On The Utility of an Elementary Knowledge of Geology to the Officers of the Army and Navy

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To cite this article: Professor T. Rupert Jones F.R.S., F.G.S., &c. (1891) On The Utility of an Elementary Knowledge of Geology to the Officers of the Army and Navy, Royal United Services Institution. Journal, 35:158, 455-468, DOI: [10.1080/03071849109417298](https://doi.org/10.1080/03071849109417298)

To link to this article: <http://dx.doi.org/10.1080/03071849109417298>

Published online: 11 Sep 2009.

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Friday, February 27, 1891.

GENERAL SIR C. P. BEAUCHAMP WALKER, K.C.B., Vice-President, in the Chair.

ON THE UTILITY OF AN ELEMENTARY KNOWLEDGE OF GEOLOGY TO THE OFFICERS OF THE ARMY AND NAVY.

By Professor T. RUPERT JONES, F.R.S., F.G.S., &c.

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INTRODUCTION.—*Maps.*—Before setting foot on a country new to them the Officers of the Navy or the Army, like ordinary travellers, ought of course be already provided with the best available maps of the district. These may be only outline maps, simply showing by hatching and other signs the hills and dales, rivers and lakes, woods and fields, farms and towns, and such like. These would, of course, be valuable, as showing relative distances and some natural features. A contoured map, however, would be still more serviceable, showing exactly the flats, slopes, and precipices; and therefore the most accessible and the most difficult passes, as well as the easiest grades for roads. If, however, the map be geologically coloured, it would indicate among other things the probable *consistency* of the ground in the valleys and on the hill-slopes, and to what extent in length and breadth, how far and in what directions, the hard and the soft materials, such as clay, sand, sandstone, limestone, schist, and granite, stretch along or across the district under notice. Hence such a map would be of far more value than the uncoloured maps; warning the road-maker, for instance, to avoid some treacherous flats and some sliddery hill-sides, before ever he put his foot upon them.

Geological Map.—The use and value of a geological map can, of course, only be appreciated and applied with some knowledge of the principles and practice of geology. Geological Science comprises (1) a knowledge of the various materials of which the Earth is com-

posed; (2) how they are arranged one with another; (3) how they came into their present position; (4) how we can most conveniently lay hand on those materials which we specially want, and prove that they are exactly of the kind required, or in the relatively right places where we wish to use them.

Geological Science.—In the first place, to obtain a real knowledge of the rocks and minerals is to many a pleasant task, but involving time and labour, with hammer and pocket-lens in the field,—microscope, chemicals, and other appliances in the study; and for fossiliferous rocks a knowledge of zoology and botany. Some amount, however, of useful acquaintance with geological and mineralogical specimens can be acquired by earnest practical study in a limited time much less than a professional teacher has to give to the subject. Secondly, as to the natural position, arrangement, and appearance of rocks, whether stratified or unstratified, experience can be got only in the country, in cuttings, pits, quarries, mines, and cliffs. Thirdly, both books and direct observation have to be brought to bear on the facts and deductions as to how the many kinds of strata and the various masses of unstratified rocks were formed and arranged. These are the manifold results of the action of water and ice, disintegrating the earth's surface at some places, and rearranging elsewhere the materials so removed; and the more striking, but not more effectual results of heat and water combined in volcanic eruptions and deep-seated disturbances and changes. Fourthly, we come to Geological Art, or application of the Science. To those who cannot give years to the study of the principles of a science success in practice of the art must be limited, whether they pose as physicians, surgeons, chemists, painters, engineers, actuaries, or actors. Some handicrafts can be practised empirically by rule-of-thumb. Amateur photographers may be successful without an acquaintance with the origin of their chemicals, the laws of light, and so on. So also to some extent Geology may be practised as an art by Officers of the Army and Navy, and by intelligent travellers and tourists.

Fortunately now-a-days some instruction in natural philosophy and natural history, including geology, is given in schools and enlightened homes; hence we have not all to begin quite in the dark when it is desirable or necessary to take up geology as a definite and practical study. Taking this for granted, let us see how we can acquire, and how we can profit by an elementary knowledge of this useful science.

Geological Facts.—Whatever may be the aspect of any place not covered with buildings, we may be sure that some or other of the earthy or stony substances common all over the Earth constitute the subsoil and ground-work. The soil itself bears evidence of its real nature by the vegetation (natural or cultivated) covering it; and the bare rocks have their peculiar lichens, mosses, and weeds, and even larger plants holding on at ledges and fissures. These are helps to any one looking for indications of geological structure. Equisetum (horse-tails) on clay, and Pteris (bracken) on sand, are good guides in our latitude; and a mere stick plunged into one or the other will be a practical witness.

Dry places and wet do not occur indiscriminately, but have those conditions in accordance with the relative water-holding power of the soil and subsoil. Sand and clay are usually concerned here also; but, if the same kind of topographical features have not been seen and accounted for before, digging and cutting below the surface will be required. Some gravel heaths offer good camping ground; but under the top gravel lies a continuous irony bed, and this usually impermeable "pan" will retain the water of sudden heavy rainfalls, and cause the ground to be supersaturated and soaking-wet in every tent in a night, unless knowledge shall have previously examined the locality and broken through the hard "pan" at proper places.

