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Autor(en): **Delany, Frances M.**

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Ring structures in the Northern Sudan

By **Frances M. Delany**, Khartoum

With 4 figures and 1 table in the text

RÉSUMÉ

Ce travail décrit trois intrusions en forme d'anneau, observées par l'auteur dans le nord du Soudan anglo-égyptien. Des roches intrusives alcalines, granites ou syenites à riebeckite, aegyrine ou amphiboles et pyroxènes normaux, y sont associées à des gabbros et des coulées de laves acides. Ces laves forment la série la plus jeune de l'Antécambrien au Soudan. Les intrusions granitiques sont de forme annulaire comparable aux «ring dykes» de la région tertiaire de l'Ecosse. En général, une première phase d'intrusion granitique est suivie par l'intrusion d'un filon granitique annulaire. Les diamètres des anneaux varient entre 1,5 km et 20 km; l'épaisseur des filons varie entre 50 m et 2 km. Le tableau 1 à la fin de cet article résume le caractère général des intrusions et la nature des roches associées aux granites. Les résultats des levés géologiques sont publiés avec la permission du Service géologique du Soudan anglo-égyptien.

Field work in recent years has brought to light several intrusions in the Basement Complex of the Northern Sudan which show definite ring structure. This paper gives a short account of the ring structures mapped by the author in north-central and north-eastern Sudan. The geographical distribution of the areas described is shown in Fig. 1, they are the following:

(1) Sabaloka: 16°18′ N.: 32°40′ E.
(2) Jebel Qeili: 15°31′ N.: 33°47′ E.
(3) Jebel Tehilla: 17°47′ N.: 36°06′ E.

Two northerly structures, J. Umm Shibrik and Salala were mapped by I. G. Gass and will be described later; four unmapped rings have been observed only on air photographs.

The Precambrian rocks of the Sudan comprise three series: an older series of ortho- and para-gneiss, a schistose series and a younger series of acid lavas. The schists include altered arenaceous, argillaceous and calcareous sediments and intermediate to basic lavas. In the Central Sudan, they compose the Green series of the Butana while in the Red Sea hills, they are represented by the Odi schists. The Odi schists are folded in to narrow isoclinal folds and generally show steep dips; they are of epi- to meso-zone metamorphism. Younger acid lavas were extruded in restricted areas over the older folded series; they have been studied in detail at the VI Cataract and can be named the Sabaloka series. Riebeckite or aegyrine bearing intrusions, ranging from syenites to granites, are closely associated with the Sabalokan rhyolites. The intrusions are contemporaneous with, or younger than the lavas. These three subdivisions of the Precambrian may correspond to the triple division of the

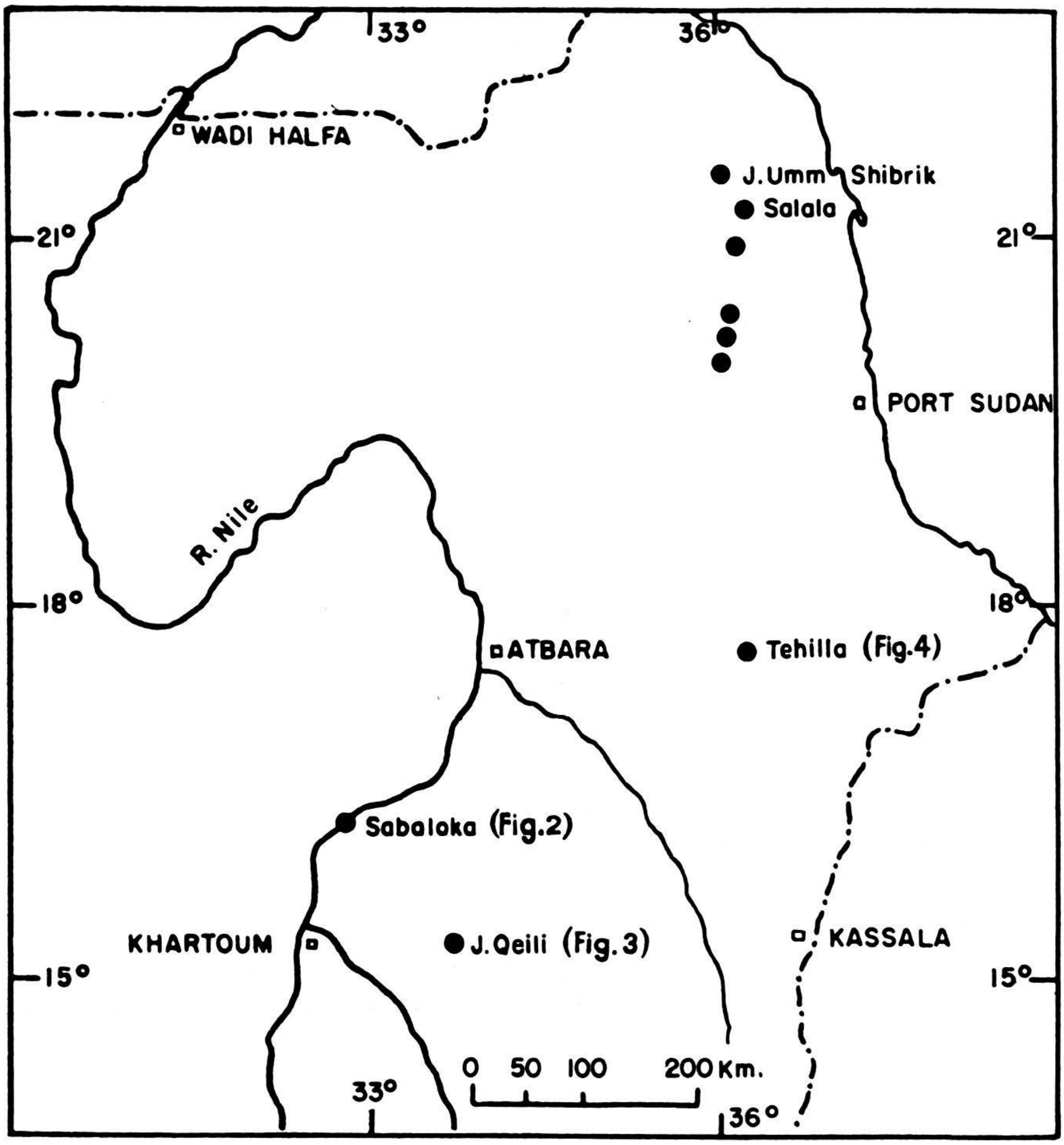

Fig. 1. Geographical distribution of ring structures in the Northern Sudan (ring structures indicated as black circles; towns indicated as squares).

