[*Reprinted from* THE TRANSACTIONS OF THE GEOLOGICAL SOCIETY OF S. AFRICA, VOL. VII., PART I., 1904.]

ON SOME GLACIATED LAND SURFACES OCCURRING IN THE DISTRICT BETWEEN PRETORIA AND BALMORAL, WITH NOTES ON THE EXTENT AND DISTRIBUTION OF THE GLACIAL CONGLOMERATE IN THE SAME AREA (Read 11th April, 1904).

By E. T. Mellor.

(Published with the permission of the Director of the Geological Survey).

[Plates VI., VII., VIII., IX. and X.]

I.—DESCRIPTION OF THE GLACIATED SURFACES.

Although good examples of glaciated land surfaces have long been known in other parts of South Africa, notably in Cape Colony, Natal and the Vryheid district, none have hitherto been found, I believe, so far north as the neighbourhood of Pretoria, or within the present limits of the Transvaal.

The occurrence of many outlying patches and remnants of Glacial Conglomerate occurring in the neighbourhood of the Elands River, twenty-five miles east of Pretoria, led me to make a somewhat careful search over that area for other evidences of former glacial action.

In July last I was fortunate enough to find a good example of a glaciated rock surface, showing clear striations, in the neighbourhood of Elands River (Plate VI.), and later, in December, a number of other similar surfaces in the vicinity of the Douglas Colliery to the north of Balmoral (Plates VII. and VIII.). These surfaces form the subject of the present paper.

The glaciated surface shown in Plate VII., which was the first met with, occurs to the north of Elands River Station, on the road which leads to the farm houses on Hartebeestefontein (210), and Kaffirs Kraal (406). Immediately to the right of the road at a distance of one and three-quarter miles from the station is a somewhat conspicuous beacon. The glaciated surface lies two hundred paces distant from this beacon along a line bearing N. 285° E.

At this point there is a small outcrop of hard red quartzitic sandstone of the Waterberg Series, which continues into a small kopje lying some three hundred yards to the north. This is probably one of those which give the name "Rooikopjes" to the farm.

This outcrop of Waterberg Sandstones emerges from below a surface-covering of yellowish sandy soil derived from the waste of the Glacial Conglomerate. While the higher portions of the kopje show the rough weathering so characteristic of the Waterberg Sandstones, those portions

which, in the progress of denudation, are just emerging from the covering remnants of glacial deposits preserve very completely both the rounded and polished surfaces and the characteristic striations of glaciated rocks.

A good idea of the extent and appearance of these surfaces will be obtained by reference to Plate VII.

The glaciated surface is shown in the foreground. The light colour of the rock as seen in the photograph is due to the reflection of light from the polished surface of the stone, which consists of a very hard, close-grained, red, quartzitic sandstone or quartzite, with a few included pebbles and fragments of hard white quartzite, such as are frequent in the sandstones and breccias of the Waterberg Formation. Although extremely hard, these fragments are ground down to the general level of the polished surface.

The bedding planes of the sandstones can be seen at the further end of the glaciated surface, and the continuation of the strike of the hard bed extends into the middle distance of the picture. The beds dip under similar beds to the right, not seen in the figure, but also polished and striated.

As will be seen from the photograph, those portions of the rock which are just emerging from the covering of soft surface material show the most perfect polish. Proceeding along the same outcrop, the glacial effects are well marked for a distance of fifty paces, and then become less and less distinct owing to their destruction by weathering.

Similar conditions are found in the case of several other beds of the same character as those shown, but lying at a somewhat higher horizon, and further up the slope to the east, the glaciation being only evident about the point where the outcrop appears from under a surface-covering derived from the Glacial Conglomerate.

On the surface represented in Plate VII., the striae, which are better seen on the original rock than in the photograph, run parallel to the handle of the hammer shown in the figure. Their direction, which is very consistent over the whole surface, is almost due magnetic north and south (S. 2° W.). The striae on several similar surfaces in the vicinity, distributed over an area of about half a square mile, show a variation of only 2° to 5° from this direction. The movement of the ice flow, as indicated by the distribution of the more highly polished portions of the surfaces, was from N.N.W. to S.S.E. (true bearing).

