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A revised stratigraphy for the Abbabis Complex in the Abbabis Inlier, Namibia

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The presence of a synclinal structure between the Black Mountain and Gamgamichabberg (about 15 km south of Usakos), made it possible to subdivide the Abbabis Complex of the Abbabis Inlier into several lithostratigraphic units. The structure is defined by the trend and dip of the sedimentary layering, the direction and dip of mineral lineations on it, and by the younging direction indicated by sedimentary cross-bedding structures. The oldest of the lithostratigraphic units, the Tsawisis Formation, consists mainly of metasedimentary schist, gneiss and meta-arkose, and subordinate marble, calc-silicate rock and conglomerate. Rocks of this formation are overlain by the three members of the Naob Formation, viz. M2 (schist and metabasite), M4 (alternating quartzite, marble, and calc-silicate rock) and M6 (metavolcanic rocks). Granitic rocks of the Narubis granitoid complex have intruded into the foregoing sequence and form the widespread homogeneous (augen) gneisses of the Abbabis Complex. Dolerite dykes (now amphibolites), are the last major igneous phase in the development of the Abbabis Complex.

Die teenwoordigheid van 'n sinklinale struktuur tussen die Black Mountain en Gamgamichabberg (ongeveer 15 km suid van Usakos) het dit moontlik gemaak om die Kompleks Abbabis van die Abbabisvenster in verskeie litostratigrafiese eenhede te onderverdeel. Die struktuur word gedefinieer deur die strekkingsneiging en helling van die sedimentêre gelaagdheid, die rigting en helling van mineraallineasies, en die rigting waarin die gesteentes jonger word soos geïmpliseer deur die sedimentêre kruisgelaagdheidstrukture. Die oudste van die litostratigrafiese eenhede, die Formasie Tsawisis, bestaan hoofsaaklik uit metasedimentêre skis, gneis en meta-arkose, en ondergeskikte marmer, kalksilikaatgesteentes en konglomeraat. Gesteentes van hierdie formasie word oorlê deur die drie lede van die Formasie Naob, naamlik M2 (skis en metabasiet), M4 (afwisselende kwartsiet, marmer, en kalksilikaatgesteente) en M6 (metavulkaniese gesteentes). Granitiese magma van die Granitoïedkompleks Narubis het in die genoemde suksessie ingedring om die wydverspreide homogene (augen-) gneise van die Kompleks Abbabis te vorm. Die inplasing van dolerietgange (nou amfiboliete) was die laaste belangrike stollingsfase in die ontwikkeling van die Kompleks Abbabis.

Introduction

The Abbabis Inlier is mainly underlain by metasediments of the Tsawisis Formation and gneisses from the Narubis granitoid complex. The distribution of these two units is very complicated and during regional geological mapping of the Damara Sequence and Damaran granitoids in this area, minor attention was paid to the AC of the Abbabis Inlier. Both units are therefore also indicated with the same symbol in Figure 2. The reader is referred to Marlow (1981) for a more detailed study of the Black Mountain–Gamgamichabberg area. The basin-like Black Mountain syncline, as indicated on the Geological Survey Sheet 2215 A & B of 1966, could however be extended by the author to the Gamgamichabberg, resulting in a revision of Smith's (1965) and Marlow's (1981) interpretations of the stratigraphic sequence of the AC in this part of the Abbabis Inlier.

The Abbabis Complex (henceforth AC) comprises those rocks in the SW Central Zone of the Damara Orogen, which are of pre-Damaran age.

Gevers & Frommurze (1929) were the first to recognize that the Damara Sequence is unconformably underlain by a basement complex of pre-Damaran age. This discovery was made on Abbabis 70 (approx. 30 km southwest of Karibib, Figure 1) and Gevers (1931) proposed the name Abbabis System, which was later revised to Abbabis Complex (SACS, 1980).

Smith (1965) mapped a small outcrop of Abbabis basement southwest of the Khan Mine (about 62 km southwest of the Abbabis Inlier) and assumed that the cores of several domes in the area consist of coeval rocks. Jacob (1974) suggested that the 'Red Granite-Gneiss', in the area around the Khan and Swakop Rivers, could be correlated with the AC of the type area (Abbabis 70). During the preparation of the 1:1 000 000 geological map of Namibia (1980 edition) the Geological Survey in Windhoek decided that the Red granite (Gevers, 1931), the Red gneissic granite (Smith, 1965) and the Red Granite-Gneiss (Jacob, 1974) represented AC rocks.