In valleys and flats, besides the cuttings (if any) for roads and drains, the riversides and ravines would give some indications; but better far the upper courses of the streams and torrents, with rapids and waterfalls, expose the hard rocks in the hillsides. If he has no map, the observer will have to pace and plot the ground in his notebook; and indicate on his plan, as it grows, the occurrence of definite bands of stone, or beds of clay and sand; noting, not only their characters and thicknesses, but especially their inclination (if any) to the horizon ("dip"), and the direction by compass, in which their exposed edges ("outcrop") stretch ("strike") along the country, if they stand out visibly; or their probable line of strike, if only partially exposed.

Structure.—Hills with Horizontal Strata.—The knowledge of natural materials, already alluded to, and an acquaintance with the geological clinometer and the compass, are thus required at the outset. Given that the strata lie horizontally, one above another, in the section seen in going up the hill, it is evident that the same set of strata lie throughout the hill; and consequently that the edges of the hard and the soft beds can severally be found (even if not indicated by ledges and scarps) along the hill-side, and around the curved end of the hill or range, and even on the other side, if it be there flanked by a valley. Thus, if a road has to be made across the hill, it would be known that necessarily it could be made up one side and down the other over the edges of the same seams, layers, beds, and banks of limestone, sandstone, clay, &c., but in reverse order. If a road had to be made round the hill, its line could be chosen on the outstanding edge of a solid rock (or in a notch cut in it) all the way. Springs would probably be issuing on some of the clays between the hard strata, and they could be avoided by the road passing along on a ledge of the rock above them. If a good road-metal were found in one of the hard sandstones (for instance), it need not be quarried at one place and taken to another part of the hill; but it would be known to occur just at the same horizon along its outcrop on the other side.

Hills with strata inclined inwards.—Should the strata exposed on the hillside be found to dip into the hill, their edges on the outside would be available for ledges just as in the former case; and very good for a road, as the drainage would soak inwards in or on the several beds. They would not, however, be found on the other side,

for there the hill would slope away, either with the topmost bed, or it would consist of different strata, higher in the series, and overlying the others at the same angle ("conformably"); in either case this back of the hill would have a grade corresponding with the dip of the beds; this is known as a "dip-slope." It would afford such footing for pathways, and surface for roads as the nature of the particular stratum, or possibly successive edges of strata (towards the top), exposed on the slope would allow, whether thick or thin; continuous or fragmentary, tough or friable.

Hills with strata dipping outwards.—If, on the contrary, the strata inclined outwards, that is towards the face of the hill-side, the latter would be modified by the broken and fallen pieces of rock from harder ledges undermined by the weakness of soft beds beneath them. Of course, a good road could not be made here except at enormous expense.

Whatever the condition and features of the hill-side they would be continuous along the scarps and slopes as far as the hill or hill-range extended. Hence in sketching the country a geological draughtsman would be saved the trouble of going to find out at every mile or so the local character of ledge, hollow, bevel, or slope; for he would know that it was due to certain strata which he had under notice where he stood, and the nature of which he could trust to be the same for great distances. Even if the hill be isolated by the dislocation of the strata, the features might be taken up again by the succeeding hill.

Hills with Synclinal Strata.—Advancing further into the unknown territory the traveller meets with hills, in crossing which he finds the structure to differ from that of those already passed, inasmuch as the "dip" is directed inwards on each side of the range, which in consequence consists of a "syncline;" that is, if exposed by transverse ravines, the strata are seen to be bent downwards, either with a concave curve, as inverted arches, or sharply let down, and even broken with the fractured edges meeting at a strong angle. Having been competent to recognize these facts, to what purpose can the observer apply his knowledge? In the first place, the trough-shape, or still more the basin-shape, of the bent strata enables them to retain all the rain that falls on the top and soaks down to an impervious layer. Hence the surface bears grass and herbage,—some springs come out on the scarps when the underground water rises above the edges of the synclinal strata, and wells can be dug with a certainty of supply. These conditions are far more certain than in the hills with inclined strata, and even in those of horizontal beds. "Synclinal hills have often been hill-fortresses, both on account of their retaining moisture enough both for pasture and for wells, and their presenting precipitous sides. The strongholds of Persian chieftains on the Turko-Persian frontier (Loftus), and Schamyl's last retreat, Gounib in Daghestan (Campbell), are examples." Majuba Hill may come within this category of hills with either synclinal or horizontal strata. Of course these valuable spots of ground have been incidentally met with and utilized by nomads and others; but the educated eye recognizes the where, why, and wherefore,

not at haphazard, but by systematic knowledge without loss of time and trouble. Schamyl was defeated only by a continued supply and untiring succession of men climbing by means of iron holdfasts in the exposed edges of the strata in the precipitous sides. Sometimes a neglected or an unobserved attack may be made by mere bold climbing.

Many mountain-tops (as Snowden, for instance, and hundreds elsewhere) owe their height to the hardness of synclinal strata, compressed downwards and inwards by the concave bending and folding, whereby the particles of rock-material, both mechanically and chemically condensed by the pressure, have thus resisted denudation more successfully than the complementary anticlinal folds of the same rock-sheets.