Saharan Precambrian adopted by French authors: Suggarian, Pharusian and, youngest, Nigritian (LELUBRE, 1953[1])).

The ring structures in the Sudan are formed by intrusions of granite or syenite with which gabbro and rhyolite may be associated. The structures are younger than the Odi (Pharusian ?) schists which they intrude in complete unconformity. Normal pyriboles and mica replace in some ring structures the riebeckite and aegyrine which characterise the sodic granites associated with the Sabalokan rhyolites. As far as present field work has shown, the rings are formed exclusively by Sabalokan, that is Nigritian, intrusions.

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[1]) LELUBRE, M. (1953): *Stratigraphie de l'Antécambrien au Sahara.* C. R. somm. Soc. géol. Fr.

SABALOKA (Fig. 2)

The most prominent feature of the dome of crystalline rocks which occur at the Sabaloka gorge, 80 km. north of Khartoum, is a flat topped mass of red hills. After flowing over the clay plain of the Central Sudan, the Nile enters a precipitous gorge carved through the Sabaloka hills, about 150 m. below the level of the plateau. The gradient through the gorge is 1'015 cm/km. The hills are formed by a thick succession of rhyolitic lavas which were extruded in a flat cake over the gneiss. The lavas show a low degree of metamorphism; strong folding is mainly due to original flow banding but the beds show a centripetal dip. A southerly dip is observed in the bedded tuffs and ash on the northern slopes of the hills and a northerly dip in the south. This is probably due to a central subsidence which followed the extrusion of the lavas and gave rise to a circular line of weakness. Into this circular fracture was intruded a magma closely allied to that of the rhyolites, which crystallised as a granophyric granite porphyry. The hills are furthermore dissected by a close network of deep dry gullies which follow lines of fracture in the rhyolites.

The ring is slightly oval in a NE.–SW. direction with diameters of 20 km. by 15 km. It is divided by the Nile gorge which follows the longer axis. Ridges of the red granite porphyry, weathering to large dark red boulders, encompass entirely the rhyolite hills. The dark red colour affords a sharp contrast with the bright red rhyolitic core, so that the massive ring structure is clearly visible. The ring is slightly excentric to the north, where a considerable area of granitic gneiss lies inside it. South of the gorge, the dyke forms two branches, separated by a screen of gneiss. The inner branch lies directly against the rhyolites and traverses the NE. corner of J. Rauwiyan Island, continuing west and east along the lower slopes of the rhyolite hills. The southern branch passes through the SW. flank of J. Rauwiyan and forms a series of low hills eastwards. Here transverse connections occur with the inner branch in two places. The contact between gneiss and the dyke on J. Rauwiyan is vertical; the dyke is chilled to a fine grained compact green rock and the first 0.1 m. of hornblende gneiss at the contact has been altered to a fine hornfels.

The trace of the ring dyke is interrupted by superficial deposits to the SE. of the Sabaloka hills, but occurs again to the NE. in a row of high buttresses flanking the main hills. The granite porphyry of the southern peaks cuts gneiss and quartz veins and dips towards the rhyolite hills at 60°. The northern buttress is a pyroclastic rock.

The dyke ridge passes far to the north of the Sabaloka hills, encompassing a plain of granitic gneiss in the centre of which lies a hill capped by Nubian sandstone. The ring dyke can be traced on either side of the Nile and is exposed at the foot of J. Milh on the west bank. South of J. Milh, Nubian sandstone obscures the dyke which outcrops again in high boulder ridges west of the rhyolite hills. South of the hills, on the left Nile bank, two branches of the dyke are again separated by a screen of gneiss. The gneiss at the southern edge of the outer dyke has been considerably displaced and sheared to an augen gneiss for some 50 m. from the contact.

Within the ring dyke, other dykes of granite porphyry cut the rhyolite hills; they are generally oriented W.–E. and show considerable ramifications. The rock is mainly finer grained and more clearly porphyritic than the ring dyke. Minor veins

