lbs. of cotton blew up 3 strong palisades, and 64 lbs. of gunpowder blew up 4 palisades.

Amongst the many subjects proposed by the Prussian military authorities to be considered during these operations, was a revisal of the engineering regulations, which have been but slightly altered during the last 40 years, and their attention was at one time directed to the dimensions to be given to gabions, and to other materials and stores. It was determined to reduce the gabions from 3 ft. 2 in. to 3 feet in height. The fascines which were formerly 18 inches in diameter, and 9 feet long, to be reduced to 10 inches in diameter.

It was also proposed that the steps for sallying over the parapets of the parallels should be 10 inches high, formed by single fascines, instead of being made nearly double that height.

The question was also broached, though no definite conclusion was then arrived at, whether in the approaches and zigzags, the returns should not be made in prolongation of each sap to the front, instead of to the rear as is the practice; it was asserted that this new method would enable the troops to defend by a good flank fire the front of each trench.

Lastly. The attention of the authorities was called to the best dimensions and sections of rifle pits, called by them "embuscades." These must depend so entirely upon circumstances, that it would perhaps be difficult to fix upon any one definite plan. The questions raised were, whether they should be so constructed as that the soldier could kneel to the front when firing, or be enabled to lie against the breastwork, or sit down on a step, turning round to fire; whether there should be a step at the back of the rifle pit, to be used as a seat, or whether a small seat should be cut out on one or both sides in rear of the breastwork.

The opinions were generally in favour of sections having a step both in front and rear, or a step in front and reverse slope.

FRED. WM. HAMILTON,

Major General.

Note.—In addition to the two plates accompanying this Paper, Major-General Hamilton also furnished a third, of profiles of the different trenches. As, except in the matter of depth, they very much resembled our own profiles, I did not think it necessary to have the plate engraved. This increase of depth is referred to in Plate I, where it will be observed that the majority of the trenches are 4 feet and some 5 feet deep.

The "Erd-Walze," or Turkish sap, alluded to on Page 202, is (I am informed by General Hamilton) a term the Prussians apply to a trench 1 foot or 18 inches deeper than the ordinary sap; this enables the sapper to work so low down as to be protected from the fire of the fortress without the use of a sap roller.—Ed.

