# Résume of the Geology of the Richtersveld and the Eastern Sperrgebiet.

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[Plates XXXII–XXXV.]

ABSTRACT.

A brief description, together with a generalised geological map, of the stratigraphy of the Richtersveld and the eastern Sperrgebiet is given, strata varying in age from the Kheis to the Tertiary being described. A new assemblage of sediments, the Gariep system, is noted and the tentative correlation of this system with the Damara suggested. Four periods of magmatic activity are mentioned. Finally, the geological history of the area is briefly described.

## I. INTRODUCTION.

During three successive field-seasons (1943–45), the authors undertook detailed geological mapping in the Richtersveld, and one author (J. de V.) was able to do reconnaissance mapping in the eastern Sperrgebiet in South-West Africa. The results of this investigation are here presented in summary form, and it should be stressed that where controversial points are lightly glossed over, this is done not because of a lack of appreciation of their controversial character, but solely because it is impossible to discuss in one short paper all the aspects of every problem to be found within this area of more than 3,000 square miles. It is hoped to publish more detailed papers on individual problems later.

Previous published geological work on the Richtersveld includes Rogers' paper published in 1915 (9), which represents a notable effort to unravel the stratigraphy of a rather involved area. Van Biljon in 1939 (10) published the results of a more local investigation. On the Sperrgebiet, Beetz (1 and 2) and Knetsch (8) have made important contributions ; while that monumental work, " Die Diamantenwüste Südwest-Afrikas " (7), though dealing with an area to the west and north-west of that here under consideration, is of more than passing interest.

## II. STRATIGRAPHY.

Taking the formations chronologically and beginning with the oldest, one finds the following.

### Kheis System.

Rocks comparable and probably to be correlated with the Kheis system are found throughout the area. The system is capable of a threefold subdivision corresponding to that of the type area between Upington and Prieska.

The Marydale series is found in the north-eastern corner of the Richtersveld and consists of an alternation of felsic and mafic lavas, with agglomerates. Where intruded by the gray gneiss, the granite of the Richtersveld Complex, or the Tatasberg granite, the lava has suffered intense metamorphism, giving rise to various granitisation products and hybrid rocks. In the north, the lavas are intensely sheared.

The Kaaien series follows conformably on the Marydale lavas where seen in the gorge of the Orange river south of Nabas (Plate XXXIII, Fig. 1). In the north, the contact is obscured by shearing, but it may be seen in the centre in a small "island" in the sand east of Peilkop. In the Rosyntjiebos mountains, the Kaaien series consists mainly of light coloured quartzites, usually fine-grained to glassy but occasionally coarsely recrystallised, with conglomerates and occasional bands of black glassy quartzite. There are numerous bands of chlorite schist, which may represent graywackés or even tuffs in places. As the series is followed northwards, quartzites become scarcer, quartz-sericite schists taking their place. Hematite schists also make their appearance. In the north, against the Orange river, there is a thin band of tillite with inclusions of dark quartz or glassy quartzite. In the horst trending north from Kuboos, the Kaaien series consists mainly of white quartzites and conglomerates with subordinate chlorite schists. In the south, along the 29th parallel, there occurs a thick succession of meta-sediments with occasional quartzites still recognisable.

The Wilgenhoutdrift series is nowhere seen in direct contact with the Kaaien series; but, from the fact that the Kaaien quartzites both to the north and to the south dip inwards towards the lavas along the Orange river on either side of the Neint Nababeep plateau, it is inferred that the latter overlie the former ((6), p. 28). The Wilgenhoutdrift series consists almost exclusively of mafic lavas, relatively unaltered near Vioolsdrif, but progressively more highly sheared and altered away from this locality. In the west there are agglomerates. In the vicinity of Stinkfontein there are some quartz-sericite schists containing sillimanite in places, and hence probably of sedimentary origin. There are also some undoubted conglomerates and a bed of white marble. The relation of these sediments to both the Wilgenhoutdrift and the Kaaien series is obscure in this highly sheared and intruded area, but on grounds of proximity they are included in the former.

