A SKETCH OF THE MEDICAL GEOLOGY OF SOUTH AFRICA.

By Lieut.-Col. BRUCE SKINNER.

Royal Army Medical Corps.

PART II.

The necessity for guarding bridges across rivers leads to the certainty that such localities will become occupied by troops in war time. When the river-bed itself is a constant source of water, the question of supply becomes one only of transport to the camp. But when the supply from the river is scanty, and perhaps intermittent, it is imperative that wells should be provided to supplement the shortage.

The following diagrammatic section (fig. 11) through the banks of the Vet River, immediately below the railway bridge, shows the points to be looked for in the search for water in similar localities.

Here we have a picture of a disappearing river, which has dwindled down from a mighty flood to an intermittent hill stream only retaining sufficient force to maintain a channel through steep sandy banks in the position marked 5. The bridge was 60 feet above the river-bed at this situation. Water during rainy seasons will be retained in small quantities at the bottom of sandy (S) and alluvial (A) strata, as the absorption by the underlying grits and sandstones (G) will be comparatively slow. Such water will further be charged with surface impurities, but a good supply will be procurable by boring into G, down to some feet below the modern bed,
keeping clear of the diabase (D). This section may be taken as a good example of the conditions prevailing in all the river-beds of this country.

A little north of this bridge is an important position called Smaldeel, or Winburg Road Station, situated nearly at the top of the rise from the Vet River. The railway station is on the side of a rounded hill, not far from the summit. The hill has a thin cap of dolerite, beneath which are horizontally bedded mudstones, succeeded by grits and sandstones with thin shaly intervening layers. Below these are mudstones. Below the last are boulder sandstones, through which the Vet River cuts its way to the east 200 feet below the level of the station, but higher up-stream than the locality sketched above, where the bridge crosses the Vet. A well had been sunk at the summit of this hill, through the dolerite cap into the mudstones; but needless to say, contained no water within reasonable depth. In such a position it is necessary to go some distance down the hill to a locality uncovered by dolerite. As, however, there is a village near the station, and during the war there was a camp near the same spot, all water within the rocks for some distance round must have become polluted with organic matter unless drawn from a great depth; still it was necessary to obtain water near, and it was found on the northern side. Here, where the hill joined in a curve with an adjacent hill, the rocks were covered with a certain amount of diluvial soil which helped to retain the water, and by sinking a well into the sandstones a constant supply was obtained, which, used for railway purposes, furnished also sufficient water for the drinking supply of the camp.

These two localities are good examples of two types of situations for which water supply had to be provided within close reach of the camp. Some places, such as Wolvehoek and Standerton, required careful investigation before a spot free from the volcanic diabase could be found, so as to provide a sufficient supply. All these instances show the extreme importance of providing an army in the field with sufficient water-boring apparatus, with machinery sufficient to raise the water from depths at which the ordinary pump cannot operate.

Dykes.—As has been pointed out above, dolerite (diabase) is practically impervious to water, and when it occurs as a dyke,
holds back the underground water. Such dykes do not always reach the surface of the ground. Working upwards from the interior of the earth, the molten material of which they were composed forced its way sometimes above the surface, when it became poured out as a lava sheet; sometimes it intruded between layers of rock; sometimes it remained at varying distances below the surface, the energy of expulsion having been insufficient to carry the mass right through the crust.

When the surface is covered with diabase it is not of any use attempting to bore through it. Also, when after boring through sedimentary rock, the bore strikes the volcanic rock, to continue the boring will be futile if the object is to find water; but if the exploration is made through sedimentary rock on the side of the dyke towards which the country slopes, the discovery of water is practically certain within a short distance of the surface. Further, it will be found that the opposite side of the dyke will require a deeper bore before water is struck, unless that side happens to form the lower end of another drainage slope whose water is held back by other dykes running across its line of flow.

*Water in Distorted Regions.*—These principles hold good also in those portions of the country which bound the region of horizontal rocks lately under consideration; due weight being given to the fact that in the distorted regions the surface water follows the dip of the rocks, sinking below the surface deposits until brought to a standstill by a change in the configuration of the containing strata. In order to calculate where to strike this subsoil water a careful estimate has to be made of the angle of dip. These tracts of country present different physical aspects, according as the strata consist of distorted sedimentary rocks, or of volcanic masses, such as the granite of the Bushveldt in the Transvaal, and that of Swazieland, and the granite bosses of the Witwatersrand or of Vredefort. The water supply of such localities depends upon the surface distribution; it does not sink into these igneous rocks deeper than their outer disintegrated surfaces.