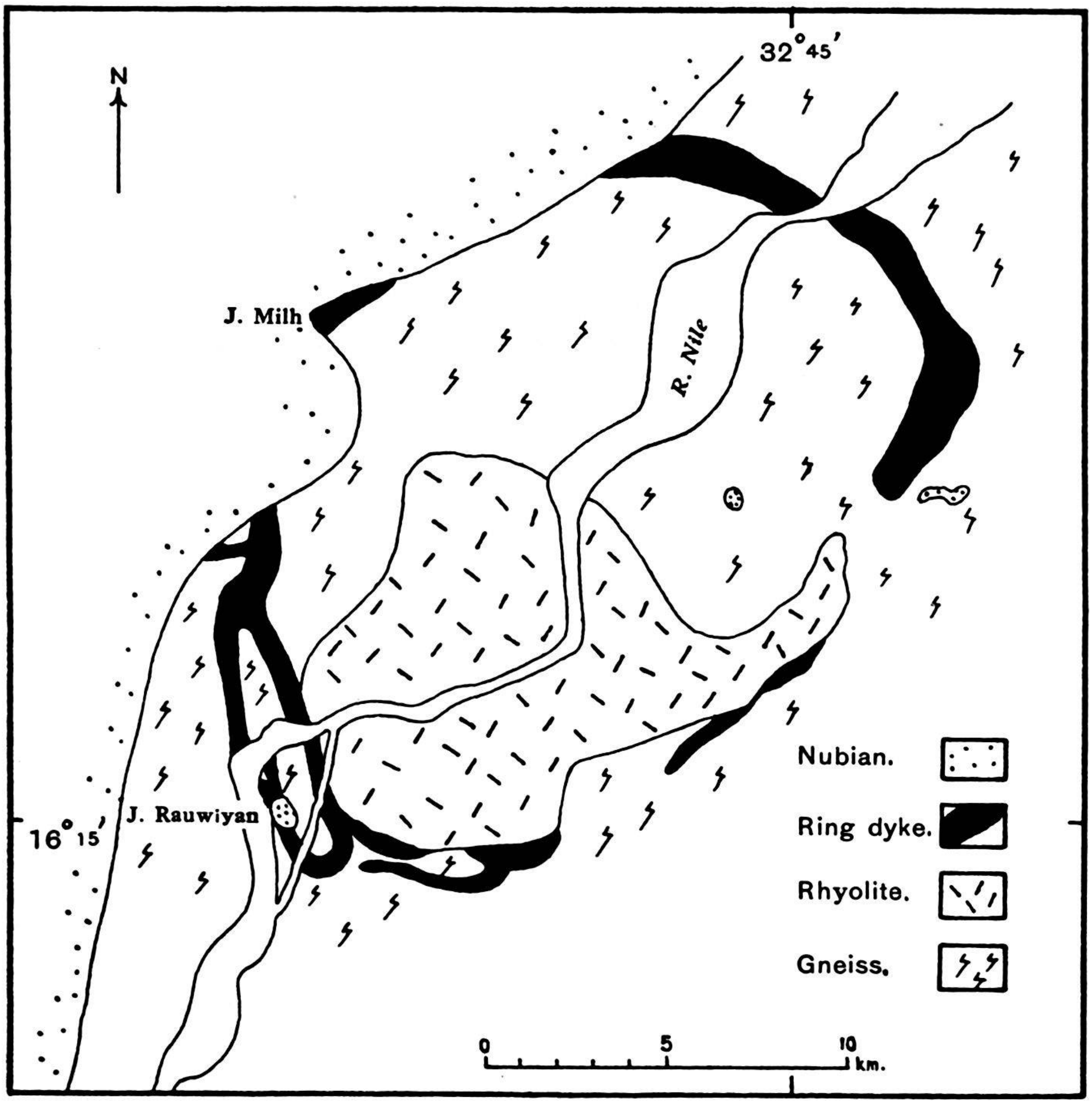

Fig. 2. Geological sketch (1:250000) of the Sabaloka gorge: a ring dyke of granite-porphyry encircling a mass of rhyolitic lavas.

of granite porphyry have been observed south of the Sabaloka hills, intruded along zones of weakness in the gneiss.

Riebeckite granite and felsites are associated with the rhyolite suite. Felsites are frequent in the crystalline rocks surrounding the Sabaloka; they either form well defined extensive ridges generally oriented about N.–S. or minor zones with no preferred orientation. A riebeckite granite NE. of the Sabaloka is not directly in contact with the rhyolites or the ring dyke. A riebeckite intrusion to the SE. at J. Sileitat and J. es Sufr appears to be younger or contemporaneous with lavas on J. es Sufr which are similar to those of the Sabaloka.

On J. Rauwiyan the ring dyke is a vertical intrusion, but in the buttresses east of the hills, it dips centrally at 60°. Elsewhere, scree masks the critical points. Average rainfall is about 150mm. per annum in this part of the Sudan and the diurnal variations in temperature are probably the most active factor in rock weathering. The boulder scree thus produced tends to magnify the apparent thickness of the granite porphyry dyke. On J. Rauwiyan the ring narrows to 50 m. but attains about 2 km. in the NE.

The centre of the porphyry dyke is a red or pink rock with phenocrysts of bluish quartz and pink orthoclase. The groundmass at the chilled edge is habitually a dark green colour with rare phenocrysts. The most chilled selvage shows flow banding and resembles closely types of coarse rhyolitic crystal tuff from the main hills. Mylonitisation of the gneiss in contact with the ring dyke indicates movement along the fracture; this shearing may have taken place before the intrusion of the dyke. Flow banding in the marginal porphyry and baking of the gneiss on J. Rauwiyan Island, shows that the dyke was intruded as a warm viscuous mass. In thin section the quartz phenocrysts show frequently signs of reabsorption and are occasionally full of dusty inclusions. The orthoclase phenocrysts are rarely reabsorbed but are very turbid. Rare microcline and albite occur. The structure of the groundmass varies greatly. In the central parts of the dyke the phenocrysts lie in a well crystallized granophyric mass of quartz, orthoclase and occasional albite, rare deep bluish-green soda amphibole and biotite. The hornblende belongs to the arfvedsonite-riebeckite group. Auxiliary apatite, zircon, chlorite and secondary calcite and zoisite occur. Near the edge of the dyke, the groundmass is patchily granophyric or contains small areas of spherulitic intergrowth; it passes outwards into a fine grained granular to felsitic type. Thin sections of the most chilled margin show small phenocrysts of dusty quartz and rare orthoclase in a fine grained granular mass of quartz with distinct flow banding outlined by dusty ore and sericite.

The red porphyry dykes occurring within the rhyolites demonstrate the close connection between the lavas and the dykes and yield thin sections very similar to those of the porphyritic rhyolites. Slightly reabsorbed quartz phenocrysts are enclosed in a peripheral intergrowth of quartz and altered, turbid, felspars. The interstitial spaces are filled by quartz, felspars and rare, much altered, dark mineral, probably an amphibole.

Inclusions of sodic micro-granite lie in the ring dyke east of J. Rauwiyan Island. Thin sections present medium grained mosaic of idiomorphic orthoclase with interstitial quartz, soda hornblende and biotite. The quartz frequently shows granophyric intergrowth with the felspars.

Field observations show that the granophyric granite porphyry was intruded into a circular fracture encircling late Precambrian Sabaloka rhyolites. Petrographical study indicates the close relationship between the porphyry and lavas and also of other felsite dykes in the area. Flow banding in the marginal porphyry and baking of the gneiss at the contact demonstrate that the ring dyke was intruded as a partly chilled mass. The last manifestations of magmatic activity are the riebeckite granites occurring near the rhyolites and a group of younger camptonite dykes which were intruded along well formed joint planes in the gneiss. The acid extrusive and intrusive rocks are certainly comagmatic; the camptonites may be the last derivates of the same mother liquid.

Fig. 3a. Air photograph of Jebel Qeili showing clearly the successive oval intrusions of the syenite complex (see fig. 3b).