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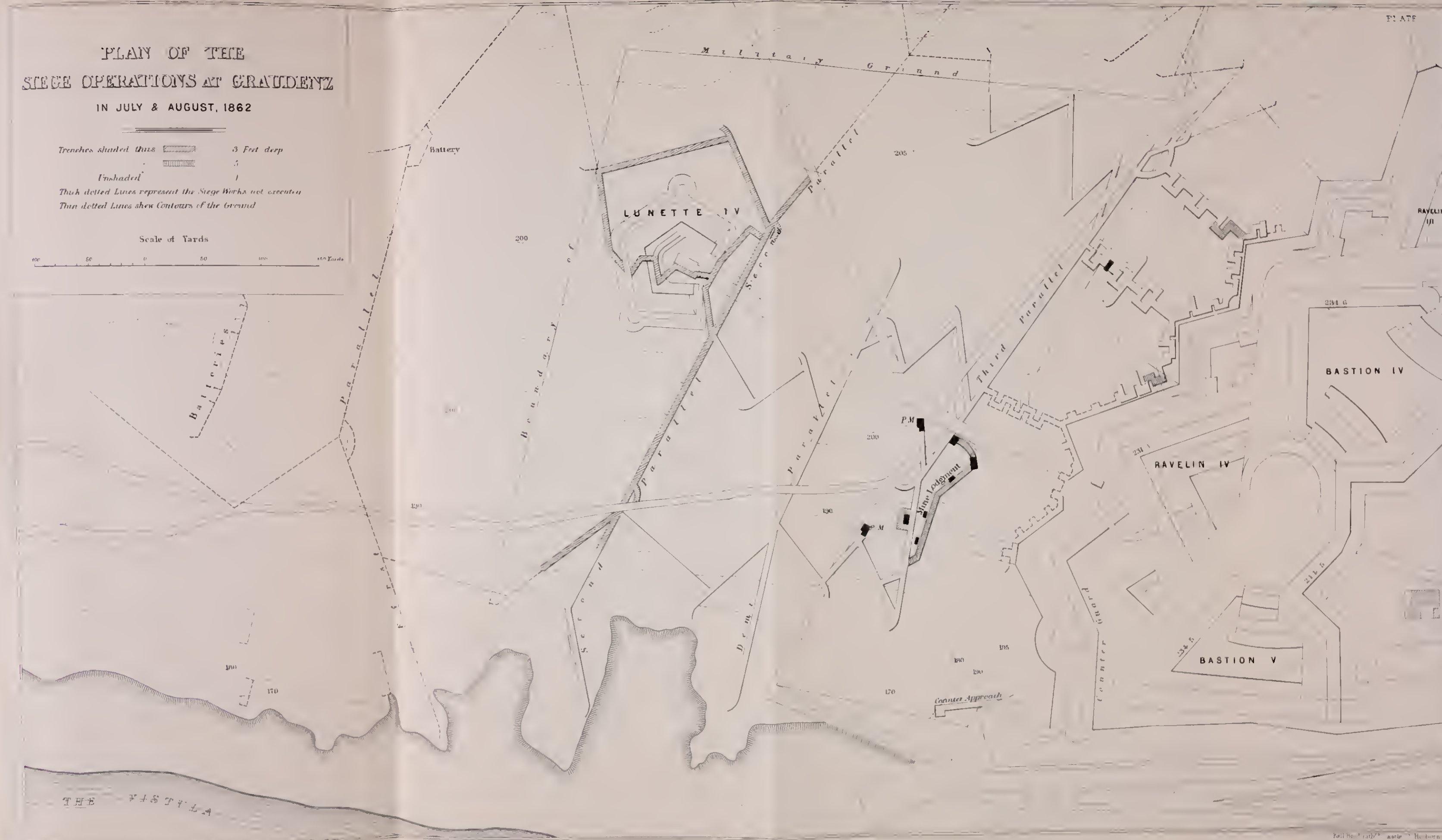
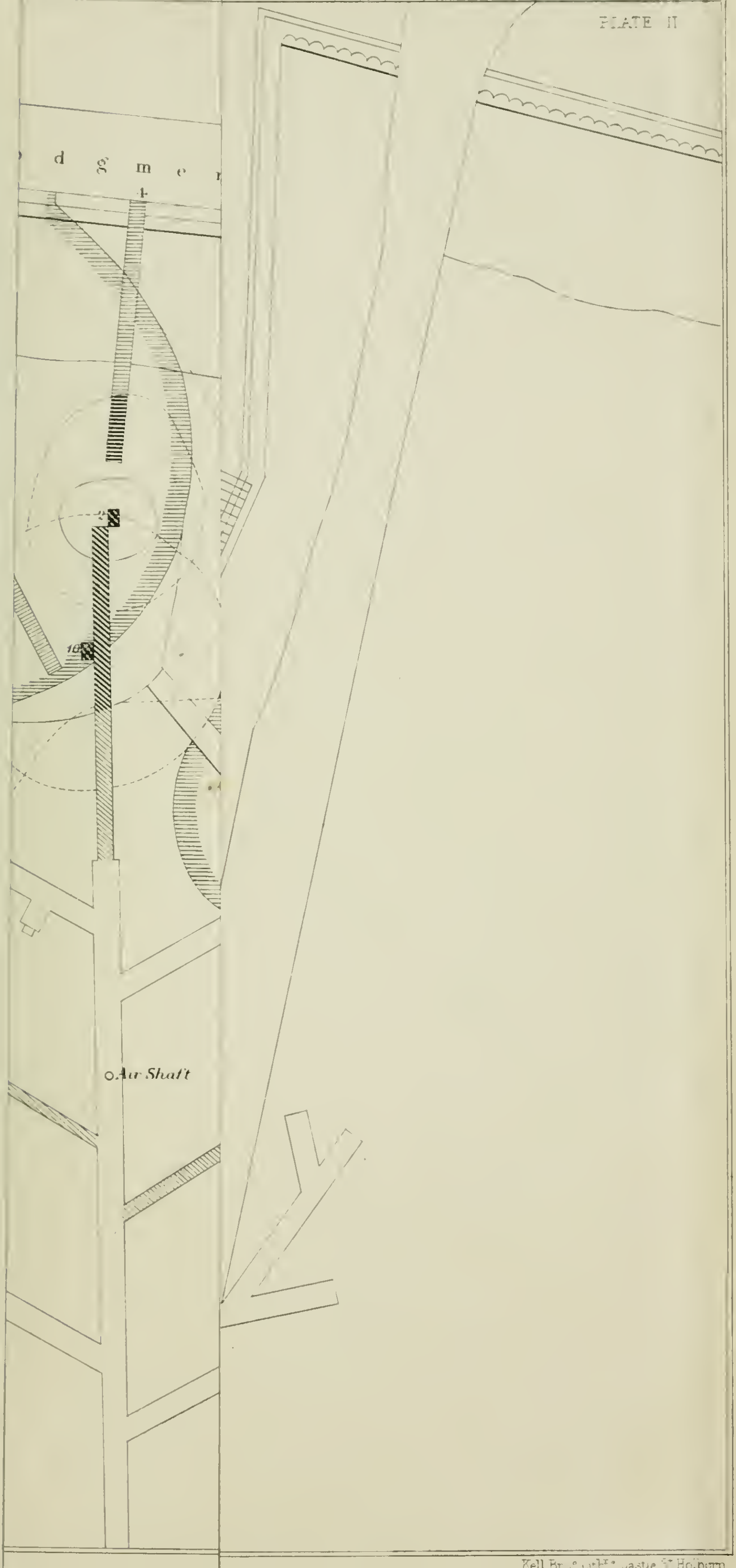