The valley of the Elands River is represented in the photograph by the depression lying apparently immediately behind the house. To the right of the area photographed rises a high and very extensive "bult," extending over a large portion of Hartbeestefontein (210), and Witfontein (181). This is largely covered by beds of glacial origin, including conglomerates and sandstones. The latter are now being quarried for building stone, near the south-west boundary of Hartebeestefontein.

Plates VIII., IX. and X. represent portions of a group of glaciated surfaces found some twenty-three miles east of those above described, and occurring to the north of the Douglas Colliery, near Balmoral.

The Douglas and Crown Collieries are worked in a flat-topped hill, representing an outlying remnant of the continuous sheet of glacial and coal-measure rocks of the Karroo System which once covered the

whole of the surrounding district. This hill has a broad swelling base, consisting of glacial conglomerates and sandstones underlying the coal-measures, which in turn rest upon the ice-worn surface of the Waterberg Sandstones, which are the predominant local rocks of age prior to the Karroo System. Around the edges of this sheet of glacial deposits, where the Waterberg Sandstone is again coming to light at the surface owing to the gradual removal of the over-lying conglomerate, several typical polished and grooved surfaces are to be found, and "roches moutonnées" are comparatively common. The latter, while retaining their rounded shapes, have lost their polish and striation by weathering.

The surfaces represented in Plate VII. and Plate IX. occur three miles due north of the Douglas Mine, just beyond the southern boundary of the farm Klipfontein (436). They are both more extensive and more perfect than those above described from the Elands River Valley. As will be seen from the photographs, the glacial striae are both decided in character and perfect in preservation. Plate IX. gives a more or less general view of one portion of the glaciated rocks, which here, as in the case already described, consist of hard red quartzitic sandstones of the Waterberg Formation, which lie at a low angle, dipping 5° N.

Here, as near the Elands River, the striae are remarkably parallel and constant in direction, a number of readings showing only a variation of about 2°.

There is also a remarkable agreement in direction with those on the Elands River, the striae running almost due magnetic north and south (from 5° west of magnetic north to 5° east of magnetic south). As in the case of the Elands River occurrences, the northern margins of the surfaces are well rounded and polished, while on the south they are often rough and angular. So that in this case also the direction of the ice flow was from N.N.W. to S.S.E. (true bearing).

The glaciated surfaces are usually coated with a thin but hard film, composed largely of oxide of iron.

The striated surfaces occur in a flat grass-covered area, with a light covering of soil derived from the Glacial Congomerate. By the removal of this covering the surfaces become exposed. Their mode of emergence is well seen in the example represented in Plate X., in which the rounded and striated rock-surface just appears from below the superficial covering. On it lies a boulder from the Glacial Conglomerate of the type common over the whole district from the Elands River eastwards, to Balmoral and beyond.

In the neighbourhood of the Douglas Colliery, besides the group just described, I was able to find several other good examples of glaciated rocks.

A number of these occur on the very high ridge of Waterberg Sandstones lying north of the railway line from the Crown-Douglas Siding to Balmoral. On this ridge stand the beacons which mark the southern boundary of the farm Goedvertrouwd (526).

Along the southern slopes of this ridge, a little below the top, runs a strip of Glacial Conglomerate, forming a continuation eastwards of the

main mass underlying the collieries. It is along the edges of this strip that the glaciated surfaces are found. They all occur on hard, red sandstones similar to those previously described.

The best example is to be found about the middle of the south side of the ridge, close to and behind a small but conspicuous feature standing out from the front of the ridge and carrying a single bushy tree. Here again the direction of the striae is remarkably constant, and almost due magnetic north and south, varying not more than 5°. The direction of flow was from N.N.W. to S.S.E. (true bearing).

A particularly fresh portion of the surface is exposed by an old prospecting trench, which was apparently put down on one of the small outcrops of concretionary ironstone, so common near the base of the glacial series.