JEBEL QEILI (Fig. 3a and 3b)

Jebel Qeili lies 130km. east of Khartoum and forms an isolated group of hills in the clay plain of the Butana, rising some 150m. above the plain. As the name implies, the hills have been chosen for the midday rest since historic times. The riebeckite

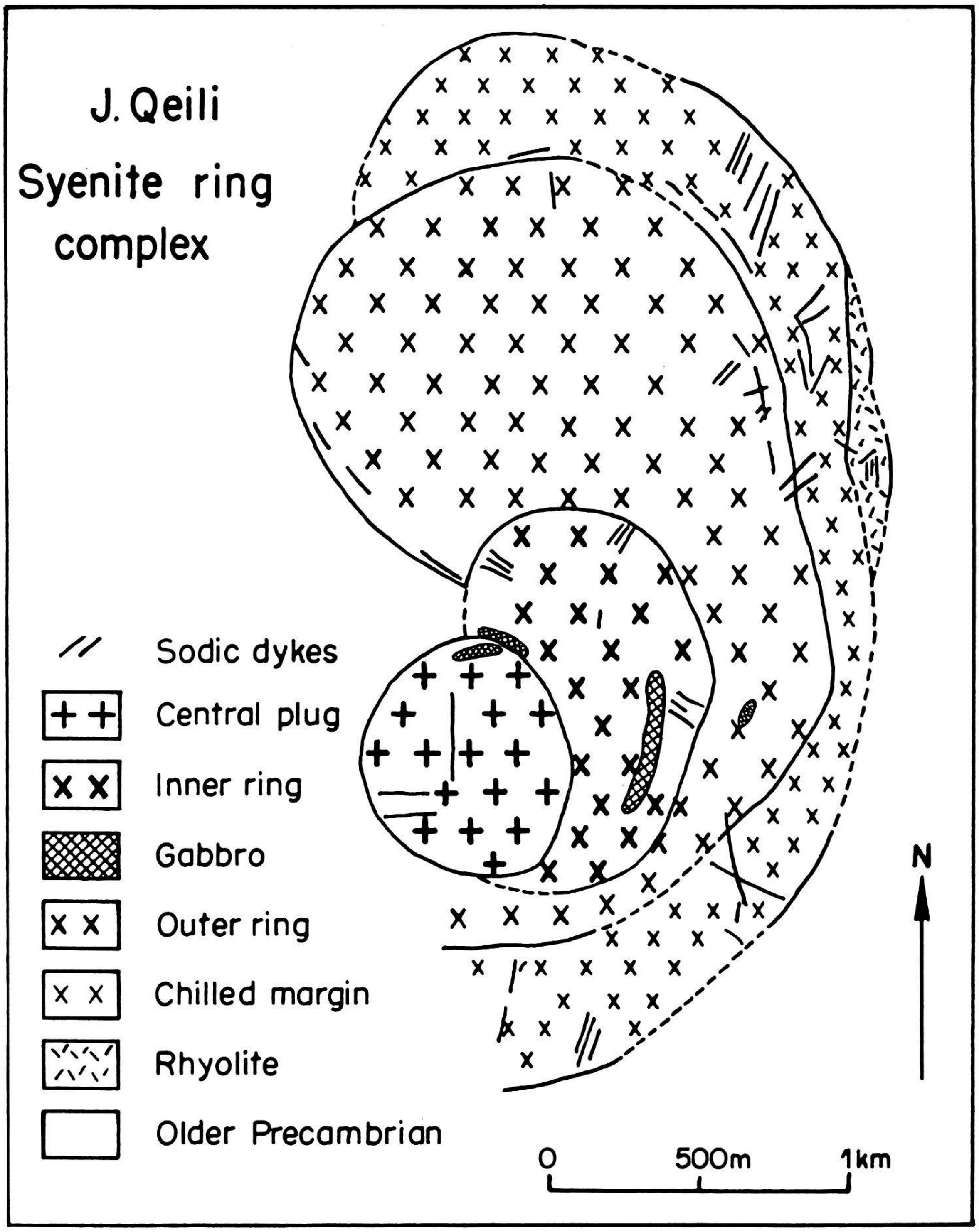

Fig. 3b. Geological sketch of Jebel Qeili syenite ring complex (see Fig. 3a).

syenite forming the main hill was recognized many years ago. Recently the annular structure of the outlying ridges was noticed from air photographs and from the air and was studied by Dr. J. B. AUDEN and the author. With the cooperation of the Sudan Survey Department, the whole group of hills was covered by vertical air photographs and enlargements on the scale of 1:6,420 were used for two ground inspections. Fig. 3a is a half size reduction of the original prints and Fig. 3b shows the geological disposition of the rocks. The ring complex is elliptical with axes of 1.6 km. and 3.3 km. The major axis lies NE.–SW.

The J. Qeili group results from the intrusion of gabbroic to syenitic derivates of an alkali rich magma through the schist series of the Basement Complex. An outer augite syenite with a chilled quartz-orthoclase margin was intruded by an essexite. The inner syenite oval cuts through the basic phase and was itself disturbed by the emplacement of the central plug of riebeckite quartz-syenite. The centres of the successive intrusions were constantly displaced to the SW. The rock types are definitely disposed in rings but later arcuate dykes, more easily distinguished on the air photographs, contribute especially to the annular appearance of the outer intrusions (Fig. 3a). Dykes of micro-syenite, sometimes with quartz and riebeckite are abundant in the syenite ovals and chilled margin. Later sodic dykes with varying pyribole content, bostonites, grorudites and felsites may be found in all the intrusions and have frequently a radial orientation, parallel to the joint systems.

The country rock around J. Qeili, observed in wells 2 km. west of the hill and in a long ridge to the NW. represents typically the Green series of the Butana and includes green quartzites, hornblende schists and altered andesitic lavas. The rocks contain abundant chlorite and epidote. The lavas show completely saussuritized felspars and skeletal outlines of hornblende. Only the lavas form topographical features and nowhere is the contact between syenite and the Green series exposed.

The chilled margin of the syenite lies in direct contact with acid volcanics on the NE. outer ridge. The lavas are very compact, fine grained, blue-black rhyolites with vertical dip and an orientation between N.–S. and N. 15° E. These rhyolites are clearly younger than the altered andesitic lavas. Small phenocrysts visible on the weathered surface, are mainly felspar and are free from stress. The base is a totally devitrified granular mass of quartz with incipient biotite and, nearer the syenite, pale augite. The rhyolite is veined and traversed by broad dykes of micro-syenite and by the later bostonite-grorudite types.

