Discussion.

Dr. S. H. Haughton.

The authors of the Resumé of the Geology of the Richtersveld " are to be congratulated on their paper, and we shall look forward to the publication of their fuller account of the geological features of this most complicated, fascinating and inhospitable area. Their work, which extended over three long and arduous field seasons, is the most detailed study of the area that has yet been undertaken and although they were greatly assisted by a complete series of beautiful vertical air photographs covering the whole area they were not thereby relieved from the severe physical difficulties which so inhospitable a region places in the way of the geologist. I well remember hearing from Dr. Rogers of his trials when he studied the area prior to his 1915 paper ; and Frommurze and I understood a few of these when we worked for a short time in the contiguous area in South West Africa.

The authors have found it necessary to sub-divide the rocks of the area much further than had been done and to institute new names for the series which could no longer be fitted into the old classification. Some of these changes are rather striking. In his original survey, Rogers lumped all the quartzites and associated rocks into one series which he called the Stinkfontein series, adopting a name suggested to him by Leipoldt. Following him, Frommurze and I placed the quartzites on the South West African side of the Orange river south of Klipneus, which are an easterly continuation of the massive rocks of the TcOulyroup or Rosyntjiebos mountains, in the Stinkfontein series. Now, these rocks are considered to be much older than the true Stinkfontein beds and are mapped as Kaaien and part of the Kheis system. For a considerable distance they are shown as in contact with and having the same strike as the Stinkfontein quartzites which, according to section E–F, rest directly upon them with a dip in the same direction.

The quartzitic rocks east of Holgat and along the coast which were mapped by Rogers as Stinkfontein beds have been separated by the authors from that series and have been assigned to the Holgat series of their new Gariep system which, like the Kaaien, is held to be invaded by the gray gneiss which is earlier than the Stinkfontein beds of the type locality. Rogers drew attention to the intrusive nature of the gneiss in the southern part of his Stinkfontein quartzite exposures and concluded that there must be gneisses of two ages—one pre-Stinkfontein and the other post-Stinkfontein. The present authors have preferred to subdivide the sediments and to date them with reference to a single gneiss.

A second point of interest is the absence of members of the Gariep system in places where the Kaaien and Stinkfontein beds are in proximity to one another. Section I–J, section E–F, and section G–H are of interest in this connection. In E–F the Stinkfontein beds are lying direct on the Kaaien without the intervention of the Gariep beds ; the same association is seen in I–J although immediately to the west of the fault south of the Hilda beacon the full succession of the thick Gariep beds is shown. Is it possible that the absence of these beds in the two fault blocks immediately to the east of them can be explained by post-Gariep, pre-Stinkfontein erosion ? The proof of the separateness of the Gariep system from that comprising the Stinkfontein, Kaigas and Numees beds would seem to depend largely upon the interpretation of the gneiss-sedimentary junctions north of the Hilda beacon and south-east of Geinaggas.

Another feature of the present interpretation is the number of tillites mentioned, each assigned to a different series. In succession upward we have—

(1) A thin band of tillite in the Kaaien north-west of Sendlingsdrift, with inclusions of dark quartz or glassy quartzite.
(2) Sheared tillite and marble in the Black Hills series south of the Kuboos granite and tillite, marble and arkose of the same age north of the Orange river.
(3) A tillite and a thin bed of marble in the Holgat series at Buchuberg on the coast.
(4) Tillites at the base of the Kaigas series, which is predominantly calcareous.
(5) The Numees tillite.
(6) A tillite in the Nabas series of the Nama system.
(7) The Dwyka tillite.

Some at least of the pre-Dwyka tillites listed were included by Rogers in his Numees tillite ; that in the Kaaien beds he did not observe. It will be of the greatest interest to read the authors' detailed descriptions of these rocks and to have it proved that tillites of so many different ages do occur within this comparatively small area.

The authors recognise frankly that many of the conclusions summarily presented by them may prove controversial. The object of this brief contribution to the discussion of their paper is not to express disagreement with them on the points raised, but to suggest that they should, as soon as possible, furnish us with a full statement of all the facts upon which their conclusions are based. The area examined by them is an extremely important one in the elucidation of the history of the south-western part of the continent and even of more distant areas ; and they are to be congratulated on having accumulated a mass of data from what has hitherto been almost a *terra incognita* to the geologist.