A second good example occurs near the end of the ridge opposite Balmoral Station. An old bridle track which runs direct from Balmoral to the Douglas Mine climbs the intervening ridge by a small gully on its south side. The track skirts the edge of the glaciated surfaces at the point where it emerges from the gully on to the flat top of the ridge. The surfaces here exposed are very highly polished and clearly striated. They lie just in the throat of the gully, and are inclined at various angles to the horizontal. The inclined nature of the surfaces appears to have locally influenced the direction of the striae, which have neither the strict parallelism nor the constancy of direction of other examples. Two prominent sets of striations cross one another, bearing respectively S. 30° W., and S. 80° W. (mag.). Others have a direction of S. 65° W. The direction of the ice flow was southerly.

At the western end of the same ridge, close to the branch line to the Douglas Colliery, the edges of a small inconspicuous outcrop of hard Waterberg Sandstone show, over a short distance of some ten yards, polished and striated surfaces.

Surfaces showing the rounding characteristic of ice action are abundant along the edge of the Glacial Conglomerate on the platform of Waterberg Sandstones lying to the east and north-east of the Douglas Mine. A more extended search would probably yield other examples retaining their original polish and striation.

II.—THE GLACIAL CONGLOMERATES.

The glaciated rock-surfaces described above all occur on the margins of areas covered by glacial deposits lying at the base of the Highveld Formation, and immediately below the Coal Measures.

These areas represent outlying remnants of the main development of the Karroo System in the Transvaal, which occupies so large a portion of the country to the south-east.

Throughout the accompanying description I have preferred the more general term "Glacial Conglomerate" to the more commonly used "Dwyka Conglomerate." As pointed out by Dr. G. S. Corstorphine, in the Annual Report of the Geological Commission for the Cape of Good Hope for 1899, there are considerable differences obtaining between the typical Dwyka Conglomerate of the southern portions of Cape Colony and the more

northern Glacial Conglomerates found in the neighbourhood of Prieska. These differences correspond to a difference in origin ; the former representing sub-aqueous, and the latter terrestrial deposits. The distinction of actual ground-moraines from sub-aqueous deposits of glacial origin applies also to the rocks described in the present paper.

The term Dwyka Conglomerate has come to mean a rock of somewhat definite lithological character, typically represented in the Cape Colony examples. The Glacial Conglomerates in the district to the north-east of Pretoria consist, like the Dwyka rocks, of glacial boulders embedded in a matrix largely made up of angular rock fragments, but this matrix has none of the igneous appearance which appears to be characteristic of that of the true Dwyka, but is usually much more sandy in character. While there can be no doubt of the suitability of a general term like "Glacial Conglomerate" to the deposits in question, there is some difficulty in the indefinite extension of an originally local name to rocks occurring a thousand miles away, and which, moreover, while probably corresponding closely in age with the southern deposits, are somewhat different from the latter both in mode of origin and in composition.

The glacial beds below which the striated surfaces occur have a fairly uniform character over the district referred to. They consist of irregularly alternating, usually more or less lenticular deposits of conglomerates, sandstones, and shales. The conglomerates have all the characters usual to ground-moraines. They contain an assemblage of boulders very miscellaneous in composition and size, embedded in a clayey, or more frequently sandy matrix full of smaller angular rock fragments. Bedding planes are rarely met with. The boulders are polished, facetted, and in the case of those composed of material sufficiently fine in grain, frequently striated. The sandstones are also very irregular in thickness, often massive and without traces of bedding ; they are white, yellow, or cream-coloured, and though often fine in texture, very rough to the touch. The shales are white or cream-coloured. They frequently show fine lamination, very regular over short distances, but not persistent over any considerable area. More frequently they partake of the nature of mudstones. These shales are more abundantly developed near the upper portion of the glacial series. In their mode of occurrence, and in their relation to other rocks, the whole assemblage of deposits is very similar to those described by Messrs. Rogers and Schwartz, from the Prieska District of Cape Colony. * Compared with the Prieska rocks, however, the matrix of the conglomerates appears to be of a less shaly nature, and the beds other than conglomerates are also more usually of a sandy than shaly character.