The variety in rock-types of the AC in different parts of the SW Central Zone contributed to the relatively late recognition of them as basement rocks. In most cases a red to buff (augen) gneiss is present (Downing, 1982; Smith, 1965; Jacob, 1974), whereas in some areas metasedimentary rocks predominate. Probably due to the higher degree of Damaran metamorphism in this area, at many localities in the western part of the SW Central Zone these rocks were remobilized and invaded by red granites (Sawyer, 1981). It is difficult to distinguish these rocks from the reddish feldspathic quartzites of the overlying Etusis Formation, but the presence of cross-cutting amphibolite dykes has been used as a criterion for AC rocks, since these are known not to continue into the Damara Sequence.

Because researchers formerly working on the Abbabis Inlier (Gevers, 1931; Smith, 1965; Marlow, 1981) did not use a stratigraphic sequence as worked out by the present author, it was thought to be worthwhile to

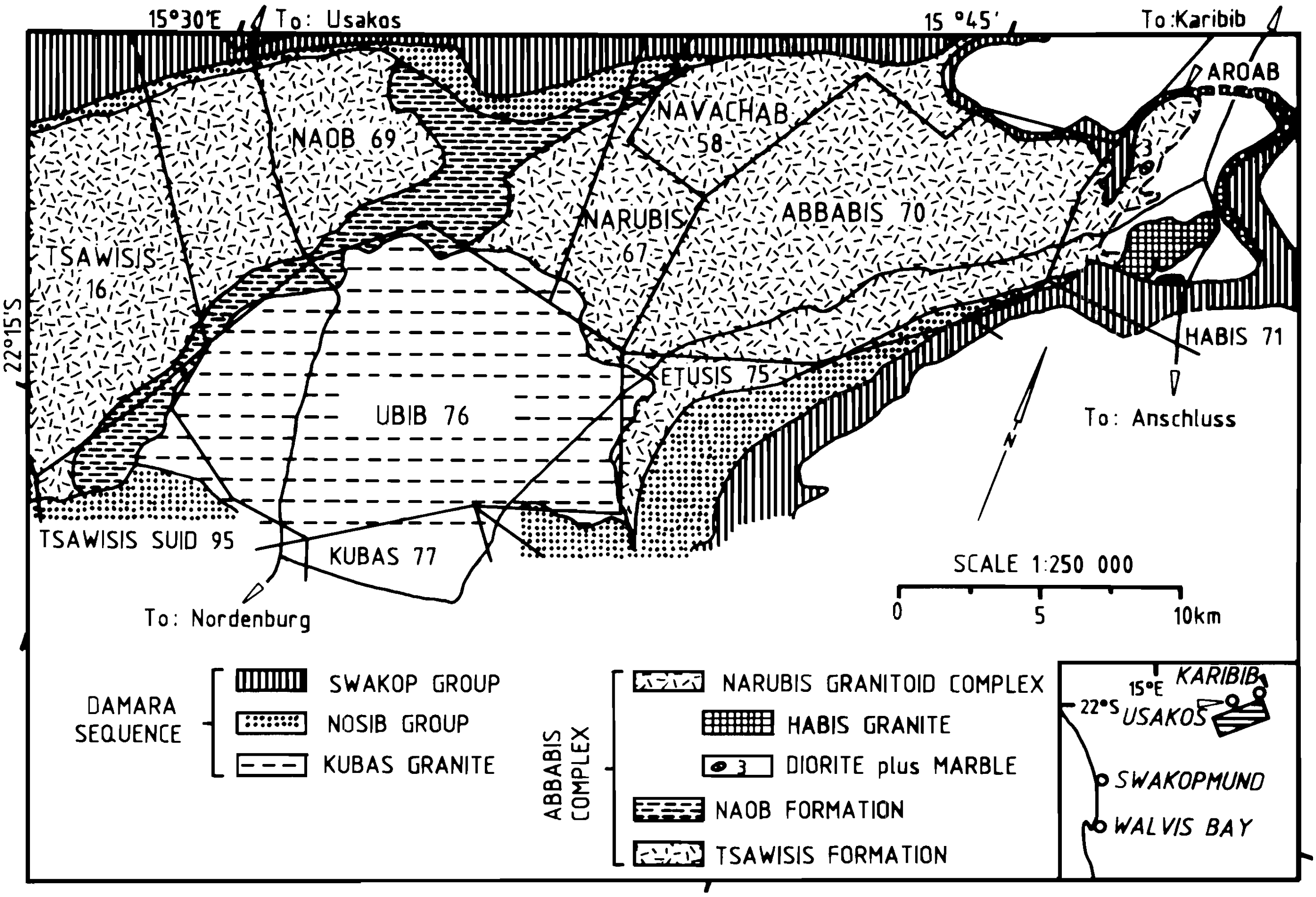


Figure 1 Simplified geological map of the Abbabis Inlier and surrounding Damara Sequence rocks. The Tsawisis Formation and the Narubis Granitoid Complex have been grouped together, because no detailed mapping of their occurrences has been carried out.

compile the information on the different rock assemblages and to present them in their correct stratigraphic sequence.

The floor of the Abbabis Complex

Gevers (1931) suggested that the floor of the AC must consist of igneous rocks, because the only pebbles he found in the AC conglomerates were of igneous origin. Marlow (1981) however, found quartzite and amphibolite pebbles in conglomerates probably underlying the dark metabasites of the Black Mountain on Tsawisis Suid 95 (Figure 2). According to the present author's subdivision of the AC, these pebbles may have been derived from rocks lower in the sequence of the AC. Marlow's find does not therefore necessarily contradict Gever's deduction. At the moment not enough data are available to allow speculations about the unexposed or unrecognized floor of the AC.