Dr. S. van Biljon.

I wish to confine myself to a few statements made by Drs. Söhnge and de Villiers in their paper " Resumé of the Geology of the Richtersveld and the Eastern Sperrgebiet."

1. (Page 268).—" 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."

The writers give no details about the ring structure. When I mapped the granite on the multiple exposure method, some years ago,* I found that coarsely porphyritic granite occupies almost exclusively the lower altitudes north of the Kuboos Mountains Block, becoming extra coarse near the northern contact, especially round Annisfontein and the Doornpoort River where Kaigas Limestone and shales occupy the wall rocks. On the other hand, the eastern part of the granite round Kaigas, at a higher level, and where large inclusions of limestone occur, the granite is relatively close-grained.

How this coarse porphyritic granite, then, can form the second ring if it occupies the outer space in the northern part of the granite and is absent in the eastern part, is difficult to understand. Furthermore, measurements of the sizes of phenocrysts on plane surfaces in the field and on polished slabs show that there is a serial relationship between size of phenocrysts and height in the granite in N–S and E–W radial directions. But the granite is not at the same height in the eastern and northern part of the mass, differing by nearly two thousand feet, it is clear that a ring structure on the above data is therefore non-existent.

Finally the strict linear relationship between height in the granite, on the one hand, and the soda, potash and lime contents of the perthite phenocrysts on the other for both coarsely porphyritic and porphyritic granite, shows again that the coarsely porphyritic granite at lower levels varies in itself and that this variation is continuous with the variation in the porphyritic granite of the Kuboos Mountains at higher levels.

From the above it is clear that height in the Kuboos massif is a function of the type of granite under consideration. It is indeed lamentable that the authors leave us in the dark about the intrusive relationships, the areal distribution and contact phenomena of the coarse porphyritic granite.

2. (Page 169).—" The detailed mapping of planar structures in the Kuboos Granite mass clearly indicates that the Pluton is funnel-shaped, i.e., it is an ethnolith, with the foliation planes all dipping inwards."

Again there is no evidence to substantiate this statement, and it is remarkable that the authors fail to give the evidence after such pains have been taken in " detailed mapping " of the planar structures. No information is given about the location of the structures, their angle of dip, their strike, the number of observations (which is very important) and the type of minerals in planar arrangement.

There are probably very few granite masses in Southern Africa where field evidence shows with such clarity that the granite takes up a space formerly occupied by sediments. The question is : *What happened to these sediments ?* It is absolutely imperative that the authors after having found the pluton so " clearly an ethnolith " should *give one an intelligible explanation of how the sediments (equal in volume to this ethnolith) disappeared to make place for a funnel-shaped igneous mass which narrows downwards into a " throat."* The authors fail to do this and therefore the statement regarding the manner of invasion of the Kuboos Granite Magma cannot be taken seriously.

The fact that the strike directions of—

(*a*) the major axes of the large sedimentary inclusions west of Kaigas and west of Doodskloof,

(*b*) the western limit of the Kuboos Mountains,

* van Biljon, S. " The Kuboos Batholith, Namaqualand, S.A. *T.G.S.S.A.*, Vol. 42, 1939, pp. 123–219.

(*c*) some of the major prominences in these mountains (Brandberg and Olynfontein Syenite),
(*d*) the spurrs of the Grootberg,
(*e*) the Springklipberg,
(*f*) the outcrops of granite west of Doodskloof,
(*g*) the granite immediately east of Kaigas waterhole,

are all more or less parallel to one another and also to the regional strike of the sediments adjacent to the Kuboos Granite, seems to be of great importance and cannot be ignored by any student who makes a serious attempt on the solution of the problem of emplacement.

I think that there is a too great a tendency among geologists to regard the movement of a plastic mass (magma) as an inherent property of the magma itself. Propulsion is the result of a force and the origin of this force must at least be hinted at in treating the rise of magmas.

By merely using the terms eruption, invasion or injection, we are only giving the result and not the origin of the propelling force. As the tectonic forces in the crust in the area in question were " dead " or nearly so at the time when the Kuboos Granite came into being, it is important to know the origin of the force or forces which propelled the Kuboos Granite Magma to its present position.