In regions of distorted rocks such as are found around the granite areas, the condition of things finds its origin in a remote past. The tilted rocks have been in their present condition for ages which are impossible of computation in figures;
their age can be measured only by the position they assume in the succession of the rocks of the country. That is to say, they are found to have been tilted before the rocks, many thousand feet in thickness, which, still horizontal, are found in some places to be placed above them. In many places where such horizontal rocks are not above them they may be assumed to have been carried off by denudation processes. The distorted rocks also are found to have suffered from denudation, for they have breaches carved in them by stream action, while their intervening valleys contain deposits formed by water-borne and wind-borne material. The diagram (fig. 12) representing the country immediately to the east of Pretoria shows the series of rocks tabulated above as (4) (see Part I.). The rocks are quartzites and much indurated mudstones and sandstones, with intrusions of amygdaloidal trap. There is a series of east and west valleys separated by ridges. The summits of the ridges are composed chiefly of the outcrops of quartzites, the bedrocks of the valleys are chiefly mudstones. The most dependent parts of the valleys contain, lying upon the older rocks, fluviatile deposit, through which at intervals winds a stream whose general direction is northerly. On the higher ground are deposits of clay and sand formed from rock decay.

Such a series of metamorphosed, and consequently hardened, rocks does not allow of much percolation. Such percolation as takes place has a tendency downwards, through fissures and joints, to an unknown depth, possibly checked here and there by the dykes of trap, but not held in large accessible quantity.

On the other hand, the surface supply is more plentiful, for the very reason that prevents percolation. In this locality the streams flow northwards through deep gaps carved through the east and west ridges to join the Apies and Pienaar Rivers,
meandering through the alluvial deposits formed by water-action at a period when the drainage, formerly west to east, had no exit from the valley. By sinking wells in this alluvium, which is sometimes of considerable depth, water can be found always. The quality is another consideration.

In a tract of country forming a belt south of Pretoria is a series of rocks called dolomitic. This belt widens considerably to the west until terminated near the western frontier of the Transvaal by a series (No. 2) of quartzites and other indurated rocks (schists). These dolomites have been dissolved in places after the manner of limestones, by underground water, with the result that surface waters disappear into underground channels, only to appear again when less soluble rocks, which act as supporters to the underground stream, and thus prevent further descent, approach the surface.

In the Waterberg to the north of the Transvaal and in the south-east (Standerton, Ermelo, Utrecht, Vryheid, Wakkerstroom and Piet-Retief districts) the conditions are those of the horizontally bedded rocks previously described.

Soils.—Mention has been made of the detrital material of decomposed rocks. A sketch of the main varieties under the name of soils is called for as further explaining the nature of the country. These soils are primarily of two classes: first a clay or brick-earth, and second sand. These main sub-divisions are varied by admixture, and by the fact that in places they retain evidence of modification, through having formed a nidus for former vegetation.

(1) The clay forms the red soil which is so conspicuous a feature of the country. It is the result of decomposition of the volcanic rocks, the most common source perhaps being the diabase so frequently mentioned in this sketch, and is consequently found most pure on those talus slopes descending from hills formed chiefly of this kind of rock. It occasionally happens that a hill is formed on one side of diabase and on the other of sedimentary rock; in such cases the contrast of the soils resulting from the disintegration of each is marked. Wherever the prevailing colour of the country is red it may be taken for granted that the volcanic rock predominates.

Diabase is chemically a ferro-magnesian silicate of alumina
and lime. The clay, when pure, forms a stiff ferruginous brick-earth, from which rich-coloured red bricks are made. The photograph (fig. 13) shows a pit from which the clay has been removed for brick-making, leaving rounded blocks of dolerite, representing the core of the blocks whose concentric weathering had provided the clay. In the background some of the clay may be seen with blocks of dolerite embedded in it.