Hills with Anticlinal Strata.—In these latter curvatures the strata, unable to bear the tension, have been broken, opened out, and destroyed bit by bit by natural agencies, often leaving valleys of great extent ("valleys of elevation," exposing lower and lower strata as "inliers"). To be certain about the nature of the two sides of such a valley, the surveyor must, of course, measure the amount of dip in the strata on both sides. If it be the same, the "anticline" is simple and true geometrically, whether cracked and fissured in the middle or not. If the dip on opposite sides of the valley be unequal, the surveyor finds accordingly such differences in the capabilities of the two stretches of country as modifications of hills with inclined strata must present.

An anticline, however, need not be worn down very low. The strata of its two upthrown sides may be continuous, as an arch; or, if broken, may have their edges resting against each other, usually with some shifting or dislocation ("fault"). "In one case the unregarded anticlinal position of the Chalk of Portsdown Hill (C. Evans) spoilt the hopes of the Royal Engineer boring for water. In another case, a knowledge of an anticlinal arrangement of the strata of Trimpey Hill enabled the late G. E. Roberts to point out how the axial, but unexplored, limestone might be got at, and burnt for lime with the coal lying against the foot of the hill. Hills having the same outline may be composed of very differently arranged strata; and, until some evidence of their actual constitution is gathered by a geologist, no one can tell any more of their interior than a child can of pies or dumplings before they are cut open."

Thus on account of the various modifications in the arrangement of strata, "some hills have their contours coincident with the outcrop of their strata, which are then horizontal; other hills may have synclinal, cycloclinal, anticlinal, or periclinal strata, with very different results as to smoothness of slope, step-edges, water-bearing qualities, native fertility or barrenness, &c., according to their petrological characters—clays, sandstones, limestones, &c."

Schistose and Granitic Rocks.—We have hitherto alluded to countries constructed of simple strata of limestone, sandstone, clay, and their varieties; but there are many other rocks,—some more or less schistose and slaty, some solid like granite,—some partly massive and partly in sheets and veins, as basalt, lavas, and whinstone dykes, &c.

After passing over maritime flats and river-plains, and crossing such hill-ranges as have been indicated above, in nearly every country the traveller finds that the easy-lying strata have been more and more disturbed from the horizontal position to undulating, curved, folded, and distorted conditions, as he examines the gorges and ravines of the higher ground and mountains; he notices here and there the veins, dykes, and bosses of intruded rock; and ultimately finds that the true strata have disappeared into compressed sheetings of laminated rock, often splintery and shilley, or tough, or even crystalline, lying and standing at all angles and often vertical. These pass into crumpled mica-schist, foliated gneiss, and solid granite in the heart of the mountain-regions. All these kinds of rocks have their peculiarities as regards the structure and aspect, capabilities and uses of the ground and districts which they constitute. In some instances the nature and constitution of the uplands and higher regions can be at least partially judged of by an examination of the gravels and boulders brought down by streams and rivers, whether issuing from springs on the mountain-side, or from the foot of a glacier which has originated on the crest of the ridge.

Fossiliferous Strata.—Of the ordinary low-level districts, however, there is much to be noted before these complicated and altered rocks are taken in hand. The important fact—that all the known strata have a definite order in place one on another, according to their relative order of deposition, has to be borne in mind. According to their relative age they are marked, signed, and, so to speak, certificated, with fossils peculiar to each, or at least to each consecutive group of strata.

As time passed on with its millions of centuries, changes took place in the relative extent of seas and lands, and in the heights of the one and depths of the other, bringing about many changes both in the living-places and feeding-grounds of animals of all sorts, and in the growth and distribution of the plants. Hence some creatures dwindled and disappeared; while others took their place and flourished. Thus with every successive group of animals and plants ("fauna" and "flora") inhabiting land and water there were differences of individual shape and structure, due to either improvement or deterioration; and there were gradual changes, from the "generalized" to the "special," ruled by the Creator's great and wonderful law of "Evolution." Hence the "organic remains" buried in the deposits of seas and lakes, and variously preserved as fossils, have to be looked for and noted. Those of the oldest rocks (first-formed and lowest in the geological series) are known as the Palæozoic ("old-life series"); the next great group above are the Mesozoic ("middle-life series"); and the uppermost group are the Cainozoic ("recent-life series"). They are also known as the Primary, Secondary, and Tertiary; and the youngest portion of the last is divided off as the Quaternary. These are also divided into several "Formations"; as (1) the Archæan, Pre-cambrian, Cambrian, Silurian,¹ Devonian, Carbon-

¹ By some the Lower Silurian is termed "Ordovician," and the Upper merely Silurian.

iferous, Permian; (2) Trias, Rhætic, Jurassic (Lias and Oolite), Purbeck and Wealden, Neocomian and Cretaceous; (3) Eocene, Oligocene, Miocene, Pliocene, and Recent.