The age of the Abbabis Complex

The first U-Pb age determination of the AC was carried out by Jacob *et al.* (1978) on two samples from Abbabis 70. The first sample consisted of a strongly foliated tonalite and the second one is described as a gneissic granite (Jacob *et al.*, 1978). The determined age of 1925 +330 –280 Ma (Jacob, 1978) is similar to the U-Pb zircon ages of 1730 ±30 Ma and 1870 ±30 Ma reported by Burger *et al.* (1976) for the Franzfontein Suite, which is intrusive into the Huab Complex, constituting the Kamanjab basement Inlier further north.

Because these data reflect the emplacement age of granitic rocks in pre-Damara times, they indicate a minimum age only of the respective complexes; the actual age of the metasedimentary and metavolcanic host rocks of these dated rocks is probably greater than 2000 Ma. However, no age determination of these host rocks is yet available.

The stratigraphy of the Abbabis Complex

In the past, several attempts have been made to establish a stratigraphic succession in the AC (Gevers, 1931; Smith, 1965; Jacob, 1974; Sawyer, 1981; Marlow, 1981).

The Abbabis Inlier is underlain by metamorphosed igneous, sedimentary, and volcanic rocks.

Sedimentary cross-bedding structures on either side of the metavolcanic core of the Black Mountain–Gamgamichabberg syncline in the area north of the Ubib 76 farmhouse (Figure 2), indicate a younging towards the metavolcanic rocks (Figure 3, a and b). On the geological map of Figure 2, average strike and dip measurements of the sedimentary layering and of lineations (fold axis and mineral lineations) have been