The lime of the parent rock seems to be the first constituent got rid of by disintegrating processes. Being readily soluble it is carried away by percolating water, but is redeposited when the water evaporates. In a quarry recently worked at the south-west corner of Naval Hill at Bloemfontein in sedimentary (sandstone and mudstone) rocks, the sandstone at one point in the quarry has the appearance of a sandy chalk (see fig. 14). On investigation it is found that behind the rock in question decomposing diabase is situated, and that the lime has been washed out of the latter and redeposited in the sandstone owing to the evaporation of the percolating water.

On talus slopes the lime does not rest. It is carried down to the valleys by the flood water. This percolates through the sandy diluvium of the valleys and rests upon the harder underlying rocks; some portion of the water is absorbed by the
rocks, some portion is evaporated. That which is evaporated deposits its lime, with the result that a layer of travertine is formed (see fig. 15). This condition is very marked in the country traversed by the railway from the Orange to the Modder Rivers.

![Image](image1.png)

**Fig. 14.**—Quarry against Naval Hill, Bloemfontein, showing (A) sandstone containing infiltrated carbonate of lime, which has been washed out of the (B) diabase rock beside and behind the sandstone.

![Image](image2.png)

**Fig. 15.**—In the bed of the Bloemspruit, east of Bloemfontein. T, layer of travertine; below it are grey shales, above is diluvial deposit.

A section at Modder River Camp in a bank which formed an ancient boundary of the river on its southern side, situated at about 1½ miles west of the bridge, showed this travertine interbedded with sandstone. At another point in the continua-
tion eastwards of the same bank a deposit of 5 feet in thickness of travertine was observed. Further down the railway towards Orange River this deposit is exposed on the surface as a white crumbling lime, and has given for the locality the name of Chalk Farm.

At Osfontein Farm, near Paardeberg, a section made for a water channel showed the travertine resting on a denuded shale, the broken fragments of the upper layer of which were partially embedded in the lime.

The thickness of the beds of travertine varies according to the quantity of diabase in the neighbourhood, and is also dependent upon the extent to which the configuration of the ground permits of the percolated water resting long enough to allow of deposit of its lime. In some situations it forms a semi-translucent amorphous faintly yellow deposit; in others it is white and friable.

The magnesia of diabase is retained by the clay more tenaciously than the lime, and is found in the water of wells dug through such soil.

The lime and magnesia having been removed from the disintegrated diabase, iron and alumina silicate are the constituents of the residual clay now under consideration. It is seldom pure, owing to the admixture of sand from other rocks. The soil formed by the admixture is selected by the farmers for garden produce and fruit trees, and that is probably one reason why the farm-house of the district is invariably at the foot of a hill; another being that the clay is more retentive of moisture. The wild olive of the country is usually found in this clay on the hillsides. In the valleys the bulbous plants so frequent in this country seem to select this soil.

The following analysis made by Lieut.-Col. R. H. Firth, R.A.M.C., of the red clay, from a sample brought to England from near Pretoria, may be of interest:—

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Water} & \ldots & \ldots & \ldots & \ldots & 4.1 \text{ per cent.} \\
\text{Organic matter} & \ldots & \ldots & \ldots & \ldots & 2.9 \\
\text{Lime} & \ldots & \ldots & \ldots & \ldots & 1.8 \\
\text{Alumina} & \ldots & \ldots & \ldots & \ldots & 25.5 \\
\text{Silica and insoluble matter} & \ldots & \ldots & \ldots & \ldots & 63.4 \\
\text{Potash} & \ldots & \ldots & \ldots & \ldots & 0.3 \\
\text{Chlorides} & \ldots & \ldots & \ldots & \ldots & 0.5 \\
\text{Phosphoric acid} & \ldots & \ldots & \ldots & \ldots & 0.4 \\
\text{Magnesia} & \ldots & \ldots & \ldots & \ldots & \text{Traces.} \\
\end{array}
\]
Although the clay is more retentive of moisture than other soils in South Africa, it is less so than the clays of temperate climates. In countries where a fierce sun rapidly bakes the top soil, cracks are produced, extending for some distance downwards; through these the subjacent moisture is evaporated, and the superficial portions become easily pulverised. The great value of the soil as a check to the rush of rain water depends much on this superficial fissuring; flood water, instead of running rapidly off, sinks into the cracks, and is thus delayed on its road to the river.