Thus it is advisable for the surveyor to be able to recognize Trilobites, Graptolites, &c. as Cambrian and Silurian; Bronteus, Pterichthys, &c. as Devonian; Productus, Lepidodendron, &c. as Carboniferous; Palæoniscus, Axinus, &c. as Permian; Ceratites, Labyrinthodon, &c. as Triassic; Microlestes, &c. as Rhætic; certain Ammonites, Reptiles, &c. as Jurassic; Iguanodon, Cypridea, &c. as Purbeck-Wealden; certain Fishes, Echinoderms, &c. as Cretaceous; and certain kinds of fossils for the Tertiary and each of its divisions.

Use of Palæontology.—Coal-beds.—The utility of this knowledge ("palæontology") is extensive. By ascertaining the fossils of a stratum you know whereabouts in the geological series it really lies; and therefore whether or no it is above or below any specially valuable stratum or formation that you may be looking for. If, for instance, you want to put your hand on coal:—in search for the great beds the old coal, that is, the true coal of the Carboniferous Period, you would not look at the lower outcrops of Devonian and Silurian strata, but go higher and higher on upper outcrops, and find the Carboniferous above them both, if it be present in that part of the country. In sinking pits the same rule would be followed; and the trouble, annoyance, and cost of trying to find coal in or below the Devonian, &c., would be avoided; whereas the Permian, and possibly the Triassic, rocks might be bored through with some hope of finding the coal. Accurate observation of stratigraphical arrangement, or the stratal structure of the country, might show in some regions that even higher strata than the Permian lie directly upon the Coal-measures; for in Belgium the formations intermediate to the Carboniferous and the Cretaceous are wanting (from old denudations, &c.), and the latter lies immediately and "unconformably" on the coal-beds. From the study of different outcrops and borings, across the South of England and parts of France and Belgium, the probable depth and condition of real coal at great depth, even below the London district, have been fairly deduced.

There are, we know, other fossil fuels beside the old coal. Some of these are well worth getting; and some are of slight value, and even deceptive to non-geologists. How are they to be looked for? Like many other useful things, including real coal, they have been found by natives or others, noticing them incidentally as they lived on the spot or passed across the country. Hence many such "finds" may have been known for ages in the locality before they got by hearsay into legends and old writings; now-a-days, reported by native and other traders, emigrants, or casual travellers, they find their way to civilized centres in paragraphs of Newspapers, and do not always escape those who write books of travel. Thus the whereabouts of many promising mineral substances are made known; but their proving to be attainable and good depends upon the applied science of the Engineer and the Geologist. Coal is met with in other rocks than the Carboniferous, but rarely fit for more than local use. It is

found in the Permian and Trias abroad; in the Jurassic in Britain and Austria; in the Purbeck, at Brunswick; in the Cretaceous of Poland, Vancouver, &c.; and great Tertiary Lignites in the Western Territories of the United States and Canada. Many a poor lignite in England and elsewhere has deceived sanguine people who might have learnt its real value by what the neighbouring strata show it to be.

Hence the necessity of knowing the aspect and composition of these fossil fuels,—the relative age of the strata with which they are imbedded,—and the relative position of those strata with regard both to others and to the surface.

Geological Materials.—In fact, a competent acquaintance with all the common rocks and minerals is desirable; so that sandstone should not be mistaken for limestone,—white quartzite for statuary marble,—lydite for black marble,—green jasper (blood-stone) for serpentine,—bottle-glass for obsidian,—blue glass for sapphire,—quartz for diamond,—or pyrites for gold. Such knowledge also guides in the choice of limestones for building, or for making lime, or for cement,—in the selection of stone for road-metal,—of clay for firebricks, pottery, tiles, and common bricks,—and in the recognition of useful materials at hand, and prevention of the ordering of similar rock from a great distance. These points are dwelt upon in my Address on the Practical Advantages of Geological Knowledge, in the "Proceedings of the Geologists' Association," vol. vi, 1880, pp. 237—270.

Conclusion.—An American author¹ truly states—"Geology now plays an important and prominent part of Military Science as well as in the curriculum of universities, although a few years since it was all but unknown to either. It now not only guides, as it ought, in the direction of mining and other practical geological operations, but also gives the key to the study of obstacles in military art."

In my paper on the practical use of geology above referred to, it is noticed that the sites of battle-fields, the lines of ancient roads, the elucidation of history by explanation of changes of coasts and river-bends, are all to be worked out with reference to Geology; and much interesting work has been done in this direction.

"The races of India have been conquered by the British, and to a great extent her rocks and soils were conquered by amateur geologists of the British Army. Before the Geological Survey of India was instituted about thirty Officers and twelve Army Surgeons had communicated valuable observations on India to the Geological Society of London."