In a district some twenty-five miles wide, lying north and south of the Eastern railway line, and extending from the Elands River on the west to Balmoral on the east, these outlying patches of glacial rocks occupy very considerable tracts of country. East of Balmoral the glacial beds at the base of the Karroo Formation still largely retain their original covering of coal-bearing rocks ; west of that locality the sandstones, shales, and grits asociated with the coal play a very inconspicuous part, having

* Annual Report of the Geological Commission for the Cape of Good Hope, 1899.

been more or less entirely removed by denudation. The hill on which the Crown and Douglas Collieries are worked is one of the most westerly localities in which those portions of the Karroo System lying above the glacial beds are at all conspicuous.

The determination of the distribution and extent of the areas of glacial deposits in the district referred to in the present paper is usually a matter of some difficulty. The glacial beds, generally speaking, are soft in character and more or less horizontally disposed. They rarely give rise to any noticeable feature, and are but seldom visible at the surface. Exposures occasionally occur on valley slopes, notably in the neighbourhood of the Wilge River and its tributaries, south of the railway line.

When the glacial deposits lie upon comparatively soft sandstone areas, as is often the case where Waterberg Sandstones are the underlying formation, the difficulty of defining the margins of the sheets of glacial rocks is considerable. Both formations in such cases give rise to abundant red sandy soils, which completely veil the solid geology of the country. Moreover, like more recent glacial deposits in other countries, the Glacial Conglomerate is very irregular in its distribution. There is abundant evidence that it has been deposited upon a land surface possessing considerable variety. Many of the escarpments and valleys which form the landscape of to-day existed in not very different form in the period immediately preceding the deposition of the conglomerates. The distribution of the glacial beds in the valleys of the Elands River, Bronkhorst Spruit, and the Wilge River, shows that all these were in existence prior to the glaciation of the district.

In those areas from which the glacial deposits are only now disappearing, as for instance that immediately east of the Elands River and north of the Eastern railway line, not only do such traces of glacial action as striated rock surfaces remain, but the whole landscape has many of the aspects of glaciated country. The gently rounded extensive "bults" of this area, consisting almost entirely of Waterberg Sandstones, are in strong contrast to the rough ridges, steep escarpments, and deeply cut gorges which characterise areas of similarly disposed Waterberg Sandstones a few miles further east in the neighbourhood of the Wilge River. In the latter locality the Waterberg Sandstones have been earlier freed from their glacial coverings, and thus re-exposed to the action of ordinary denuding agents.

The original irregularity of deposition of the glacial series has been accentuated by subsequent irregularity of denudation. The remaining patches occur at very different levels, and may be present on one slope of a hill and entirely absent from the other.

The most northerly of these patches so far met with occupies portions of the farms Leeuwfontein (148) and Rietfontein (89), about ten miles north of Bronkhorst Spruit Station, while the most westerly is a small patch lying on the top of a high "bult" on the farm Zonderwater (173), about one mile west of the Elands River and three and a half miles south-east of the Premier Diamond Mine (see Map, Plate VI.).

These patches, composed of remnants of the Glacial Conglomerate, are common in this part of the valley of the Elands River, and include very

miscellaneous collections of boulders, among which rocks derived from the Waterberg Sandstones or from the Red Granite are predominant.

Further east, the glacial deposits cover a very large area on the farms Hartebeestefontein (210) and Witfontein (181). Fragments of a coarse grit are also frequent over the highest part of this elevated tract, and may indicate the presence of some of the grits and sandstones which normally occur above the glacial beds.

The presence of the Glacial Conglomerates on some of the high and gently swelling "bults" in the neighbourhood of the Elands River is usually shown by the abundant sprinkling of weathered-out boulders which strew the surface. These boulders vary much in size, and sometimes attain very large dimensions, reaching six to eight feet in longest diameter. In composition they also show very considerable variety, but they nearly always include a large proportion of rocks of Waterberg origin. These are chiefly hard, close-grained quartzitic sandstones, similar to those of the glaciated surfaces. Waterberg conglomerates of the usual type, consisting of well-rounded medium-sized pebbles of white quartzite in a brown sandy or quartzitic matrix, are also frequent. These banket-boulders have apparently been a puzzle to local prospectors, the larger ones, simulating banket outcrops, being often trenched upon.