The chilled margin is a streaky red-black or a more uniform grey, unbanded rock. West of the vertical contact with the rhyolite, the contact of the chilled margin with the syenite dips east; elsewhere the contact is vertical. The rock is formed by an intergrowth of quartz and orthoclase, sometimes granophyric; augite and biotite form minute granules. Biotite and ore may occur in veinlets through the rock. Transition to the syenite takes place over a few metres: the slightly granular chilled margin coarsens rapidly to a mosaic structure of orthoclase with interstitial quartz; disparition of the quartz and accentuation of the idiomorph felspars creates the syenite.

Inside the chilled margin lies a grey-brown syenite with a generally low pyribole content. The syenite is composed principally of large plates of orthoclase, often perthitic; quartz is extremely rare. The coloured mineral is a pale green diopside which is occasionally rimmed by green hornblende. Soda hornblende is very rare. Within this outer syenite, an area of basic xenolithic syenite is exposed in a rocky water reservoir NW. of the main central hill. On the whole the outer syenite appears to have been more contaminated than the inner syenite. Jointing is conspicuous; in the east, the stepped slope of a ridge is due to a well formed set of joints dipping east at 9°–15°. Jointing in the west is vertical and the syenite forms better defined hills.

Prior to the intrusion of the inner syenite, the essexite was emplaced. Basic boulders outcrop sporadically between the central plug and the inner syenite ridge east and north of the main hill and were observed in the spoil heap of an unsuccessful well west of the hill. Isolated boulders lie east of the inner syenite. In handspecimen, the essexite shows dark minerals and blue-grey felspars in equal proportions. Thin sections contain large fresh basic felspars, mainly andesine, and a barkevikitic hornblende with pleochroism varying from pale yellow through brown to green. Biotite present shows a moiré pattern and high interference colours. Diallage occurs and auxiliary ilmenite. The gabbro and syenite were never seen in contact, nor was any interveining observed.

The inner ring of syenite forms a well marked ridge north of the J. Qeili main hill. Its geometrical position in the ring complex and with regard to the gabbro, shows the syenite to be a separate intrusion from the outer syenite. In the field, the rock resembles this latter, but is much less jointed and weathers to boulders and exfoliating slabs. Two zones of close parallel sheet jointing cause linear erosion in the ridge at N. 105° E. and N. 165° E. The felspars present, as in the outer syenite, are large plates of orthoclase, sometimes perthitic; the riebeckite-arfvedsonite hornblende present contrasts with the normal hornblende of the outer syenite; augite is rare. Apatite is abundant and quartz practically absent.

The central mass of J. Qeili is a vertical plug of pegmatitic to even grained, white, riebeckite quartz-syenite with clusters of small xenoliths. The rock differs from the syenites and its excentric position in regard to the other rings indicates that it represents the youngest intrusion. The hill shows prominent vertical N.-S. jointing and subordinate jointing approximately W.-E. Thin sections show large orthoclase, some perthitic, with interstitial, though not abundant, quartz and a soda hornblende of the riebeckite-arfvedsonite group. Quartz is always present and the rare plagioclase observed is albite. Crystals of hornblende in the pegmatitic areas attain 3 cm. in length. Contaminated rock shows xenolithic clusters of orange-brown biotite, muscovite, brown-green hornblende and diopside augite with abundant apatite and some calcite, felspars and quartz.

Arcuate dykes of micro-syenite are frequent near the periphery of the outer syenite and penetrate the chilled margin in the north. They are up to 5 m. thick and clearly finer grained than the main intrusions. These dykes were not observed in the central plug but vein the older rhyolites. Aegyrine augite, a soda hornblende, pale augite and a green-blue normal hornblende are the usual coloured minerals enclosed in laths of orthoclase with little interstitial quartz; twinned plagioclase is rare.

The latest magmatic derivates were intruded along joint planes and frequently show roughly radial orientation. They occur in all members of the complex and cut across the micro-syenite dykes. These dykes all show alkali affinities with aegyrine augite and soda hornblende present in varying quantities. The felspars are generally sodic; andesine phenocrysts were observed in a slightly basic dyke which may be a xenolith. The quartz content varies. The texture is generally bostonitic, rarely porphyritic. Depending on the proportions of their constituents the dykes may be described as bostonites, grorudites or aegyrine felsites. A green felsite from the SE. corner of the ring complex is continued roughly along the strike by a similar felsite in the NW. of the complex. The rock contains phenocrysts of arfvedsonite in a quartz rich groundmass of untwinned sodic felspars.

To summarise, at J. Qeili two successive ring intrusions of syenite with an intervening alkali-gabbro phase and a later plug of riebeckite quartz-syenite are younger than a small remnant of rhyolite. The rhyolites lack the typical metamorphism of the Green series which forms the country rock in the Butana. They probably represent a localized extrusion similar to the Sabaloka rhyolites.

JEBEL TEHILLA (Fig. 4a and 4b)

Jebel Tehilla lies in northern Kassala Province, on the west border of the Red Sea Hills at the limit of the central Sudan plain. It forms a subcircular group of granite hills traversed by the Kassala-Port Sudan railway and road. Tehilla is the most southerly of a row of ring granites, aligned, as shown in Fig. 1, approximately N.–S. along longitude 36°. The granite forms "boiler-plated" hills, 300–350m. high, interrupted in several places by low cols which lie along zones of strong shattering. The diameter of the plain thus encircled is 8km. from N.–S. and 11km. from W.–E. Outcrops in the plain take the form of boulder strewn hills in the north and low parallel ridges in the south. Outlying ridges encompass the ring and form part of the circular structure.

The geological sequence at Tehilla may be briefly described as follows. A basic rock was emplaced near the boundary between older gneissose Precambrian formations and the younger Odi schists. The gabbro occurs in a main intrusion and also veins extensively the schists. Later, a coarse granite invaded the older rocks, assimilating extensively the schists but leaving the gabbro nearly unaltered. This lack of metamorphism of the gabbro may indicate that it is younger than the first phase of acid intrusion. The chilled margin of the granite forms the outlying ridges. In the last stages, magma welled up in a wide oval dyke and abundant narrow dykes. The main ring dyke is divided into many branches separated by screens of schists. The granite belongs to the younger Precambrian intrusions. Even younger are the Tisibrahimit dykes which form a subparallel swarm of aplites and extend eastwards from Jebel Tehilla for some 37km. to a further granite with concentric structure in the Khor Kamoieb.