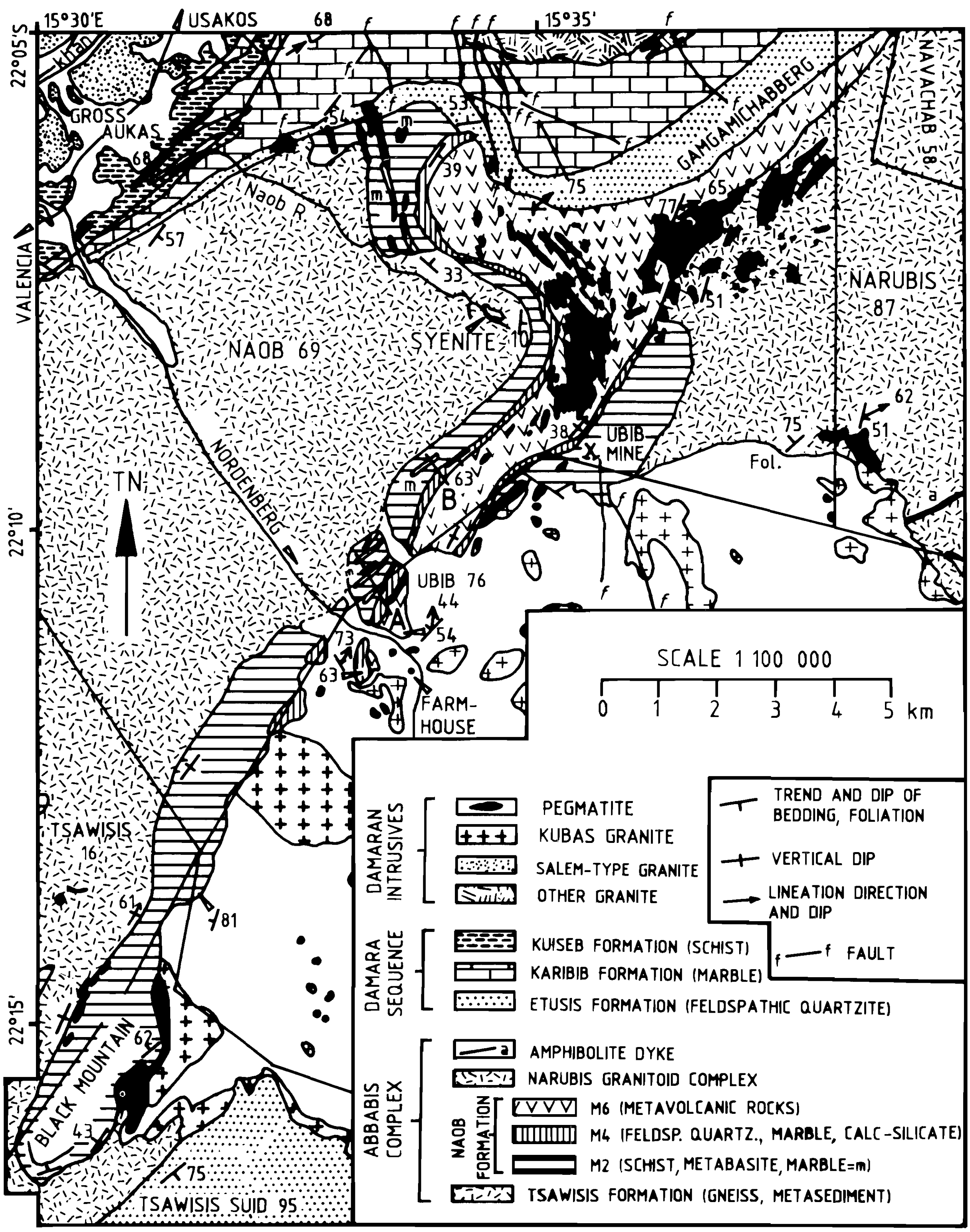
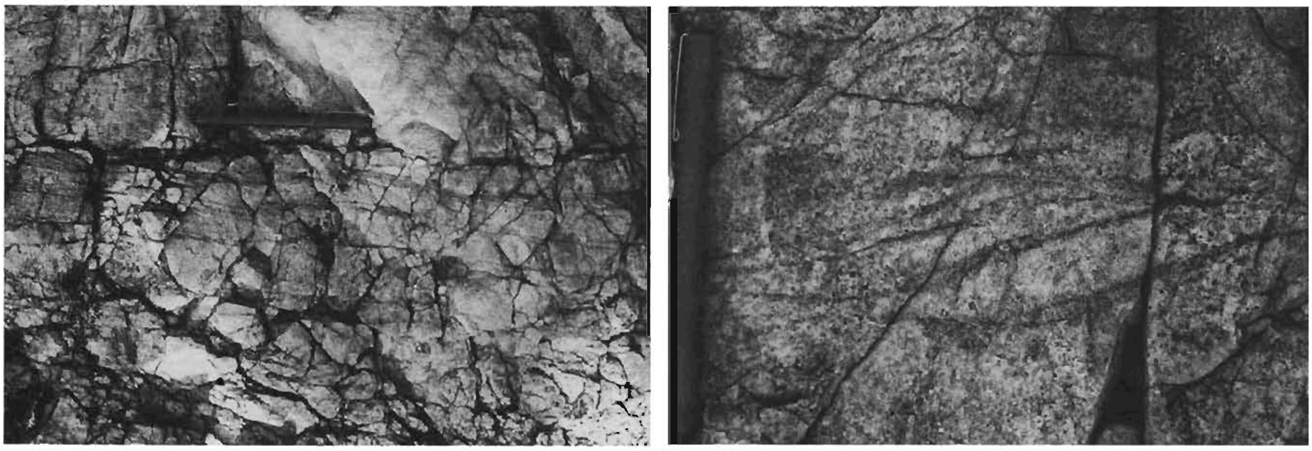