Second in frequency of occurrence to rocks of Waterberg origin are boulders composed of the Red Granite or its associated varieties—syenites, granite-porphyries, etc. These are especially abundant along the valley of the Elands River to the east of the Diamond Farms, and in the neighbourhood of the Wilge River. In the latter area, where the Glacial Conglomerates rest upon shales of the Pretoria Series, shale boulders are also commonly met with. The glacial beds, here as elsewhere, have been influenced considerably in composition by the rocks locally subjected to ice action.

In some localities the Glacial Conglomerate rests directly on quartzites of the Pretoria Series, as for instance on the southern border of the farm Jackalsfontein (294). I have not been successful in finding any glaciated portions of the quartzites, which owing to their brittle character rapidly break up into angular fragments under atmospheric influences when exposed at the surface. The Pretoria quartzites would, on this account, be unlikely to retain such markings as glacial striae for any length of time after exposure at the surface.

To the south of localities where the Glacial Conglomerate lies upon Pretoria quartzites, boulders and blocks of the latter are very abundant in the conglomerate. They are especially common on the farm Witklip (532), and often attain very great dimensions.

III.—DIRECTION OF THE ICE-MOVEMENT.

With regard to the direction of movement of the ice, which gave rise to the deposits above described, the evidence of the striated surfaces points clearly to a movement in a generally north to south direction, or more exactly N.N.W. to S.S.E.

The evidence of the striae is confirmed by the composition and distribution of the boulders in the conglomerates, a very striking feature being

the predominance in any particular locality of boulders composed of rocks occurring most abundantly, or possibly in some cases exclusively, to the north.

The extensive nature of the glacial deposits and their distribution at very various levels, as well as the remarkable constancy in direction of the striae, not only over the same local areas, but on rock surfaces lying twenty-five miles apart, all suggest a very considerable magnitude for the ice sheet to which they owe their origin.

The direction of flow in the area described agrees approximately with that observed by Messrs. Rogers and Schwartz† in the neighbourhood of Prieska, Cape Colony, which is from N.N.E. to S.S.W. The same direction is given by Schenck‡ from a locality near the junction of the Orange and Vaal Rivers.

On a number of glaciated surfaces described by Dr. Molengraaff§ in 1898, from three localities in the Vryheid district, the striations were found to bear respectively S. 28° E., S. 58° E., and S. 33° E. (true bearing). Though not regarding the question as settled, Dr. Molengraaff considered that "so far all the evidence was in favour of a moving body coming from a south-eastern direction." In this case, therefore, the direction of flow would appear to be contrary to that of the ice in the instances described in the present paper, and to the occurrences in the neighbourhood of the Vaal River, in Cape Colony.

IV.—SUMMARY.

The observations recorded in the present paper may be briefly summarised as follows :—

In the district lying between the Elands River, twenty-five miles east of Pretoria, and Balmoral, outlying patches of glacial deposits, representing the lower portion of the Karroo System, are of frequent occurrence.

The glacial deposits consist chiefly of conglomerates, with some sandstones and shales.

The conglomerates are similar to boulder-clays in general composition and in relationship to underlying rocks. The matrix is, however, frequently rather of a sandy than clayey character. The contained boulders are very miscellaneous in size and composition. They always include a preponderance of rocks occurring most abundantly, or exclusively, to the north of their present position.

The glacial deposits were laid down upon a land-surface of considerable variety, many features of which re-appear with slight modification in the landscape of to-day.

In areas from which the glacial deposits have comparatively recently been removed, glaciated rock-surfaces are of frequent occurrence.

---

† Rogers and Schwartz, l.c., p. 96, "The Orange River Ground Moraine," Trans. S.A. Phil. Soc. vol. xi., part ii., p. 117.

‡ A. Schenck, Ueber Glacialerscheinungen in Süd Afrika.