An educated Traveller, an accomplished Staff-Officer, and a Naval Surveyor, may use geological knowledge to advantage in a scientific journey, in a military reconnaissance, and in surveying coasts and islands. Either of them with geology "can see further than a mere surveyor! He can see more than the outline of hill and vale, or of gorge and peak! He can see which of the hillsides is sandrock or limestone or granite, with all their certain or probable properties or conditions! He can see where a valley has its floor of porous

¹ A. W. Vogdes, Lieut. U.S. Artill., "Course of Sciences applied to Military Art. Part I.—Geology and Military Geography. Geology." 1881. Page 2.

gravel, or of light loam, or of stiff clay, or of black peat! What is more, he can appreciate their relative value, or their relative evils, to him and to others! He traces the run of clay-bands, or of hard rock along or across the country! He can tell what is on the other side of some hills he looks at,—nay—even what he may expect to find on the other side of a mountain-range! He sees the rolling and pitching of strata to right and left, from hill to hill; and he knows what further strata they bear on their broad backs, east or west, north or south. The escarped side of a hill will tell him whether the back-ground is a plateau, flat or sloping, good for roads, or made up of rifted rocks and crumpled strata, impassable! He knows whether yonder ridge, dividing the valleys, continues the dry sandrock, the grassy limestone, or the barren granite of the neighbouring mountains! He knows *reasonably* a volcanic cone, a trappean knoll, a basaltic cliff,—also their possibilities and values. He will not set compass on such a rock, for he would lose his direction; he would not lay telegraph-wires on them, for his electric slave would rebel at their touch! He can tell where water lies in the synclinal or the faulted strata, for his indication is the knowledge of observation, not the ignorance of the ‘dowsing fork’ or ‘divining rod,’ for which, indeed, the Australian savage, watching the gnats dancing over a water-spot, ought to have a supreme contempt.¹

“He knows whether the strata in a plain slope from the mountain or towards it, and therefore how the water soaks and runs beneath. As a General of genius, or the educated Soldier, ‘has an eye for a country,’ for positions and manœuvres, so the Geologist has an eye for the capabilities of a country. The earth is open to his educated eye, just as a diagram may show surface and section. Further, he can enjoy the varied tints of morn and eve, and sketch with pleasure the lights and shadows of Nature’s architecture, as well as those who know only the outside; whereas his knowledge of the *structure* adds pleasure to his enjoyment, gives distinctness to his touch, and renders his description of each part, high or low, rough or smooth, definite and to the purpose.”

The value of geology, in a military point of view, is not lost sight of in Lord Wolseley’s “Soldier’s Pocket-book,” 5th edit., 1886, p. 244. In the “Manual of Field-fortification, Military Sketches, and Reconnaissance,” published by Authority (1871), a knowledge of geology is insisted upon as absolutely necessary (p. 156). Indeed, it is therein stated that, “In the present day a Survey and Report upon a country would not be considered complete unless it contained some amount of geological information.”

In the “Journ. Royal United Service Instit.,” vol. vi, p. 342, F. W. Hutton, 23rd Royal Welsh Fusiliers, F.G.S., states, “As Geology is the most useful of the sciences to a soldier, so is a soldier’s profession the one of all others best adapted for its study.”

¹ See General Portlock’s valuable remarks on the advantage of cultivating the Natural and Experimental Sciences as promoting the social comfort and practical utility of Military Men, “Journ. Royal United Service Institution,” vol. iii, 1859-60, p. 296.

The CHAIRMAN: Gentlemen, having listened to Professor Rupert Jones' very instructive lecture, it is my duty to invite discussion.

Brigade-Surgeon STAPLES: There seems to be a great reluctance to follow Professor Jones in his lecture, and I must say I do not wonder at it. I have only risen because of that great reluctance, and not to occupy the ground which I hope my temerity will induce combatant Officers to take up presently; but to say a few words for one section of the army Officers who are alluded to by Professor Jones, I mean the army Surgeons. In my experience, an elementary knowledge of geology, of all other allied sciences, is the most useful to them, in some of the questions upon which we are called to give a responsible opinion to a General or commanding Officers. These questions, of course, cover a great deal in relation to the sites of camps and barracks, where we are associated with the Royal Engineers, questions of health with regard to soil, &c.; but I want to draw particular attention to the question of water supply, and I wish to illustrate what I have to say by practical experience. I think that will be the best plan to make myself intelligible to the meeting. In two stations in which I was quartered when I was in the Army, I had a great deal to do with giving a responsible opinion on the question of water supply. One I will not refer to, but the other I wish to particularize. It was a station at which there were two sources of supply. The geological formation seemed, as far as I could make out from the map, to be the same; that is to say, it was what I think geologists call an amorphous sand, lying upon shale and limestone. It was not a difficult problem, with a certain knowledge of chemistry, to give an opinion as regards the water, and yet the latter was absolutely different in the two sources. I never could explain it, and in time came home from the station and gave up the subject. It was to me an intense puzzle. One day in London, and some years afterwards, I was passing the School of Mines. I went into the library, and asked the librarian if there was any gentleman in the place who had paid attention to the question of geology and water supply, if he would kindly introduce me to him. It is a little embarrassing that I am speaking in the presence of the gentleman himself, but I hope he will kindly excuse me. He listened to what I had to say very kindly, and after I had put the question before him, he said, "Have you a geological map of the place?" I said, "Yes." I do not want to be pedantic, or for it to appear that I had a great knowledge of geology, for such was not the case. I only want to bring out some of the points kindly put upon the board by Professor Jones. He said, "What is the formation bounding this sandy plain?" I said, "That is limestone." "Can you show me a section of the limestone?" I got him one, and he then put the case of the water supply quite clearly. The difference simply depended on the stratification of the limestone. Opposite one source, I think what the Professor called the "inclination" of the limestone was more or less horizontal, or approaching the horizontal; it inclined in such a way that the rain falling upon it rushed out over the sandy formation and impregnated it with lime. Above the other source the stratification was almost vertical; the water sunk into the limestone and did not reach the sand, hence the difference in chemical composition. I think any one can draw the conclusion from the foregoing that an army Surgeon would be better equipped scientifically if he had a good elementary knowledge of geology. It seems to me at all events that, if they had, their opinion on questions relating to water supply would be much more authoritative and better than it is. I thought these few remarks would enable others to get up and say something as regards the lecture, from their particular points of view.