The Grootderm series which occurs near the mouth of the Orange river, is separated from all the other formations by a thrust fault indicating that it (the Grootderm series) has been thrust east and south-east over the rocks of the interior. The Grootderm series consists of a lower division of sheared mafic lavas and a conformable sedimentary upper division—sheared graywackés, grits, schists, thin quartzites, etc. The Grootderm series is *very tentatively* correlated with the Wilgenhoutdrift series.

### Gariep System.

West of a major dislocation and both north and south of the Kuboos pluton, strata that had previously been mapped as Kaigas (9 and 10) were proved to be invaded by the gray gneiss near the Hilda Trigonometrical beacon, and must thus be much older than was thought by Rogers and van Biljon. Similar rocks occur from north of the Aurus waterhole to south of Geinaggas in South-West Africa, and to these strata the name "Gariep system" has been given, after the Nama name for the Orange river. They have been further subdivided into three series, named from top to bottom :—

Holgat series,
Hilda series,
Black Hills series.

In the Richtersveld, the Black Hills series was seen only south of the Kuboos granite, where it forms a fairly narrow strip of sheared tillite and marble, with westward dip, building up the range of hills of that name. The base is not seen, since the series starts against the fault separating it from the Kaigas to the east. In the south, it is cut off by the gray gneiss which invades both the Black Hills and the overlying Hilda series. North of the Orange river there is an anticline with N.W.–S.E. strike exposing similar strata consisting of tillite, marble and arkose. They have been cut by both the gray gneiss and the granite of the Richtersveld Complex. South-east of Geinaggas, erosion has cut through the crest of this anticline, exposing a core of gray gneiss intrusive into the Black Hills series. In this gray gneiss are long narrow xenoliths of quartz-sericite schist, almost certainly Kaaien, and it can be plainly seen here that the Black Hills series unconformably overlies these schists. Therefore, if the correlation of the schists with the Kaaien series is correct, the Gariep system must be considerably younger than the Kheis.

Following conformably on the Black Hills series in both areas is the Hilda series, composed of arkose, schist and marble. In the vicinity of the Aurus waterhole and south of Nudabib the succession has been inverted by overfolding towards the south-west.

East of Swartbank and Holgat, the Hilda series is conformably followed by a thick succession of dark gray " arkoses " and schists, to which the name Holgat series has been given. The " arkoses " are the result in part, it is thought, of the felspathisation of the schists. At Buchuberg, on the coast south of Alexander Bay, there are quartzites in the series and also a tillite and a thin bed of marble.

It is believed that the Gariep system may be capable of correlation with the Damara system of central South-West Africa. In view, however, of the large hiatus of hitherto unmapped and geologically almost unknown territory separating the two areas, it was thought advisable to introduce local names for the succession in the area under consideration. If this correlation is correct, the following more detailed correlation may be suggested :-

| | | | | |
|---|---|---|---|---|
| Gariep system | Holgat series ... | ... | Khomas series | Damara system |
| | Hilda series ... | ... | Marble series | |
| | Black Hills series | ... | Chuos series | |

### Gray Gneiss.

This is the oldest and most widespread of the intrusives. Chemically it falls between soda-granite and granodiorite ; it contains biotite as the mafic constituent, with or without hornblende. In places it is more mafic and occasionally more leucocratic, no doubt owing to the absorption of older mafic and felsic rocks. The gneissose structure is always present regionally but is seldom very marked, and may be entirely absent locally. The texture is invariably granulose.

### Hoogoor Granite.

After consultation with Dr. D. J. L. Visser, this name has been given to the following granitic intrusion because it attains its maximum areal and most typical development on the farm Hoogoor, some 40 miles west of Pofadder. It appears to have been confined to the contact between the gray gneiss and the

meta-sediments and -lavas to the south, in which it appears as *lit-par-lit* injections on a grand scale. It is generally of a reddish colour, and mafic minerals are not common. It is possible that this granite may be a later phase of the main period of intrusion of the gray gneiss, and its origin may also be due in part to granitisation and palingenesis accompanying the earlier magma. The already highly altered sediments and lavas were further metamorphosed, and this metamorphism was carried still further with the injection of the abundant pegmatites which immediately followed the Hoogoor granite, of which they probably represent the more volatile rest liquor. The metamorphosed rocks were extensively muscovitised by the pegmatites, which also gave rise to the sporadic deposits of beryl, spodumene, etc.