PLATE
PLAN OF THE
SIEGE OPERATIONS AT GRAUDENZ
IN JULY & AUGUST, 1862
Trenches shaded thus 3 Feet deep
5
Unshaded 1
Thick dotted Lines represent the Siege Works not executed
Thin dotted Lines shew Contours of the Ground
Scale of Yards
100
50
0
50
100
150 Yards
Military Ground
Battery
LUNETTE IV
Batteries
Parallel
First Parallel
Boundary of
Parallel
Second Parallel
Second
Demi parallel
Third parallel
Mine Lodgement
P.M.
RAVELIN III
RAVELIN IV
BASTION IV
BASTION V
Counter Guard
Counter Approach
THE VISTULA
205
200
200
190
190
180
170
170
180
190
195

PLATE II



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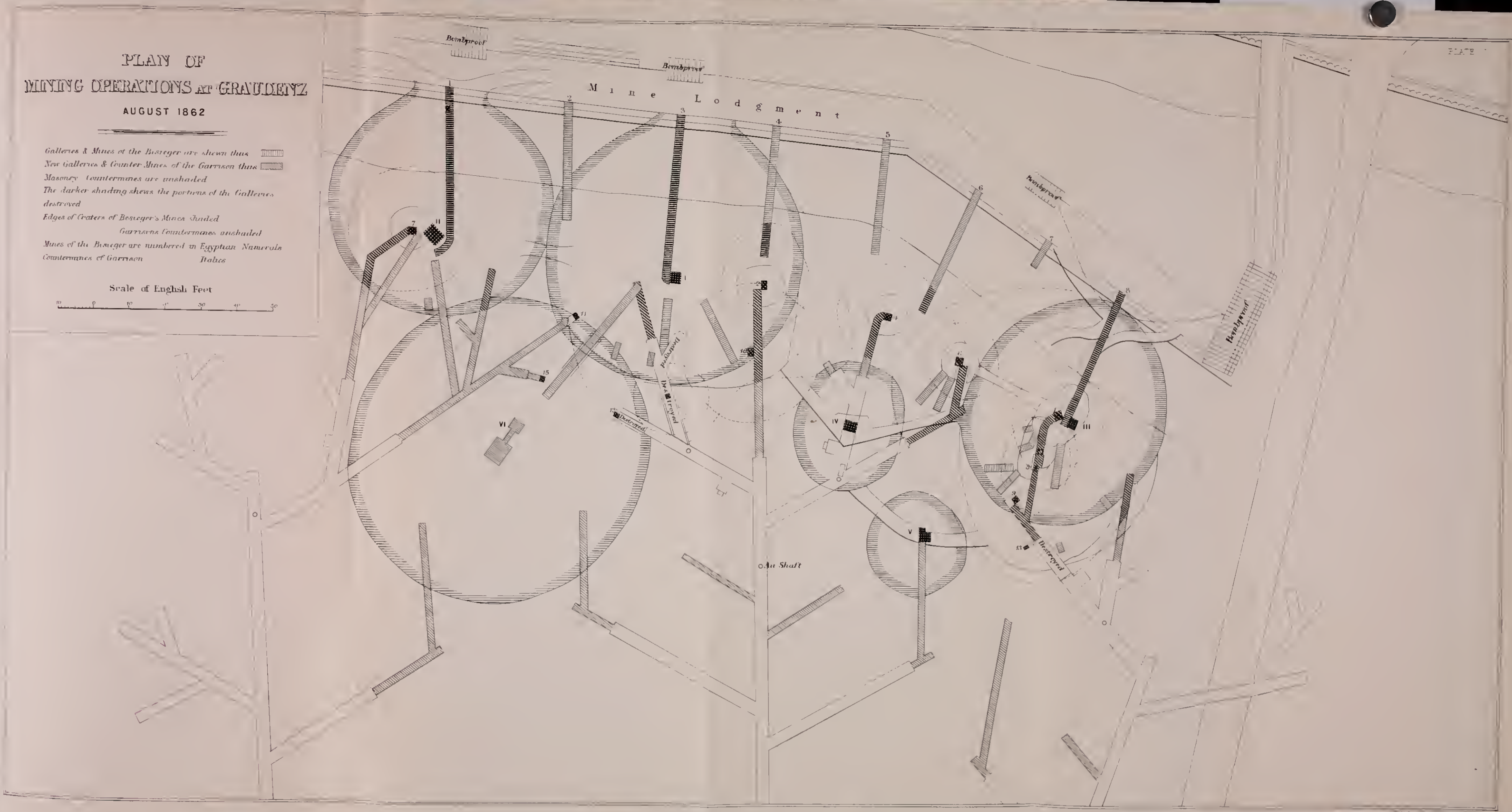
PLAN OF
MINING OPERATIONS AT GRAUDENZ
AUGUST 1862
Galleries & Mines of the Besieger are shewn thus
New Galleries & Counter Mines of the Garrison thus
Masonry Countermines are unshaded
The darker shading shews the portions of the Galleries destroyed
Edges of Craters of Besieger's Mines shaded
Garrisons Countermines unshaded
Mines of the Besieger are numbered in Egyptian Numerals
Countermines of Garrison Italics
Scale of English Feet
Mine Lodgment
Bombproof
Destroyed
Air Shaft