Major SMITH, R.A.: I, like Dr. Staples, consider myself unworthy to speak on this occasion, as I, too, am only a student of geology; but I am encouraged by the fact that a great part of what I have learned was picked up under the learned Professor's own teaching. My remark is a very simple one. Dr. Staples has drawn attention to the use which a slight knowledge of geology may be in explaining certain difficulties connected with water supply. It is my misfortune to have to look through some 200 or 300 reconnaissance reports of very varying merits, which are pitchforked at my head every year from the Home District. I find in nearly every one of these an attempt made to give a general description of certain areas of country round London, and in nine cases out of ten it proves a somewhat egregious failure; and I believe this failure—this utter inability—to be able to describe tracts of country

in language which is at all concise, or which will commend itself to scientific ears, is simply the effect of want of knowledge of elementary geology. Any Officer who had a slight knowledge of this character could describe in very few words almost every area of country you ever meet with round London. It is quite sufficient in most cases, simply to say a certain village or district lies direct upon the London clay, nothing intervening, or perhaps upon the Thames alluvium; that another place is simply on the outskirts of the chalk-downs, just two or three words like these convey a perfectly adequate knowledge to any expert in the question on nearly everything you want to know, whether for administration or more directly tactical purposes—the question of water supply, the manufacture of roads, the convex or concave curvature of the hill-slopes, or anything you like to know. The elaborate circumlocution which persons have to employ in describing the most ordinary physical features of English country who have not that geological knowledge shows what an extremely desirable thing it is to possess some acquaintance with the elements of the science which the Professor has been advocating. With regard to the lecturer's remarks on the field of Gravelotte, I find myself, unlike the schoolboy in Macaulay, in the painful position of having to confess my entire ignorance of the obvious connection between the "Inferior Oolite" (which I think he mentioned) and the bad strategy, or worse—the moral obliquity of poor Marshal Bazaine. Perhaps, in his concluding remarks, he will kindly enlighten us as to the simple, yet subtle, linking of cause and effect in this case. It would be interesting also to hear something about the physical structure of Inkpen Beacon, which he purposely omitted. If I am not mistaken, the cavalry manœuvres of this past year took place not far from there; and it strikes me that on these two points some information would be very grateful to the audience.

MR. RUTLEY: There are many extremely interesting points which Professor Jones has touched upon in his lecture, and he has no doubt done very wisely in restricting his remarks to questions mainly of stratigraphy, because there are some stratigraphical questions in connection with strategy which are of great importance from a military point of view. For example, that of water supply is of paramount consequence. The search for coal is of course a matter which is of deep interest in times of peace; in times of war there would be, however, few opportunities of making suitable investigations. The questions which Professor Jones touched upon towards the end of his lecture were most suggestive, and it is to be hoped that his discourse may be the precursor to another, in which he will deal with the relative strength of positions, and the influence which geology has upon them. Of course, in the teaching of geology to the various branches of the Service, it is a matter of great moment to dwell upon the different characters of the ground, how in certain districts only boggy ground may occur, or soil which is so incoherent that it is perfectly unfitted for purposes of transport, or for the passage of artillery. That seems to me one of the chief points to consider, and the proximity of such a boggy position to one which could command it, and from which forces could inflict very severe damage upon an enemy, whose knowledge of the country was less thorough than their own.

MR. TOPLEY: The field covered by Professor Jones is so large, and he has put the matter so very clearly before us, that I will not attempt to follow him in all the numerous points he has referred to; but will limit myself to two points. First, as to the importance of geological maps in aiding us to understand topography. Professor Rupert Jones commenced his lecture by some remarks upon that point; but a great part of what he said subsequently was bearing out his introductory remarks, and showing how very easy it is with a little geological knowledge by studying a geological map to understand the features of a country infinitely better than it is possible to do with only a hill-shaded, or even a contour map. The geologist sees at a glance the whole look of the country from a geological map, however small the scale may be, much better than any one can do from an ordinary map which does not show the geology. Of course, if we have both, if we have a carefully hill-shaded or a contour map, and also a geological map, putting the two together, we have a more perfect knowledge of the country, and the larger the scale the better it is. Passing from that, I would like to say a few words as to the special application of some maps of the Geological Survey which I have placed