§ Dr. G. A. F. Molengraaff, "The Glacial Origin of the Dwyka Conglomerate," Trans. Geol. Soc. of S.A., vol. iv., part v., Oct., 1898.

The direction of the ice movement, as shown by the resulting striations and by the distribution of the boulders, was from N.N.W to S.S.E.

That the ice sheet was of very considerable magnitude is shown by the extent of the deposits and their occurrence at very various levels, and by the parallelism and constancy of direction of the striae in widely separated areas.

EXPLANATION OF PLATES.

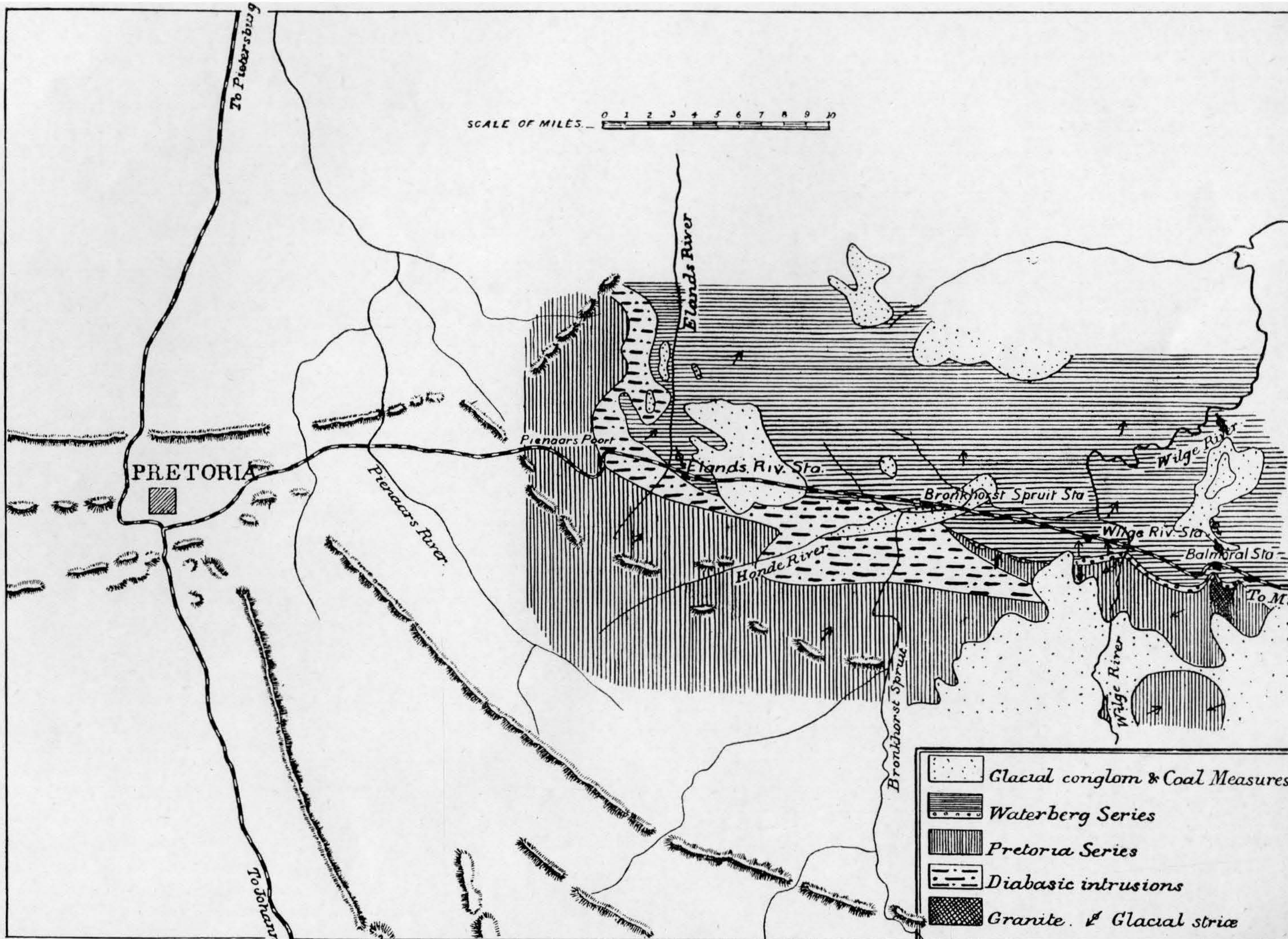
Plate VI.—Sketch Map, showing the distribution of some of the larger areas of Glacial Conglomerate.