### Richtersveld Complex.

This represents an intrusion of granitic magma with, in the south, granite-porphyries. The granite is quartz-rich, non-porphyritic and generally medium-grained, but with local aplitic and pegmatitic facies. Beetz's so-called " red granite " of the Witputs-Aus area appears to be identical with this granite. At and near Rooiberg in the south, assimilation of the Wilgenhoutdrift lavas has taken place, giving rise to syenite-porphyries, porphyritic quartz syenites, quartz shonkinites, akerites, etc. The mountain of Rooiberg itself exhibits a remarkably perfect ring structure, with a core of granite surrounded by a ring of porphyritic quartz syenite and syenite-porphyry—the latter probably representing the hood phase of the former—and this again enclosed by a ring of quartz shonkinite, akerite and similar more mafic types.

### Stinkfontein Series.

It is not definitely known whether or not the Stinkfontein series is younger than the granite of the Richtersveld Complex as these two formations are never seen in contact, but for various reasons the sediments are believed to be the younger.

The Stinkfontein series is capable of a four-fold subdivision : a basal conglomerate ; a lower sandstone and quartzite ; an upper conglomerate ; and an upper sandstone and quartzite horizon. The conglomerates are coarse, with pebbles of quartzite up to 7 or 8 inches across set in a sandy or gritty matrix. Locally they reach an exceptional thickness : e.g., the basal conglomerate about midway between Stinkfontein and the Rosyntjiebos mountains is upwards of 2,000 feet thick. The sandstones are gritty and light-coloured or pinkish, usually felspathic, always strongly cross-bedded, and locally ripple-marked. Sandstones and quartzites are about equally represented.

The series has a steady westerly dip of near 50°, and appears to attain a thickness of at least 25,000 feet just north of Stinkfontein. It should be pointed out, however, that large-scale cross-bedding, similar to that found in the foreset beds of a delta, may apply here, and that therefore the apparent thickness may greatly exceed the true thickness. Northwards, however, the thickness rapidly diminishes, and where the series is cut off by a fault north of Numees, it has been reduced to a mere thousand or two feet. It is obvious that the Stinkfontein series represents an extremely rapid accumulation of material in a steadily deepening and probably local geosyncline.

Interbedded with the sediments are numerous bands of contemporaneous lava, agglomerate and tuff. These are nowhere very thick, but occasionally crop out continuously for 25 miles or more. The lavas are trachytic to andesitic in composition.

### Kaigas Series.

A definite unconformity separates the Kaigas and Stinkfontein series immediately north and south of the Kuboos granite, the only localities where the two formations are in contact.

The Kaigas series may be said to be composed of four main rock groups calcareous rocks, e.g., limestones, marbles and calcareous slates; arenaceous rocks, e.g., small-pebble conglomerates, grits, arkoses, thin sandstones; argillaceous rocks, e.g., slates, phyllites, schists; and tillites. The basal member over the greater part of the Kaigas–Stinkfontein contact south of the Kuboos granite is a tillite (Plate XXXV, Fig. 1), and at least two more impersistent tillites are found north-west of Annisfontein. Lateral variation is rife within the series.

From south-west of Annisfontein to north of Obib the Kaigas series has been folded into an open anticline with south-south-easterly pitch. There are isoclinal folds on the eastern limb south of Sendelingsdrif and numerous small open structures on the western limb west of Annisfontein. In the latter area there are numerous thin limestone bands. Farther north, i.e., stratigraphically lower in the series, there are at least three main limestone horizons separated by an alternation of argillaceous and arenaceous types. In the vicinity of Annisfontein the Kaigas sediments have been metamorphosed by the Kuboos granite, with the production of marble, tactite, hornstone, etc. There are some fine examples of chiastolite slates.