(2) The sandy soil of South Africa is the result of disintegration of the sandstones and mudstones. Sand is washed down rapidly by the heavy rains to the valleys, where it is swept into the rivers and is responsible for their muddy condition. In valleys whose outlet has not been free the sand has been deposited in layers varying in colour with the amount of vegetation which was once present at the period following deposit. In some districts there is no carbonaceous deposit; but wherever found, the sand bears evidence of having been deposited in depressions of the surface. In some places the deposit of sand presents a flat expanse between neighbouring hills, indicating silted-up lakes; in others it is the site of a stream or river which has cut its way through such a silted up lake, and in doing so has exposed the stratified nature of the deposit. Along the Modder River, banks of this stratified sand as much as 40 feet in depth may be seen. This fluviatile deposit may be expected to contain the fossil remains of the fauna and flora of the period during which it has been laid down. The records of such remains are scanty. Very occasionally a few shells of fluviatile molluscs, such as the ubiquitous Unio, may be discovered embedded; occasionally small lenticular patches contain the remains of ferns. A portion of a horn-core of a wildebeeste was dug out at one spot, while at another a minute phalanx from the foot of some mammal was found by the writer.

The superficial sand is easily moved by the wind, and after a dust-storm the surface is found ripple-marked over wide areas. It is not unlikely that the ripple-marks so often found preserved in the old sandstones may have been produced by a similar process.
The camel thorn (mimosa) grows freely along the sandy banks of the rivers and on the sand flats, when these are not high above the water level. Where watered, melons are produced freely on this class of soil. As a rule, however, the vegetation is scanty in proportion as the sand prevails, and lasts only for a short period after the rainy season.

(3) In some localities a black clay is found. This is the result of the clay from a diabase rock having had its moisture retained owing to some mechanical obstacle to outflow of the flood water, and as a consequence having formed the site of a considerable vegetation. On decay the plants have left their carbon in the soil, thus producing the black colouring. Occasionally wide tracts of such dark clay are found, but then contain a considerable sandy admixture. When once the obstacle to outflow of the water has been removed, these clays, unpleasant swamps in rainy weather, rapidly dry and form a crumbling soil full of fissures from the shrinkage of the clay under the heat of the sun, as well as from the removal of some of its components in solution by the percolated water.

To the soldier the nature of these soils is one of some moment. If his camp is pitched on a sandy area, a breeze fills his clothes, his bedding and his food with grits and dust. The trenches dug round his tent are obliterated at one time by rain, at another by wind. His tent-peg and picketing-pegs will not hold. His latrines, easily dug, provide scanty material for chemical combination with the excreta, while the emanations travel upwards through the porous covering, and solutions travel rapidly downwards. The glare from the sun is painful; the mid-day heat is excessive, and the night radiation and evaporation when the sky is clear reduce the temperature to such an extent that the diurnal ranges become extremely wide.

The clays are cold and damp during rains, but rain is not frequent. Though the red and black soils absorb more heat than the sands, the air above them is not so hot in the mid-day, while at night the fall of temperature is not so marked as on sandy soil. There is less dust, partly because of the coherent nature of the soil, partly because vegetation tends to grow better on the clays. Broadly speaking, the clays are the soils of the high ground, the sands of the lower—even if for
no other reason this fact is sufficient to indicate that the clays in South Africa are usually preferable as sites for camps, temporary or permanent. Latrines are more advantageously placed in such soils than in sands, while the minor objections adverted to above regarding trenches and tent-pegs are not applicable in clays. The glare is nil, while dust-storms, though carrying a dirtier-looking material, do not produce the same amount of dust as over the sandy soils.