Plate VII.—Glaciated Surface on the Elands River. Elands River Valley in the middle distance. The hammer shows the direction of the striae.

Plate VIII.—Glaciated Surface to the north of the Douglas Colliery, near Balmoral.

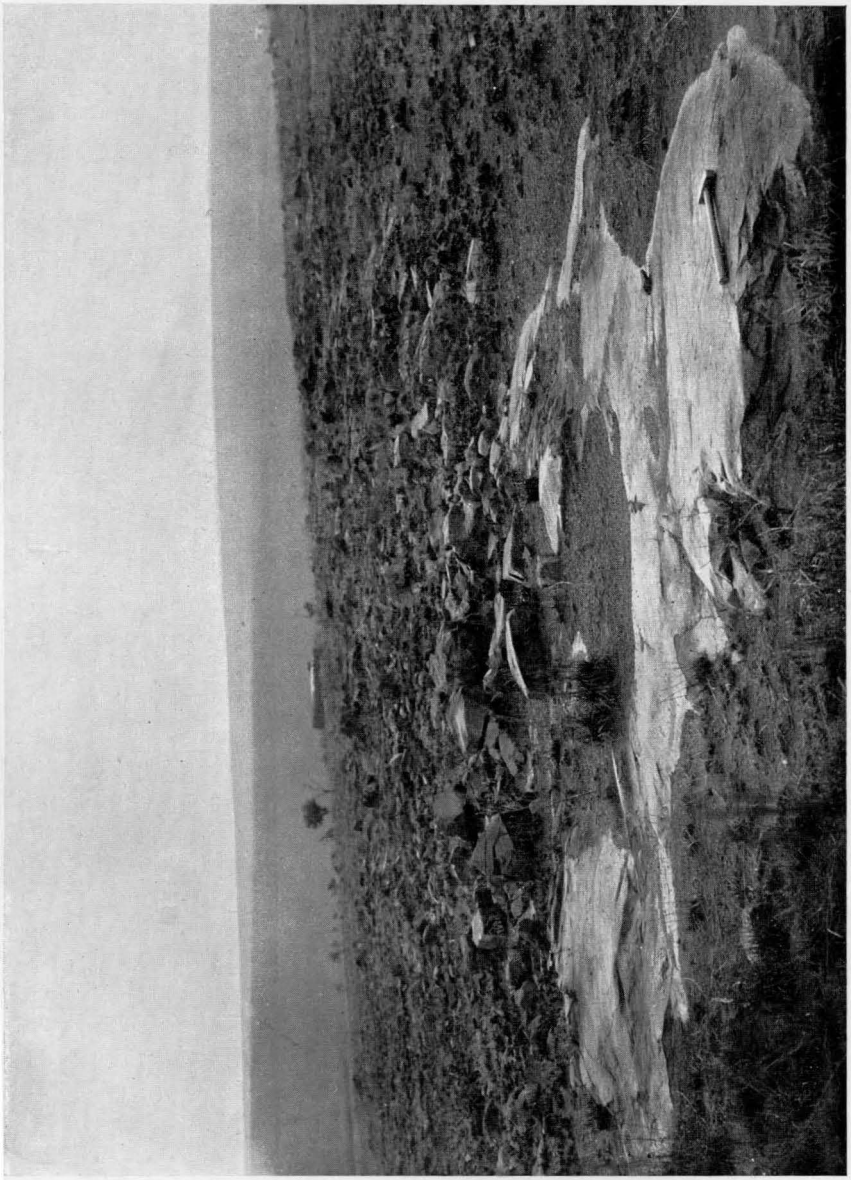
Plate IX.—The same.