Between Obib and Geinaggas, the Kaigas beds probably are separated from the Gariep beds to the north by a fault, this fault being of pre-Numees age and probably continuing southwards on a slightly curved course below the Numees tillite syncline as far as the later Kuboos granite. This fault is therefore never actually seen at the surface, but its presence may be inferred with fair certainty. (See sections CD and EF.)

### Numees Series.

An unconformity everywhere separates this series from the underlying rocks. It has been preserved in two main structures: the Sendelingsdrif syncline, commencing some 15 miles north of the Orange river and continuing almost due south to Annisfontein, where it is cut off by the Kuboos granite but is continued south of the pluton; and the Koivib–Nudabib syncline, which overflows its boundaries near the latter place in a gentle anticline and reaches the boundary fault of the Witputs trough near Witputs. In the vicinity of Numees there are some fault-outliers of lesser extent, and also some inliers in the Dwyka near Nabas (too small to be shown on the map).

Lithologically the series at Numees shows the following succession (see Fig. 1):—

| | |
|---|---|
| Upper limestone | ± 80 feet (top eroded away). |
| Dark arkoses with thin limestone lenses | 300–400 feet. |
| Lower limestone | 40– 60 feet. |
| Tillite | at least 600 feet. |

The tillite frequently contains thin limestone lenses and impersistent bands of gravel and dark shale. It is usually sheared—sometimes, e.g., near Sendelingsdrif, with exceptional intensity, as illustrated in Plate XXXV, Fig. 2. On the eastern limb of the syncline near Sendelingsdrif, a basal limestone has been locally developed, and its apparent thickness increased by the secondary replacement of tillitic material by carbonate.

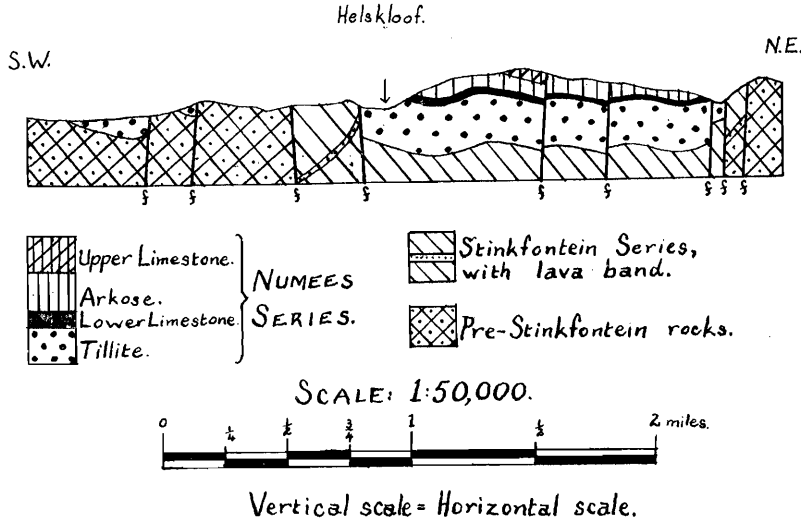


Fig. 1.

S.W.–N.E. section about 2 miles south of the Numees copper mine illustrating the succession in the Numees series and the post-Numees faulting.

### Swartbank–Kuboos–Tatasberg Plutons.

This line of intrusions is largely granitic in composition, there being the following three main types :—

A coarse porphyritic granite, usually pink, with large felspar phenocrysts twinned according to the Carlsbad law.

A medium-grained non-porphyritic granite, usually crowded with xenoliths.

A granite-porphyry or porphyritic aplogranite.

In addition, syenites and syenite-pegmatites are found in the east-central portion of the Kuboos mass.

Both the Kuboos and Tatasberg plutons exhibit a ring structure. In the former, the outer ring is of granite-porphyry invaded by the coarse porphyritic granite, which forms the second ring. Inside this second ring is a third, composed of the medium-grained granite, which surrounds a mass of syenite. In the case of the Tatasberg mass, the outer ring is composed of the coarse porphyritic granite, which surrounds an inner area of medium-grained granite. The satellite to the north-east of the Tatasberg is composed almost exclusively of pink granite-porphyry. The Swartbank pluton shows only a few outcrops in the dune-covered terrain and the granite is always very weathered, but it appears to consist of both the coarse porphyritic and the medium-grained varieties.