Figure 2 Simplified geological map of the Black Mountain– Gamgamichabberg area (modified after Marlow, 1981). The Tsawisis Formation and the Narubis Granitoid Complex have the same symbol.

indicated based on information from Marlow (1981) and the author's own work. These measurements schematically represent a much larger amount of data. They show that not only the schist and metabasite of the Black Mountain but also the metasediments and metavolcanic rocks just north of the Ubib Mine form synclinal structures, both probably with the same axial plane. A large part of the southeastern limb of the syncline is obliterated by an intrusive Damaran granite (Kubas granite).

The presence of the syncline enabled the author to recognize a lowermost stratigraphic unit mainly consisting of schist and paragneiss (Tsawisis Formation), followed by the Naob Formation consisting of a sequence of schist and metabasite (M2), feldspathic quartzite, marble, and calc-silicate rock (M4), and



(a) (b)

Figure 3 Cross-bedding in feldspathic quartzite of the northwestern (a) and southeastern (b) limb of the Black Mountain–Gamgamichabberg syncline, north of the Ubib Mine. In (a) the pen lies parallel to, and in (b) perpendicular to, the almost horizontal bedding plane. Naob 69 and Ubib 76.

followed in turn by a unit of metavolcanic rocks (M6). Granites, now (augen) gneisses, and pegmatites invaded the metasedimentary and metavolcanic sequence (Narubis granitoid complex). The AC rocks were intruded later by pre-Damaran dolerite dykes (now amphibolites).

Table 1 gives a comparison of the stratigraphic column of the AC, as established by Sawyer (1981), Smith (1965), Marlow (1981), and the present author.

Tsawisis Formation

Paragneiss, coarsely crystalline feldspathic quartzite, and schist underly the Black Mountain–Ubib Mine syncline and form the lowermost stratigraphic unit of the Abbabis Inlier. These rocks form the Tsawisis Formation in this study, after Tsawisis 16, where they are well exposed. An estimate of the thickness of this formation is not possible, because a floor to these rocks is not present. Overprinting by Damaran deformation makes it more difficult to estimate its minimum thickness. The inhomogeneity on outcrop scale (Figure 4) might suggest a sedimentary rather than an igneous origin.

Compositionally the gneiss and quartzite vary between

Table 1 Comparative stratigraphy of the Abbabis Complex

Sawyer (1981), area south-east of Walvis Bay	Smith (1965), Abbabis Inlier	Marlow (1981), Abbabis Inlier	Brandt (this paper), Abbabis Inlier	
	ortho-amphibolite	amphibolite dykes	amphibolite dykes	
(augen) gneiss		gneisses (several of granitic composition	ortho (augen) gneisses	Narubis granitoid complex
			metavolcanic rocks (M6)	
gneiss, schist, glassy quartzite	biotite schist-gneiss + para-amphibolite	metasediments (quartzite, schist, conglomerate, marble, calc-silicate) + interbedded metabasaltic and pyroclastic rock	alternating (feldspathic) quartzite, marble, calc-silicate (M4)	Naob Formation
calc-silicate, marble	dolomitic marble, calc-silicate		schist (dark) and meta-basite (M2)	
quartz-feldspar gneiss, quartzite, micaceous quartzite, schist	Abbabis gneiss, phyllitic quartzite, conglomerate		schist- (para-) gneiss meta-arkose, subordinate marble, calc-silicate, conglomerate	Tsawisis Formation

Note: Horizontal lines do not always imply correlations.