upon the table. The ordinary geological map shows the solid rocks; but frequently there are also superficial deposits covering which, when we come to study them in detail, modify the features of the country and the surface soils enormously. I have here two examples of a map on the 1-inch scale of the country on the south of London (Sheet 6); it stretches from near Godstone to beyond Maidstone. One is an ordinary geological map showing the ordinary rock-formation, the other is a map upon which the drift deposits are shown. Those two maps cover the same district. On the one map all the light green is one tract of bare chalk; on the other map, it is shown covered up by all sorts of drifts which considerably modify the soil. All the south of England is now thus mapped out by the Geological Survey. In addition to the ordinary 1-inch map, we have also larger scale maps of the district. Here is a War Office map specially prepared some years ago, and used before the 6-inch Ordnance maps were made; but now we survey the country on the ordinary 6-inch scale. The bare chalk is shown by a wash of light-green, and the various drifts overlying it are shown by tints of brown, purple, yellow, and so on. The very great difference of the soils is shown—for instance, the ordinary bare chalk makes a comparatively hard and firm soil on which cavalry and artillery could very well manœuvre. The gravel along the bottom of the valley is shown, and also some gravel on the hill-top, whilst the stiff clays which cover mostly the higher ground are clearly shown. It might be a matter of some importance for the Intelligence Department if it availed itself of maps of this kind in collecting information, say, upon such a special point as the defence of the Metropolis. What an enormous difference it would make to an army manœuvring over that country, if it could choose its positions on a chalk soil, and force its opponent on to stiff clay. The Geological Survey is constantly appealed to by engineers and others in search of water supply, by people who want sites for houses, and so on; and the value of the maps from these points of view has long been known. Just at present there is a communication going on between our office and the new Board of Agriculture to see how far the map can be utilized for agricultural purposes; but a further application, I think, might be made of them for military purposes from the point of view here described. It would surely be of considerable advantage if the information of the various surveys were collated and kept in the possession of the War Office to be made use of in such ways as the authorities thought desirable. I have here also the geological map of the country around Aldershot on the 6-inch scale, which being a special military district I thought might be of interest; this also shows the surface soils.

Professor RUPERT JONES (in reply): My observations have not been criticized, but courteously added to; indeed, the subject has not been exhausted by any means. I may recommend one or two books. First, a paper by myself, an accumulation of notes of lectures, given during my time of service at the Staff and Cadet Colleges, together with experiences gathered by the kindness of my Staff College friends, as well as from my working amongst them. It is called "The Practical Advantages of Geological Knowledge," and is published in the "Proceedings of the Geologists' Association," vol. 6, April, 1880. There are in it many things not merely military, but for general purposes. It contains the names of many army Surgeons and Officers who worked as geologists in India before the Geological Survey was instituted there; and also some Missionaries who did much towards the knowledge of Indian geology. Therein also two papers in the Journal of your own Institution are alluded to: one by General Portlock, and another by Captain Hutton, who is now the Professor of Geology in the University of Otago, New Zealand. Dr. Staples spoke of army Surgeons, and I have nothing to add to his observations. It was perfectly true that the same kind of sands at the two different places would be affected by the presence or absence of water from the neighbouring limestone: and, of course, there are many conditions to be accounted for, which would be recognized by the geological eye almost directly. Major Smith put it very clearly that geological language is short and clear. Such technical language should be used on every occasion, if possible. It is only because people do not know enough, that they will not allow such useful words to be used. Long words sometimes carry a great deal of condensed meaning. Major Smith referred to the country about Metz and Gravelotte, a model of which is before us. Now, really I acknowledge that, unless I went

over the matter again, I could not readily point out why these strata of the Inferior Oolite, dipping to the east and coming out raw and ragged over the valley on the west, with the Soft Lias clays below, should not have been more or less advantageous or otherwise in the conduct of that series of battles. Though a position on a height is good, yet if you have nobody to back you at a crisis you may as well go away. Particularly, however, I think that some of the lines there were scanty of water, because the villages could not have had sufficient water, except by means of deep wells. With regard to battlefields, it is all very well to know why a battlefield has been good, and why a battlefield has been bad in a geological point of view, after the fight is over. Such observation afterwards is pleasant and very satisfying to make; but very difficult to find out beforehand. Who can tell where the next battle will be? Any General would be guided, like Napoleon or the Duke of Wellington, by the apparent fitness of the district. The undulations of Waterloo, no doubt, struck him as being very useful, and he thought he would get the best of it, and certainly he did; but he thought little of their being formed of the Tertiary strata there. And so in many other places you can see afterwards why they were fit, and why they were good; but I doubt whether any military man would in the course of a great war, with very rapid movements, do more than trust to topographical information, and pick out the best places, partly for political reasons, of his surroundings as well as for the details of the place. Geological maps would help him in details; but he must bring his men together, I take it, according to the nations who are helping or not helping them. In the Peninsular War there were geological points here and there seized upon; but, in a great many instances, you had to take what positions you could. If you were sent to build a fort at a place, you must build it there; it is not whether it is good or bad geologically. You must be prepared, however, to know whether it is difficult or easy under the circumstances. With regard to Walbury Camp, referred to. It is on the top of a chalk-hill; and shows how clever our predecessors were in finding out and using what they wanted. This hill rises above a valley consisting partly of soft alluvium, and further on there are some Tertiary sands and clays, making a good agricultural district; and elsewhere there is an uprise of some of the beds from below the Chalk, which also can be used for agriculture. They did not think much of agriculture in those days, and these were swamps and forests. The chiefs took their positions on the high ground, which, by the way, bore the great lines of traffic, such as the "Ridgway;" and they fixed their earthworks on these chalk ranges in the neighbourhood of the roads and passes. Whether looking on the roads and fords along the valleys, or on the passes up through the chalk-hills near by, still these camps or forts always had to do with the guarding of these important lines of communication. Of course that could not be shown here, without a map having these points marked upon it. Some of us have such maps, with the roads and earthworks of the Ancient Britons, the different succession of inhabitants, and the Romans. Walbury is perched on a hill, commanding a very large area that must have been passed by people wanting to go into other parts of the kingdom, which was then divided into small territories, and conflicting parties existed, as now. Mr. Rutley pointed to the strength of positions; that comes to the same thing as battlefields and the erection of forts. You must take what you can get, and afterwards, no doubt, it is interesting to know why such battlefields were better or worse. Of course it is wrong not to know the value of details. One of the maps that has been shown to us by Mr. Topley puts me in mind of one particular point, in that terrible battle (which you must all remember) whereby London was lost, and so on—namely, the battle of Dorking. There, I am sorry to say, the English did not know their geology. They came down off the hill opposite Dorking—the hill (now Cubitt's Hill) parallel with Box Hill. I do not know where they started from, but they intended to attack the Germans on the rising ground of Dorking itself. Unfortunately there was no geologist there to tell them of the outcrop of soft Gault clay, on which the stream runs, between the high ground at Dorking and the Chalk on which the English stood, as can be seen in one or more of these diagrams. A geological Staff Officer would have said, "It is a valley of Gault," and would have known the consequences! Those handsome troopers—the Guards, I think, red or blue, rode into that valley; and of whatever colour they were when they dashed in, they were certainly blue who came out. They had rushed