The question of water supply mainly depends in this country on other conditions, described above, than the condition of the soil, which after all is generally scanty. Surface wells are not to be thought of except in an emergency. If they should be necessary, the clays of the higher ground must be avoided as not affording water; this will be found in the more dependent part of the country if the soil happens to be deep enough to have guarded the percolated water from evaporation. Sometimes the valley has been formed as a deep trough in the bed rock, and this trough has filled up with diluvial clay and sand, as on the east of Pretoria, or in some of the natural "pans" (lakes or ponds) which are scattered about the country. It will probably be found that a pan, apparently an arid expanse at its surface, contains water at some depth below ground. Apart from their value for agricultural purposes, these superficial deposits are chiefly of use in detaining the water of the surface, at the same time protecting it from immediate evaporation, thus giving it time to percolate into the subjacent rocks. Were it not for this detaining influence the surface water would so rapidly run off the rocks that but little would be absorbed and the river-beds would be absolutely dry for the greater part of the year, having no percolated water to fall back upon to maintain their supply.

In South Africa, as in every other country, the upper slopes of the hills or koppies are practically bare of soil. This is more apparent in arid countries whose rainfall is of an intermittent and torrential character. The bases of the hills are the sites of a larger accumulation of detritus, or talus. This consists of rock fragments lying in some amount of decomposed rock constituents.

Hills formed by crust distortion, resulting in tilting of the rocks, have this talus slope more pronounced on one side than
The other—more on the side where the edges of the rocks are exposed than on that presenting the bedding plane of the strata. Horizontally bedded rocks retain their soil on those positions where rain and wind have least effect in removing the detritus. Usually further down the hill, where the slope becomes more gentle, the rock fragments diminish in size, while the disintegrated material predominates, constituting "soil." Hence we find at the foot of hills a soil (see fig. 16) composed of the products of the decomposition of the rocks composing the hill. These products have been described above for the country now under consideration.

Fig. 16.—A hill of horizontal rocks, showing a talus slope. T, talus; S, soil.

There are other points in regard to this soil which must not be overlooked, as they form an important feature when arranging the disposition of camps, apart from the supply of drinking water.

Water falling on this soil runs down the slope in large part on the surface. Some is absorbed and descends until it reaches the underlying harder rock. Gravity produces a downward current in the absorbed water, which moves, though less rapidly than the surface water, towards the stream bed. Some of this absorbed or percolated water is taken up by the underlying rock, in proportion varying with the character of the rock, but not to any great extent until the valley level decreases the rapidity of the fall by gravitation, and so gives more time for the slower percolation into the harder rock.

Consequently we have during rainfall on these slopes a
superficial washing of the soil, and a deeper soakage of surface impurities into the soil, increasing in quantity from the upper part of the slope downwards, and all travelling towards the bottom of the valley. When the rainfall ceases the moisture remaining in the soil does not all travel downwards; a proportion is evaporated. As the superficial portion is evaporated some of that lower down travels up by capillary attraction, and is also evaporated. This action is lessened in those soils whose surface rapidly bakes hard. But whatever the character of the soil, the water which has been evaporated leaves behind it dissolved and suspended matters. The earth has been just sufficiently studied as a culture medium to show that pathogenic bacterial life may exist in it for a considerable time; so that when such a slope has been inhabited it must become impregnated with dangerous human excreta.

It is obvious, therefore, that the higher the camp is placed on such a slope, or above such a slope, the less is the chance of fouling of the site, because the soil is less, and because such soil as exists presents less surface above the camp from which percolation may take place, and travel down beneath the site of the camp. Equally obvious is the fact that all dumping grounds should be on a portion of the slope lower than the camp. It is so obvious that the observation would not be worth recording were it not that experience has shown that the obvious frequently escapes recognition.

The lower the ground, and the nearer the water-level to the surface, the greater is the prevalence of the mosquito. This fact is mentioned, as, though not strictly a physical one, it points an additional reason why low-lying ground should be avoided, especially alluvial flats. A temporary camp may be necessary in such a position, but a permanent camp should never be placed on such ground; for these flats must be looked upon as presenting aggravated examples of the evils indicated above of placing camps on localities where soakage of superficial impurities can find a lodgment. Such localities may become for strategic reasons unavoidable; such reasons are the only ones which will justify their occupation when other sites may be available. Draughty, liable to wide fluctuations of temperature, damp, their soil lending itself to the retention of impurities, alluvial flats are localities which should be avoided as camps.
Mineral Springs.—In certain parts of the country where the superficial rocks are composed of the older formations, mineral and thermal springs come to the surface. They appear to be resorted to chiefly for the treatment of rheumatism, a frequent disease of South Africa. So far as our Army was concerned, the best known of these springs was that at Warmbad in the Transvaal, and the following analyses made in June, 1901, of the waters there, furnished by Capt. (now Major) W. W. O. Beveridge, D.S.O., R.A.M.C., may prove of interest:—