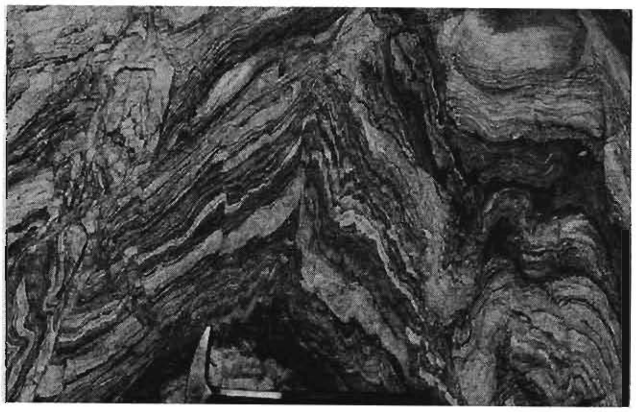


Figure 4 Migmatitic gneisses and schists of the Tsawisis Formation of the Abbabis Complex. The sequence suggests a sedimentary rather than an igneous origin. Tsawisis 16.

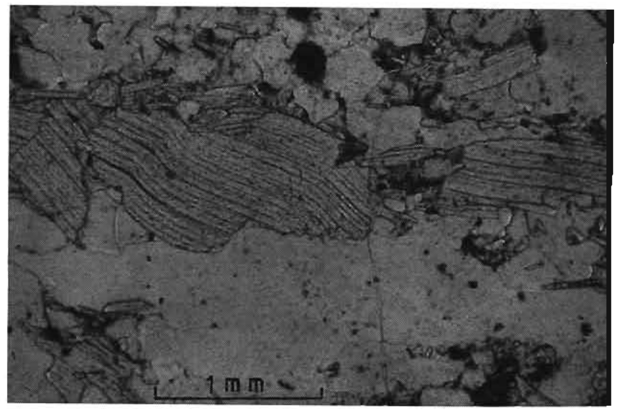


Figure 5 Deformed muscovite, mechanically rotated into the fabric plane of an Abbabis Complex gneiss. In rocks of the Damara Sequence, the muscovite is in most cases post-tectonic and therefore strain-free. Habis 71.

meta-arkose and (feldspathic) quartzite with 'angular quartz, well-orientated muscovite laths and partly sericitized microcline. Plagioclase, subhedral apatite, zircon and euhedral pink garnet are present in accessory amount' (Smith, 1965).

An interesting phenomenon the author found in one of Smith's thin sections is that the gneissose fabric is defined by undulose muscovite crystals which were mechanically rotated into the fabric plane and have only a habit orientation and not an optical one (Figure 5). Gevers (1931) also indicated that in most sections muscovite is strongly deformed. The same phenomenon has been found in another basement occurrence. Large deformed muscovite crystals have not been described in the Damara Sequence of this area, which always seems to be of post-tectonic age.

Locally grey biotite schist occurs, resembling that of the Kuiseb Formation. Feldspar porphyroblasts have been found in these schists within a few metres of the contact with the Damaran Kubas granite and may be the result of contact metamorphism.

Biotite-sillimanite schist, containing minor garnet, muscovite, and tourmaline, is reported by Marlow (1981). According to the same author oligoclase is present and the garnet is partly replaced by chlorite. He also indicated that sillimanite is present as radiating bundles of needles and that biotite may be slightly replaced by colourless mica or chlorite.

Dark biotite and/or amphibole schist and subordinate metabasite, marble and calc-silicate rocks also have been found in the Tsawisis Formation. Subordinate amounts of yellowish-brown dolomitic marble have been described by Smith (1965). They are composed mainly of dolomite and small amounts of calcite, whereas graphite, tremolite, forsterite, and epidote are present as accessory minerals. Gevers (1931) mentioned the occurrence of secondary quartz in these marbles. Locally, calc-silicate layers are interbedded with the metasedimentary sequence. These rocks consist of quartz, feldspar, and diopside with accessory garnet, epidote, and sphene (Smith 1965).

Conglomerates contain angular or rounded, predominantly quartzitic, and subordinate finely crystalline amphibolitic pebbles in an epidotized feldspar-, garnet-, pyroxene-, and ilmenite-bearing siliceous matrix. Biotite granite and vein-quartz pebbles in a biotite schist matrix have also been found (Marlow, 1981). Gevers (1931) recorded deformed quartz, feldspar (angular fragments), and gneiss pebbles in conglomerates on Abbabis 70 and Naob 69.

Naob Formation

The assumption, that the Black Mountain–Ubib Mine area is a syncline, suggests that the metasedimentary rocks and metabasites of that structure overlie the metasediments of the Tsawisis Formation. This rock unit is called the Naob Formation in this study, after the farm Naob 69, where the rock-types in question crop out extensively.