The linear distribution of the Swartberg, Kuboos and Tatasberg granites suggest fissuring or a zone of weakness in depth. On this line the Kuboos Granite is the major occurrence. If this granite according to the authors narrows downwards in depth, on what grounds do the authors of the paper in question consider the Tatasberg Satellite *to widen* in the same direction ?

If the statements enumerated above are an attempt to explain the textural and compositional variation of the Kuboos Mass* by a method of separate injections, a method which has also been invoked to explain the transverse chemical variation in certain concordant igneous masses, then, according to the evidence listed above, the authors were not convincing.

The excuse may be tendered that the paper is only a resumé and therefore the scantiness of evidence. In answer to this I can only say that even a resumé must in the first place rest on proof.

Authors' reply to discussion.

Reply to Dr. S. H. Haughton.

Dr. Haughton has pointed out several problems with which we were unable to deal at length in our very short paper.

(1) As regards the separation of the quartzites of the TcOrroroup or Rosyntjiebos mountains from the Stinkfontein quartzites : this hinges on one key field observation, namely, that the Stinkfontein series always rests with a sedimentary contact on the gray gneiss. Rogers (1915) mentions a gneiss cutting the Stinkfontein series in the vicinity of Oograbies mountain, south of the area under discussion, and also that the sediments near Port Nolloth and Kleinzee are invaded by granitic gneiss. One of the authors (P.G.S.) has examined the schists along the Buffels river to Kleinzee, and believes that they are the southward extension of the Holgat series. The ridges farther inland may in part be correlated with members of the Kheis system, but nowhere along this cross-section could sediments of the Stinkfontein series be found. We see no need for invoking a younger granitic gneiss (gray) to explain all the contact relationships.

In the case of the quartzites of the Rosyntjiebos mountains, it was found, both on the southern and on the northern flanks, that the gray gneiss invades the quartzites. The greater age of these quartzites relative to the gray gneiss could be established beyond the shadow of a doubt. These quartzites and schists were therefore correlated with the Kheis. Then, on the eastern crest of the mountains east of Kuboos, near Van der Sterrsberg, there was found the unconformity separating the Stinkfontein basal conglomerates and quartzites from the quartzites and schists of the presumably Kaaien series. Bands of darker (ferruginous) quartzite in the Kaaien series disappear under conglomerate and quartzite of the Stinkfontein series. This unconformity shows up very well on the aerial photographs. There is a difference of some 20° in the direction of strike, and over 30° in the amount of dip.

* *Op. cit.* pp. 149–154 and pp. 169–177.

(2) As regards the relation between the Gariep system, on the one hand, and the Stinkfontein series on the other, the evidence is again of a similar nature. Immediately north of the Hilda T.S., a gneiss correlated with the gray gneiss may be seen to invade the limestones and tillite of the Black Hills series with accompanying contact metamorphic phenomena. Just east of the beacon, the Stinkfontein series lies with a sedimentary contact on this same gneiss. It is therefore again established beyond any doubt that the Stinkfontein series is much younger than the Black Hills series, and hence younger than the Hilda and Holgat series which follow conformably on the Black Hills.

The Holgat series consists predominantly of quartz-sericite-biotite-felspar schists which grade locally into arkosic types, due, we believe, to granitisation. There can be no question of correlating these para-schists with the arenaceous Stinkfontein series.

(3) The relation of the Gariep to the Kheis system is admittedly uncertain and in many ways anomalous, as pointed out by Dr. Haughton. We have only two small grains of fact :—

(*a*) S.E. of Geinaggas it may be seen that the Black Hills series rests unconformably on quartz-sericite schists, these schists being *tentatively* correlated with the Kaaien.

(*b*) Below the Stinkfontein series at the Hilda T.S. there are some large meta-quartzite and quartz-sericite schist xenoliths in the gray gneiss, again tentatively correlated with the Kaaien series. (It should be pointed out that the only quartzites known from the Gariep system are the lenticular beds occurring high up in the Holgat series at Buchuberg on the coast.) Unfortunately, the quartzite xenoliths at Hilda and the Black Hills series are not seen in contact, as the broad sandy bed of the Holgat river intervenes.