The country north of Jebel Tehilla is mainly banded mica gneiss, locally garnetiferous, which passes northwards into a migmatite. In the J. Odud range, a foliated mica granite invades the Odi schists and is itself traversed by dykes of Tehilla granite. The green Derudeb granite lies south of the ring granite. It veins the Odi schists and is cut by a multitude of metamorphosed dolerites. The Odi schists generally form the hills rising above the plains where the Derudeb granite outcrops.

The Odi schists exposed SE. of the J. Tehilla complex include principally a limestone-quartzite group, altered andesitic lavas and chlorite-epidote schists. Mainly the limestone-quartzite group was affected by the southern half of the ring granite. The sediments can be traced in a semi-circle from the SE. of the ring to the west col. Here the granite ring is interrupted and the air photographs show a beautifully concentric structure, formed by ridges of schists which strike parallel to the ring dyke and describe a complete arc of a circle. The schists continue along the NW. margin of the granite to the north col. Here the beds have been assimilated and to the north occur only as xenoliths in a coarse, much sheared zone of Tehilla granite.

The numerous ridges in the southern portion of the central plain are of quartzites and limestones lying vertically or inclined northwards. The calcareous beds may show intense rumpling, lense out, and, near the granite ring, contain large siliceous boulders squeezed out of the neighbouring quartzites. These schists, as in the west where they strike concentrically around the ring, are traversed by numerous granite dykes. Contact metamorphism generally recrystallizes the pure white limestones to a coarse aggregate of calcite rhomboeders; rare garnet diopside marbles and horizons bearing olivine, periclase and brucite were observed. Marble with wollastonite and black garnet occurs near the gabbro at the SW. apex of the ring. The green siliceous limestones are little altered, and the quartzites remain well bedded, compact, green, brown or white horizons.

The highest grade of metamorphism was observed in arcuate ridges of hornfels in a hill of gabbro in the NE. section of the central plain. The hornfels forms conspicuous ridges through the boulders and slabs of gabbro. A view of the hill from the south shows that the hornfels dip towards the centre of the plain. They are fine grained white to green rocks resembling compact quartzites and contain generally two pyroxenes and a hornblende. The pyroxenes observed were enstatite, hypersthene and diopside. The hornblende is a pale green colour. Basic plagioclase and quartz form the rest of the thin section. Apart from small hornfelsed zones of schists in immediate contact with the granite ring, and highly metamorphosed small xenoliths in the granite, it seems that the gabbro intrusion altered the older rocks more profoundly than did the granite.

The basic intrusion, a gabbro or more typically a troctolite, occupies the northerly part of the central plain and also forms a belt outside the ring to the north and NE. of the granite. Contacts with the granite are exposed in both areas. Smaller dykes of gabbro cut the schists, forming doleritic sills parallel to the bedding. In a hill near the centre of the plain, a branch of the main gabbro intrusion cuts vertical quartzites; three W.–E. granite dykes intersect the gabbro-quartzite complex. NE. of the main Tehilla ring, a steep sided ridge of granite rises some 10 m. vertically above a slab of spherically weathering gabbro. Offshoots of granite vein the gabbro which also occurs as xenoliths in the acid rock and shows signs of contact metamorphism. The gabbro is on the whole rarely veined by granite and it may be younger than the first acid intrusion but older than the intrusion of the main granite ring dyke and its accompanying minor dykes.

The gabbro contains predominantly olivine and andesine-labradorite felspar, and is a troctolite. Augite, sometimes rimmed hornblende and biotite, is known; opaque ore is present in small quantity. Samples where hornblende and biotite tend to form clusters were collected near the margin of the gabbro; the mica shows a curious pleochroism, varying from colourless to a deep red-brown. Generally the gabbro is coarse grained, but it becomes doleritic in the marginal facies and in the dykes, where it also contains more augite. Gabbro screens are frequent in the gran-