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium chloride</td>
<td>8.64</td>
</tr>
<tr>
<td>carbonate</td>
<td></td>
</tr>
<tr>
<td>sulphate</td>
<td>12.28</td>
</tr>
<tr>
<td>Potassium sulphate</td>
<td>1.8</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>0.80</td>
</tr>
<tr>
<td>Magnesium sulphate</td>
<td>2.05</td>
</tr>
<tr>
<td>Peroxide of iron</td>
<td>3.15</td>
</tr>
<tr>
<td>Silica</td>
<td>0.35</td>
</tr>
<tr>
<td>Lithium carbonate</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>0.22</td>
</tr>
</tbody>
</table>

Their value in the treatment of rheumatism appears not to have been equal to the expectation formed from their local reputation.

The sulphur springs on the south-western side of Cape Colony appear to have some curative effect for the above complaint. An interesting point is related of those near the source of the Olifant's River, near Modderfontein, south of Clanwilliam, to which annual visits are paid by the Dutch farmers for bathing purposes. These people trek to the springs, encamp beside them, and bathe in the sulphuretted waters, which are collected in a pool for this purpose. In 1902, at the date of the annual visit, which coincided with the time of the Mont Pelée eruptions, the water of the springs at Olifant's River were found so hot that the visitors were unable to follow their usual practice of bathing.

Besides this al fresco watering place, other localities in South Africa have been resorted to by the colonists on account of their mineral and thermal baths, Malmesbury having recognised establishments for patients undergoing "cures."

The mineral wealth of South Africa has not been touched upon, as having no apparent bearing upon the medical aspect of the recent campaign; but as the supply of fuel may be an important consideration as an adjunct to sanitation, the position
of coal-bearing strata is of interest. Such strata have been worked in the Molteno District in Cape Colony, in the north of Natal, in the Orange River Colony, and the Transvaal near Vereeniging, between Klerksdorp and Potchefstroom; along the Pretoria-Komati Poort Railway, at Ermelo and Vryheid. Deposits exist in Zululand and Basutoland; and further coal measures will be found in the Orange River Colony.

The coal of South Africa is the result of lacustrine deposits of carbonaceous material, and contains a considerable proportion of mud. It is found in the series of rocks shown in the table on p. 261, as Molteno, and is of Triassic age. Strata corresponding to the carboniferous of Britain have been found,* containing remains of plant life generically similar to those which produced our northern coal measures; but coal measures of the Carboniferous period of geology have not been found in South Africa. The Zululand and some of the Natal coals are probably of an age corresponding to that when the Permo-Carboniferous flora of Vereeniging flourished. These coal-fields, however, do not appear to be of much economic value.

In conclusion, it may perhaps be stated that the practical outcome of this sketch is to show the necessity for drawing a broad line between water supplies having shallow or surface origins and those obtainable from deep sources. To obtain the former is comparatively easy, and on them will depend the immediate supply of a moving force. Such waters are almost certainly impure. To obtain water from deep sources requires that the force be supplied with boring apparatus and pumps. These apparatus are essential if garrisons are to be supplied with water from sources which are conveniently near, and which will ensure a supply bacteriologically as well as tactically safe.

This central question of water supply dominates mankind both in peace and war; its preservation is the ultimate objective of all sanitary measures.

*A section of a specimen of silicified wood which forms an important fossil in the Molteno and Red Beds has been kindly made by Mr. A. Earland, of the Quellett Microscopical Club, and indicates the coniferous nature of the wood, the type of structure being Araucarian. It is similar to silicified wood (Araucaryoxylon), found by the French geologists in Madagascar, in strata resting against the central massif.
434  A Sketch of the Medical Geology of South Africa

BIBLIOGRAPHY.


KEANE, A. H. "South Africa." (Stanford's Compendium, part 2.)

MERRILL. "Rocks, Rock-Weathering and Soils."


RECLUS, E. "The Earth." (Edited by A. H. Keane.)

RUSSELL, I. C. "River Development."