into the valley—they could not cross the soft, tough, blue Gault with safety—and the battle was lost. I might have mentioned some other things with regard to clay. I remember a circumstance, when I lived in the neighbourhood of Sandhurst;—here is a diagram of the country—and the diagram just below it shows the relationship of Sandhurst on the one side to the neighbourhood of Wokingham on the other. Wokingham stands on a patch of sand above the clay called “London Clay.” We had a servant who said she came from Wokingham. After some time, she went for a holiday, and came back with a very handsome bunch of celery, and said that her father had sent it from his garden for the Missis. I said, “Then you do not live at Wokingham?” “No, Sir, we do not live at Wokingham.” “Why did you say you lived at Wokingham?” “Oh! we call it so, but it is more than a mile from Wokingham.” I knew it was, and why? Because celery grows on clay, and the only clay about there is a mile or so from the town. The other day I had the pleasure of hearing Sir Charles Wilson speak on the subject of geology being valuable for military men, especially for our Engineers; and he spoke of an instance where a spy had been taken and brought before the Intelligence Department of the place, and a sharp eye saw that he had with him something that showed the kind of country that he came from. If I understood rightly, his legs had mud on them, and this indicated whence he had come; and they got from him the information they wanted. Mr. Topley’s remarks on the new maps of the Geological Survey are very valuable. I am sorry we cannot spend a little more time about this subject to-day. There was a paper written lately by one of our geological colleagues, containing a statement that I, could not help copying out, because it belonged to this matter; and, if you will allow me, I will refer to it. He was working in Bavaria amongst some particular igneous rocks—very difficult work. He states there was a dense fir forest clothing the whole of the slope, and preventing any very satisfactory evidence being obtained. “Here and there, however, a knob of rock rises above the soil of pine-needles, the path beside the stream shows an occasional low section, and the bed of the stream affords a little additional information as to the general nature of the diabase and its varieties.” He traced it, however, up through this fir forest by little projecting masses, and by the small exposures in the riverside, until he completed his map and section. Somewhat similar instances occur with travellers. The Arctic explorer, McClintock, states that he often went across the desolate Montreal island with no other guide than a dyke, which kept in a straight line, and he followed it. If he did not know aught else of the country, he could trace that. He did not know the rock, microscopically, as to whether it was quartz or trap-rock: but he knew that it was a safe guide for him, and he used it all the time they were stopping there.

The CHAIRMAN: Gentlemen, as I am perfectly incompetent to criticize Professor Jones’ lecture, I have allowed him to make his remarks before I rose myself. My scientific knowledge of geology is infinitesimally small. They certainly did not educate the Officers of the Army when I entered some fifty-five years ago as well as they do at the present time, and my scientific knowledge of geology is only sufficient to allow me to discriminate between chalk and cheese. I do not know whether you will allow cheese to be a geological formation, but I am quite sure you will all agree with me in tendering a very warm vote of thanks to Professor Jones for the lecture he has given us this afternoon. I can only say one of the greatest advantages we ever attain at this Institution, is when we can persuade gentlemen not of the two professions who support it, to come and give us lectures on subjects which are likely to enlighten us, and when gentlemen also in the same category are good enough to get up and speak to the subject. I, therefore, have to request that you will allow me to present a very warm vote of thanks to Professor Rupert Jones from all here present for the lecture he has given us, and also from those who have not spoken, to the gentlemen who have been good enough to rise and elucidate the lecture.