In view of the paucity of facts, therefore, we have to assume pre-Stinkfontein faulting to preserve the Gariep system west of the present Stinkfontein mountains, with renewed faulting, possibly along the old fault-planes but with movement in the opposite direction, in post-Stinkfontein times. Admittedly not a very satisfactory explanation, but entirely within the bounds of possibility. It should be noted, too, that the problem is no longer the relative ages of the Gariep system and the Stinkfontein series, which has to our minds been solved (see (2) above) ; but the relative ages and the peculiar mutual disposition of the Kheis and Gariep systems.

(4) We should like to assure Dr. Haughton that the number of tillites in the Richtersveld at times proved a source of embarrassment to us, but we are morally certain that they are tillites, and we think that their separation is correct. Their identification is based largely on texture, i.e., angular pebbles scattered irregularly through a fine-grained matrix, and lack of sorting. There is a possibility that some (e.g., the Kaaien, Holgat and Kaigas tillites) may represent valley scree deposits formed in a mountainous region with a severe arid climate ; but the faint bedding observed locally suggests accumulation under wet conditions.

The tillite near the base of the Kaaien series is entirely isolated from any other tillites, so that mutual relations could not be determined directly. The same applies to the tillite in the Holgat series. Evidence has already been produced to prove, however, that the Kaaien and Holgat, if not of different systems, are at least different series.

The Black Hills tillite is pre-gray gneiss in age, and a great thickness of conformable sediments separates it from the Holgat tillite.

The tillites of the Kaigas series are post-gray gneiss, because post-Stinkfontein, and hence younger than any of the preceding three.

The Numees tillite is younger than the Kaigas series, which it overlies unconformably.

Evidence has been adduced elsewhere to prove that the Nabas tillite is younger than the Numees tillite.

The Dwyka tillite may be seen to overlie unconformably both the Numees and the Nabas tillites at Nabas.

Thus in short the evidence in favour of the separation of the tillites.

In conclusion, we should like to thank Dr. Haughton for his critical discussion. Our paper is a very abridged version of our findings in an area in which there are a number of different systems and series exhibiting a remarkably similar lithological succession. In mapping such an area, one is inclined to set up hypotheses which may, through continued usage, be accepted by the investigators as facts, and it is through the criticism of others that one is induced to reconsider and reweigh these field hypotheses.

Reply to Dr. S. van Biljon.

In reply to the sharp criticism by Dr. van Biljon, we should like to assure him that we plan to publish a more comprehensive paper on the Swartbank-Kuboos-Tatasberg plutons in the near future, and therefore propose not to deal at present with the details of the questions raised by him.

GENERALISED GEOLOGICAL MAP OF THE RICHTERSVELD AND THE EASTERN SPERRGEBIET

REFERENCE

- Sand
- Dwyka Series.
- Nama System.
- Swartbank-Kuboos-Tatasberg-Plutons
- Numees Series.
- Kaigas Series.
- Stinkfontein Series.
- Richtersveld Complex.
- Hoogoor Granite
- Gray Gneiss
- Holgat Series
- Hilda Series
- Black Hills Series
- GARIEP SYSTEM
- Sediments
- Lavas
- Grootderm Series (Wilgenhoutdrift Series?)
- Wilgenhoutdrift Series
- Kaaien Series
- Marydale Series
- KHEIS SYSTEM
- Faults
- Horizontal structure
- Vertical structure
- Dip of strata
- Strike and dip of foliation
- Contorted dip of strata

SCALE 1 : 500,000

10 5 0 10

MILES

Surveyed by P.G.Sühnge and J.deVilliers, 1943 - 1945.