Plate X.—A Glaciated Surface in early stages of exposure. A glacial boulder rests upon the striated rock-surface.



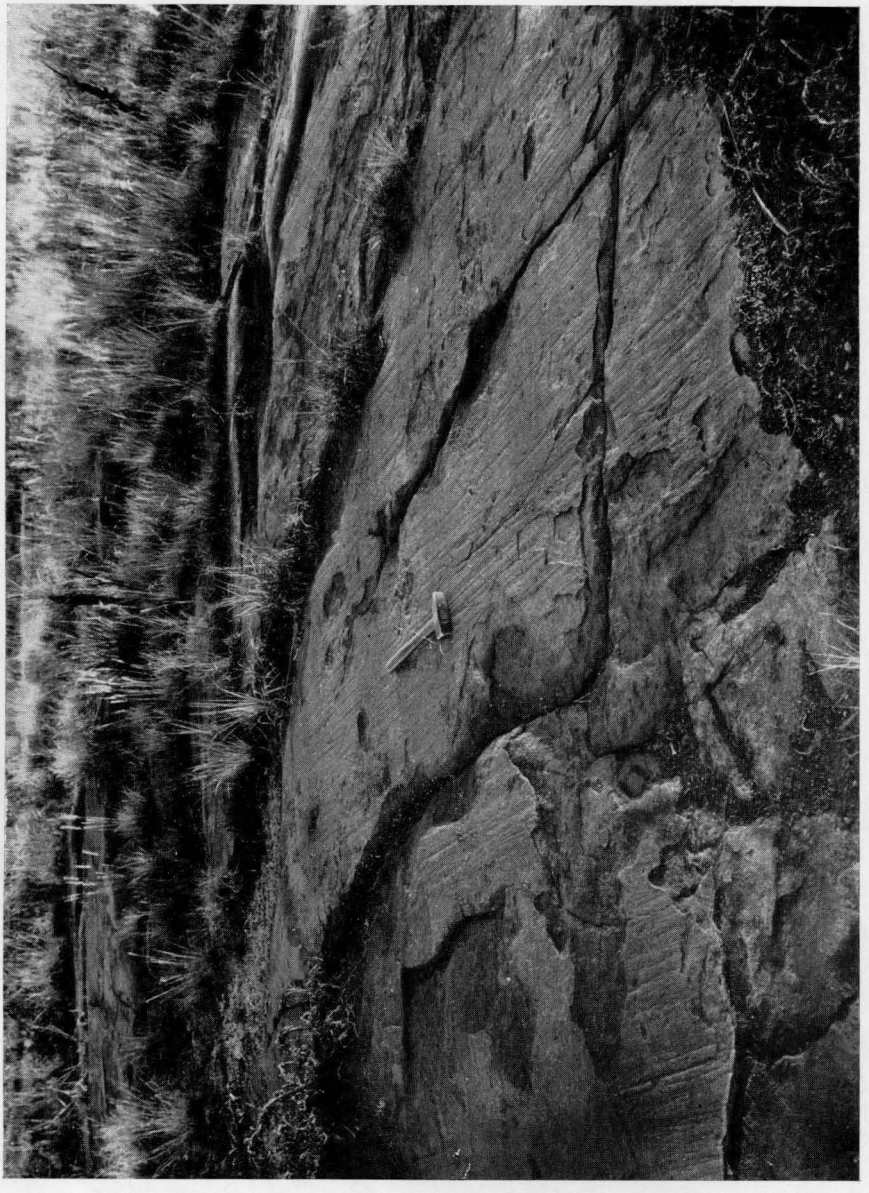
West, Newman, London, proc.

General Map of District East of Pretoria, showing Distribution of Glacial Conglomerate: E. T. Mellor.



Glaciated Surface on the Elands River.

West, Newman, London, proc.



Glaciated Surface North of Douglas Colliery, Balmoral.

West, Newman, London, proc.

Glaciated Surface North of Douglas Colliery, Balmoral.

West, Newman, London, proc.

A Glaciated Surface in Early Stages of Exposure.

West, Newman, London, proc.