The detailed mapping of planar structures in the Kuboos granite mass clearly indicates that the pluton is funnel-shaped, i.e., it is an ethmolith, with the foliation planes all dipping inwards. The peripheral angles of dip are the least, the angles increasing as the centre of the mass is approached. The highest dips are found not in the absolute centre, but somewhat to the east and south, and it would appear as if the " throat " of the ethmolith is situated below this point.

While it is definitely known that these intrusions are post-Numees in age, their age relative to the Nama could not be determined in this area. It may be possible to date them near the Chamgab river by making use of the dykes of their age, of which there are four main varieties : bostonites, granite-porphyries, diabases (kersantites) and camptonites.

### Nama System.

The usual subdivision is possible :—

The Kuibis series at the base composed of quartzites, small-pebble conglomerates, coarse arkoses.

The Schwarzkalk series, composed of limestones (black and foetid, pink, blue), shales, quartzites, arkoses, cherts, clay-pebble conglomerates.

The Schwarzrand series, composed of green shales mostly, with quartzites and thin limestones.

The Fish River series (near Witputs), composed mainly of sandy strata with shales.

The limestones of the Schwarzkalk series in the Neint Nababeep plateau are especially numerous near the Orange river, but the majority pass laterally southwards into white quartzites and arkoses.

At Nabas there is a local development at the base of the system, below the Kuibis quartzite, of a succession of shales, quartzites, conglomerates, limestones, limestone-conglomerates and a 50-foot thick tillite. This succession has been called the Nabas series, and has been described elsewhere ( (4), pp. 140–141).

### Dwyka Series.

At Vioolsdrif and Nabas the Karroo system of South-West Africa crosses the river as beds of siltstone and tillite of the so-called " red " Dwyka. They are of importance in enabling us to date some at least of the post-Nama faulting.

### Tertiary to Recent Deposits.

An interesting assemblage is represented in the area.

*Raised beach deposits* exist along the coast. They are diamondiferous in places, and have been worked to a height of 145 feet above M.S.L. Fossils in them show evidence of a change from warm to cold water conditions. Remnants of raised beaches have also been found farther inland, to a height of approximately 594 feet above sea-level.

*River terrace gravels* are found along the main rivers, especially the Orange. Surfaces have been measured at 380 ft., 240 ft., 203 ft., 175 ft., 145 ft., 120 ft., 100 ft., 60–80 ft., 50 ft. and 20 ft. above river-level at various localities, chiefly Vioolsdrif, Nabas, Sendelingsdrif and Swartwater-Arries.

*Older sands.*—This term includes the rock-waste and coarse sand found choking the principal valleys leading down to the Orange river; talus; deflation residua; etc. They probably embrace a long period of time.

*Silcrete* is found mainly near Alexander Bay, and also underlying some of the secondary limestone near Grootderm.

*Secondary products* are found throughout the area. These include mainly calcification products (at the base of the Numees tillite and as large sheets of secondary limestone in the Grootderm series); ferruginisation products (in the Kaigas series and in the Grootderm series); and silicification products (mainly in the Grootderm series).

*Wind-blown sand* is found mainly in dunes on the coastal plain.

*Alluvium* is found along the main river channels.

## III. GEOLOGICAL HISTORY OF THE AREA.

The geological history of the area may be summarised as follows :–

(1) After the Kheis sedimentation and volcanic activity, there was a period of folding along E.–W. axes east of the Neint Nababeep plateau, these axes swinging round to N.–S. west of the plateau.

(2) After erosion, the Gariep sedimentation followed, this being in turn succeeded by an intense orogeny, folding taking place along N.–S. axes south of the Orange river swinging round to N.W.–S.E. north of the river. In the area bordering on the Sperrgebiet, overfolding towards the south-west is general. The sharp folds indicated in sections GH and IJK are purely schematic.

(3) Intrusion of a granitic to granodioritic magma (gray gneiss), probably largely contemporaneous with at least the latter part of the last orogeny. Widespread granitisation of the older rocks, especially the volcanics.