Drawn in the Geological Survey Office, Pretoria, 1946

HORIZONTAL SCALE 1 : 500,000 VERTICAL SCALE EXAGGERATED

Faint lines indicate bedding or schistosity

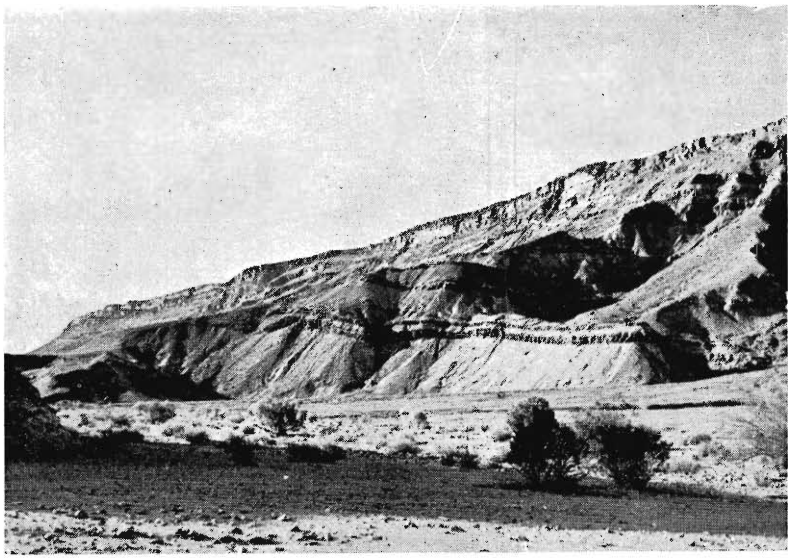

FIG. 1.
The western escarpment of the Neint Nababeep plateau at the mouth of Klein Helskloof. Schwarzkalk beds with a capping of dark limestone.

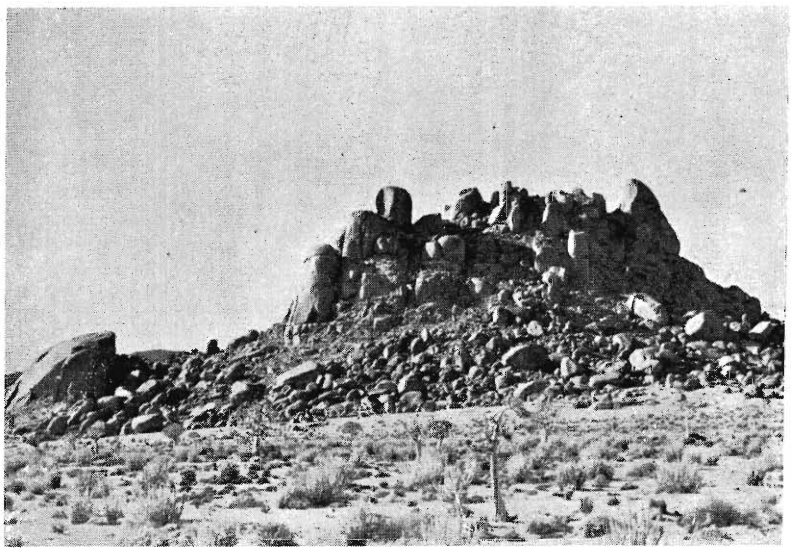

FIG. 2.
Typical koppie of Tatasberg granite.

FIG. 1.
Tillite at the base of the Kaigas series south of Geigas.

FIG. 2.
Extremely sheared Numees tillite north-east of Sendelingsdrif.
Note the elongated inclusions.

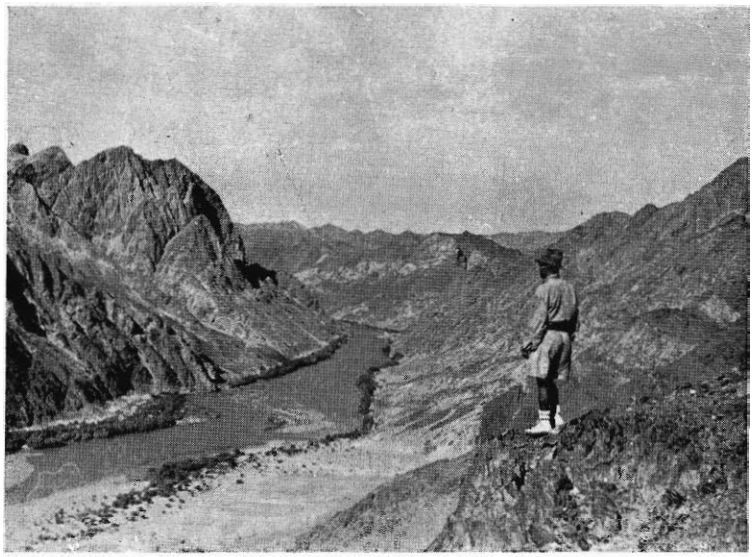

FIG. 1.
The gorge of the Orange river through the Rosyntjiebos mountains. The figure in the foreground is standing on sheared Marydale lavas ; beyond him the contact of these with the lighter-coloured Kaaien quartzites can be seen.

FIG. 2.
Kaaien quartzite peaks along the Bak river.