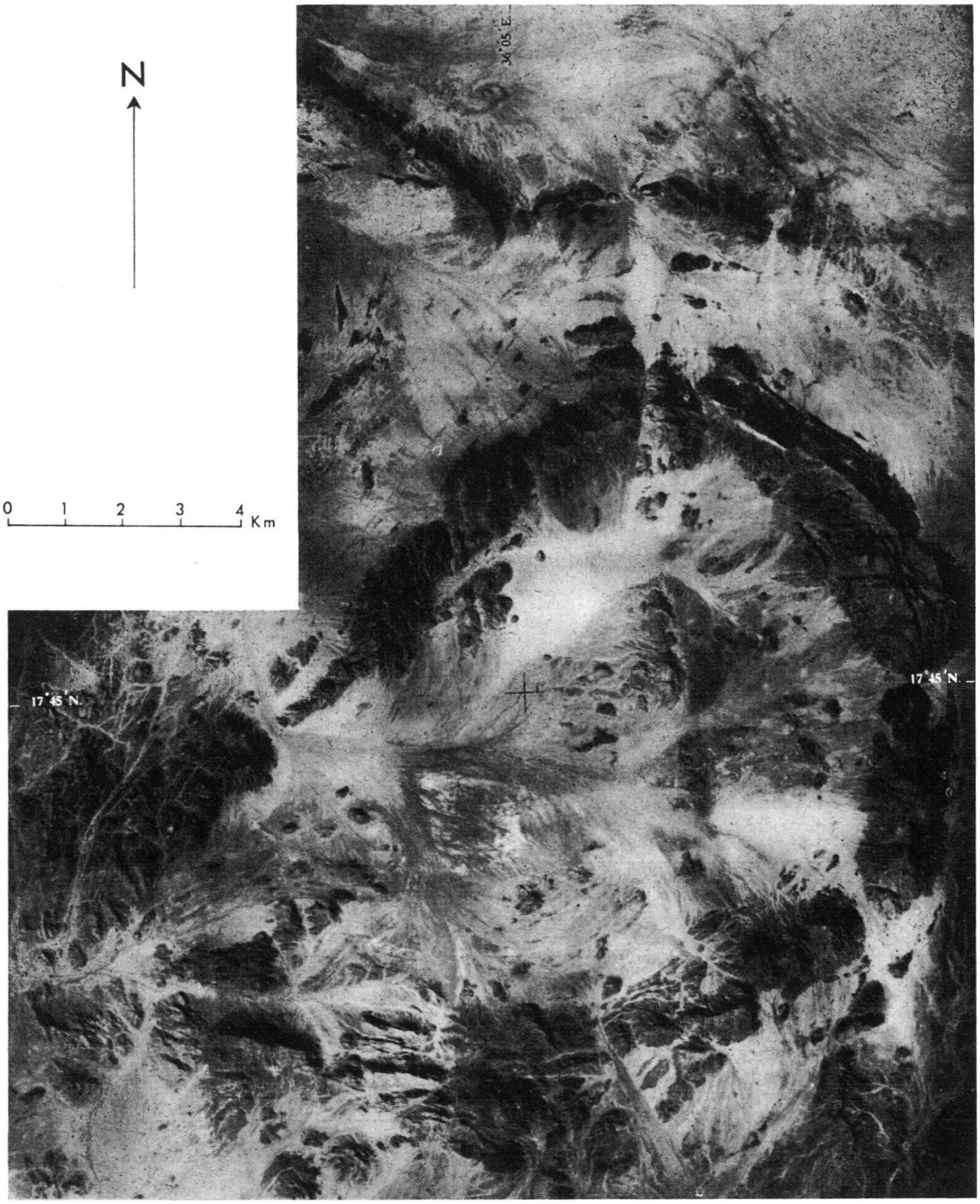

Fig. 4a. Air photograph of Jebel Tehilla: the oval of high mountains is formed by the main granite dyke (see Fig. 4b).

ite in the east of the ring. The olivine in these rocks is generally much altered and lies poikilitically in large plates of purple pyroxene.

The areas between the main granite ring and the outlying ridges is occupied, over 3/4 of the circle, by a coarsely crystallised facies of the Tehilla granite. The area

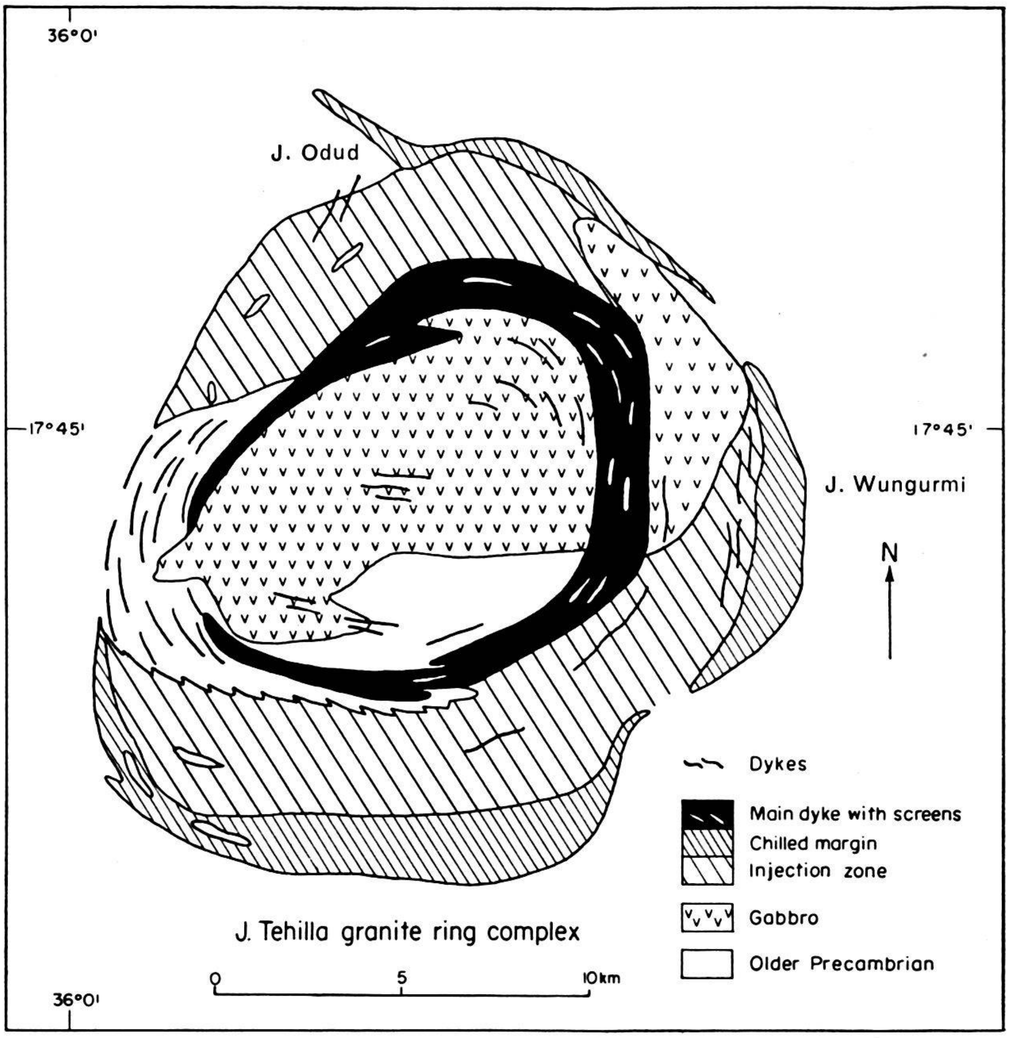

Fig. 4b. Geological sketch of Jebel Tehilla granite ring complex (see Fig. 4a).

contains abundant large xenolithic blocks of the older Precambrian rocks, most of which retain their original strike and have scarcely been re-metamorphosed. The zone is interrupted in the west, where, as the main ring granite, it is dissolved into a multitude of minor dykes. In the north the granite is intensely jointed and near J. Odud passes into a highly sheared augen gneiss. Along the outer northern margin of the granite ring, the shearing lies concentric to the ring. In the east, gravels mask extensive areas between the main ring and the lower slopes of J. Wungurmi; the rare exposures show granite veining gabbro and schists.