(4) *Lit-par-lit* intrusion of the deformed sediments and lavas by a granitic magma (Hoogoor granite) and emplacement of pegmatites.

(5) Intense shearing, mainly along a N.N.W.–S.S.E. direction.

(6) Intrusion of the granite of the Richtersveld Complex, probably a quiet welling-up of magma. However, at Rooiberg there is evidence of the prying open of the crust.

(7) After prolonged erosion, the local (?) Stinkfontein geosyncline developed, and a rapid accumulation of coarse sediments followed, accompanied by contemporaneous volcanic activity.

(8) This was followed by slight folding but fairly intense faulting, the latter being especially noticeable on the eastern flanks of the Stinkfontein mountains between Stinkfontein and the Rosyntjiebos mountains. Dominant direction of faulting: N.–S. or slightly east of north.

(9) Intrusion of firstly mafic dykes (gabbros and amphibolites) and later more felsic dykes (quartz syenites and quartz diorites), the former especially filling fault planes. These dykes are definitely post-Stinkfontein but pre-Nama in age. They are also pre-Tatasberg granite, and have not been seen in the

Kaigas series, which they may therefore antedate. Dominant direction: N.N.E.–S.S.W., and also to a much lesser extent N.N.W.–S.S.E. These dykes prove definitely that the Stinkfontein series is older than the Nama system.

(10) The Kaigas sedimentation followed after a period of erosion, and was ended by slight folding along N.–S. or N.N.W.–S.S.E. axes.

(11) Intense normal faulting along N.–S. directions, followed by a long period of erosion.

(12) Numees sedimentation, followed by folding along N.–S. axes south of the Orange river and N.W.–S.E. axes north of the river.

(13) Intense normal faulting, featuring renewed movement along many of the faults formed under (11). (See section EF.)

(14) Intrusion of a line of plutons (Swartbank, Kuboos and Tatasberg) nearly at right-angles to the dominant tectonic direction. No intense folding took place during the emplacement of these plutons.

(15) Nama sedimentation (this may antedate (14)—no reliable data).

(16) While no intense post-Nama folding is known from the area under consideration, such has been reported by Beetz and others from the Lüderitz littoral. The western edge of the Neint Nababeep plateau at Modderdrif shows some signs of folding.

(17) Pre-Karroo faulting on a small scale may be seen at Nabas and Vioolsdrif. The Annisfontein fault may possibly be referred to this period.

(18) After a long gap in the geological history, the Karroo sedimentation took place.

(19) In the northern and western Richtersveld there are numerous dolerite dykes with E.–W. and N.–S. strike. These are tentatively referred to the post-Karroo, but admittedly on slim evidence. Two similar dykes cut the Schwarzkalk series in the Neint Nababeep plateau.

(20) Crustal tension is indicated by post-Karroo faults at Vioolsdrif and Nabas. To this period of tension may probably be referred the post-Nama faulting of the eastern Neint Nababeep plateau, S.E. of Stinkfontein, north-east of Sendelingsdrif (not shown on the map), and the faulting and monoclinal flexuring in the Huns plateau, including the Witputs trough.

(21) The recent history of the area is mainly one of oscillations in sea-level, with a general gain in elevation of the land to the extent of at least 600 feet.

The following points should be noted :—

(1) The age of the Grootderm thrust is unknown. However, its peculiar trace in an area of predominantly N.–S. structure suggests that it may be post-Kuboos granite in age (hence post-Nama ?), the crust along the strengthened Swartbank–Kuboos line refusing to yield during the orogeny noted under (16).

(2) The nature of the contact between the Kaigas series and the Gariep system west of the Kuboos granite is obscured. Lateral variation in the Kaigas series may be sufficient to explain the disappearance of these strata; but, on

the other hand, there may be a fault under the sand. If the latter postulate is accepted, this fault may be the extension of the deduced N.–S. fault underlying the Sendelingsdrif syncline and there separating the Kaigas and the Gariep.

(3) If the Kuboos granite is post-Nama in age, then some of the faulting noted under (13) may be included under (17). It should be noted that the presumably post-Karroo dolerites are unaffected by these faults.

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