The outer ridges of granite, which lie roughly concentrically to the main ring, appear to be formed by the chilled margin of this coarsely crystallized facies of the Tehilla granite. The rock is rarely porphyritic and always finer grained than the main intrusion. The mosaic structure of idiomorph alkali felspar laths is on the whole more pronounced than in the main granite and quartz lies more obviously interstitially between the felspars. This chilled granite encircles $^3/_4$ of the main ring. In the north it forms the pronounced ridge of J. Odud which in the west cuts through schists invaded by an older foliated granite. In the east, the ridge lies through gneiss and after a short interruption is continued east of the main ring, in the high buttresses of J. Wungurmi. South of the Tehilla ring, chilled granite forms a well marked wide ridge limited southwards by the green Derudeb granite. Along the contact, a large packet of andesitic lavas of the Odi schists have been faulted down to lie in an abnormal position between the chilled Tehilla granite and the older green granite. Xenoliths of schists are frequent in this southern portion. The chilled granite ridge thins out and vanishes westwards, as does the main granite ring.

The main granite intrusion forms an oval dyke up to 1 km. thick. The inner axes of the oval are 9 km. and 11 km. The granite forms serrated ridges which rise 300–350 m. above the central plain. The main break lies at the narrow apex in the SW. where the Kh. Agwatiro flows out of the central plain. Here the main granite dyke dwindles to a narrow dyke and vanishes in an area of gabbro which extends the central gabbro area across the ring and veins the schists to the west.

The vertical nature of the ring dyke and its contacts are well exposed at the north and south cols. At the former, the southern slopes of the granite hills rise nearly vertically above the gabbro. The section exposed on the northern slopes over some 300 m. shows a succession of vertical granite dykes intruded into the bedded quartzites, limestones and gabbro sills. The principal ring dyke, here about 500 m. thick, is formed of a coarse porphyritic granite with small xenoliths of older rocks and wide vertical screens of unassimilated schists which divide the main dyke into minor branches. Dykes of secondary importance in the bedded series vary in texture from granitic to felsitic; the wider dykes may attain some 10 m. but narrower dykes are the rule.

The southern breach in the ring, where the railway line enters the Tehilla plain, is situated where the main granite dyke is subdivided into three branches by screens of limestone and quartzites. The air photographs also indicate slight offsetting across the breach.

The ring is further breached where major shatter belts have exposed the granite to erosion. The main jointing is N.-S., a direction which occurs frequently in the younger granites of the Sudan. This N.–S. jointing is vertical and causes high pillar-like formations, which are especially remarkable along the outer northern margin of the ring. W.–E. jointing, parallel to the Tisibrahimit dykes, is also marked and, in the east, is followed by younger dykes which cut the granite. A set of radial joints is of some importance; they cause the SE. breach which is filled partially by a fault breccia. Slicken-slide surfaces are abundant throughout the granite and indicate considerable small scale faulting after its emplacement.

The granite is a white, grey or yellowish rock with red-pink varieties. The colouration tends to occur patchily. It contains visible felspar, quartz and rare coloured minerals. Fine grained zones of red quartz-orthoclase rock or a non-porphyritic granite with pronounced mosaic structure of quartz and orthoclase intermingle with the normal porphyritic granite. The prominent alkali felspar (anorthoclase) shows pronounced gusseting, patchy extinction, microperthitic structure and often marginal intergrowth with quartz. Albite-oligoclase felspar is rare or absent. A halo of plagioclase with multiple twinning may rim the alkali felspar. Quartz is abundant and accompanied by small blades of muscovite. Dark minerals are rare; an olive-green hornblende normally present may be accompanied by augite. Ore, apatite and sphene are plentiful.

The numerous acid dykes which cut the schists and gabbro are mainly micro-granites and micro-granodiorites; finer red felsites occur. In the west, the dykes are markedly arcuate and strike, as do the schists, concentrically around the narrow apex of the ring dyke. In the central plain the dykes tend to lie W.-E. and crown the ridges formed by the schists.

Rapid inspection of air photographs by the author and the Sudan Survey department have brought to light several ring structures north of Tehilla. The structures all appear to be formed of a rock with typical granite weathering and are alined along the longitude 36° E., a line followed roughly by a major drainage line which cuts through the Red Sea hills from south to north. The two ring structures mapped by I. G. Gass, Salala and J. Umm Shibrik also lie near the 36° E. longitude.

Area	*Sabaloka*	*Qeili*	*Tehilla*
Ring intrusion	granophyric granite porphyry	three riebeckite-aegyrine syenites	Quartz-orthoclase granite
Width of dyke	50 m.-2 km.	—	1-2 km.
Dimensions of ring	20 km. × 15 km.	1,5 km. × 3,3 km.	11 km. × 9 km.
Associated rocks	Rhyolites	Rhyolites, gabbro	Gabbro
Sequence of intrusion	1. Rhyolites 2. Ring dyke 3. Soda granite 4. Camptonites	1. Rhyolites 2. Ist syenite ring 3. Essexite 4. 2nd syenite ring 5. Central quartz-syenite plug 6. Sodic dykes	1. Gabbro 2. Permeation 3. Granite ring 4. Tisibrahimit sodic dykes
Structure of ring	Vertical to centripetal dip Oval NE.-SW.	Vertical to centrifugal dip Oval NE.-SW.	Vertical Oval NE.-SW.

Table 1: Characteristics of the three ring complexes described in the present work.

CHARACTERISTICS OF THE SUDAN RING STRUCTURES

The three ring structures, Sabaloka, Qeili and Tehilla, described in this paper are formed by the youngest acid intrusions of the Precambrian rocks. They represent an alkali rich magma from which soda rich minerals have crystallized. Free quartz is absent or present. Riebeckite and aegyrine are the most typical sodic pryiboles. The felspar present may be orthoclase or anorthoclase, probably the latter; in all the granites, the crystals show very patchy extinction and microperthitic intergrowth with albite. Plagioclase, when present, is albite; rare microcline occurs at the Sabaloka. The quartz content alone has permitted a differentiation into syenite or granite. Typical associated rocks are an acid extrusive phase, rhyolites, and a basic intrusive phase, essexite or troctolite.

The rhyolites are presumed to be comparable to the Nigritian of the Sahara and therefore the granites are also placed in this youngest subdivision of the Precambrian, though the name Sabalokan would be preferable for the series in the Sudan. Age determination and chemical analyses would clarify both the stratigraphical and petrographical relationships of the rocks.

The three ring structures are compared in tabular form below.