The lowest member of the Naob Formation (M2) consists of very dark to black schist and metabasite. Similar dark schist has been found outside the present area in the Ostrich Gorge (12,5 km southwest of the Rössing Mine) and seems to be typical of the AC succession.

The upper portion of the Naob Formation (the members M4 and M6) comprises a variety of metamorphosed sedimentary and volcanic rocks.

Lower member M2

Dark biotite schist and massive dark biotite-rich, calc-silicate rock form the lowest stratigraphic unit in the Black Mountain–Ubib Mine syncline. The sequence in both limbs of the structure is between 300 and 750 m thick.

Smith (1965) described a biotite-sillimanite gneiss from the Black Mountain. This rock consists mainly of biotite and sillimanite; these together with quartz are poikiloblastically enclosed by orthoclase. Sillimanite seems to replace biotite. Garnet is present as an accessory mineral. Gevers (1931) also found some kyanite and cordierite. These two minerals were not mentioned by Smith (1965) or Marlow (1981), but the presence of cordierite is confirmed by the author. The presence of kyanite is of interest, because that mineral has not been found elsewhere in the Damara Sequence or the AC of the Central Zone.

On Naob 69, to the northeast of the Black Mountain, the dark rocks tend to become more schistose and less feldspathic. This change coincides with an increase in intercalations of biotite-hornblende schist (Smith, 1965).

Several ortho-amphibolite layers have been found on Naob 69, one such rock showing in thin section a decussate texture of hornblende and tremolite laths. In places the tremolite is concentrated in certain layers, with interstitial feldspar and accessory opaque minerals.

Middle member M4

The on average 150-m and maximum 650-m thick middle member of the Naob Formation contains fine impure to coarse feldspathic quartzite. The latter consists mainly of quartz, subordinate feldspar and interstitial muscovite, biotite, garnet, sillimanite, magnetite, sphene, hornblende, epidote, chlorite, and calcite. Zircon and apatite are accessory minerals (Marlow, 1981). Cross-bedding is developed locally (Figure 3, a and b).

Marble in this member reaches a maximum thickness of about 60 m. Apart from one unit, most layers are much thinner and are laterally not very extensive. The rock consists mainly of dolomite and calcite; diopside and epidote are subordinate, and grossular occurs only in certain layers. The carbonate crystals are deformed and cataclastic lenses (on a cm scale) of diopside, epidote, tremolite and scapolite are scattered throughout the rock.

Finely to coarsely crystalline calc-silicate rock, up to 40 m thick, is intercalated in the other metasediments of this member. In thin section, the rock consists mainly of quartz, feldspar, and diopside; epidote and tremolite are accessories.

Upper member M6

The metavolcanic rocks of the upper member of the Naob Formation are composed mainly of amygdaloidal metabasalts. These dark green to black rocks attain a thickness of about 400 m, but the contact with overlying rocks is not exposed. In thin section these rocks show a planar fabric of green hornblende and labradorite, poikiloblastic diopside and accessory quartz, epidote and an opaque mineral, probably magnetite.

Macroscopically the amygdales consist of quartz with a varying amount of epidote and garnet. Under the microscope, some of the lensoid amygdales have been found to consist of coarsely crystalline, unstrained, pure quartz aggregates. Others have more complex assemblages of quartz, labradorite, hornblende, diopside, epidote, ore, chlorite, tremolite, and carbonate.

Irregular quartz veins and numerous lenses and veins of skarn have been found, the latter consisting of a varying amount of epidote, garnet, calcite, and large tabular hematite crystals (up to 3 cm in diameter).

Marlow's (1981) recognition of pillows in this member is not accepted by the author and his Plate 1 is thought to depict the typical weathering pattern of massive metabasaltic rock.

According to Marlow's (1981) geochemical work, the composition of the metabasalt ranges from basaltic to andesitic; the unit has the geochemical characteristics of tholeiitic continental basalt. Some of the rocks with high MgO, Cr, and Ni, moderately low Al203 and low FeO/(FeO+MgO) values, may show komatiite affinities.

In Figure 6 two sections are presented through the northwestern limb of the syncline as measured by Marlow (1981).

Narubis Granitoid Complex

The relative ages and correlation of granitoids belonging to the AC are more uncertain than in the case of the metasediments and metavolcanic rocks. Numerous intrusive rocks of granitic composition occur within the AC. They are now (augen) gneisses of great textural, mineralogical, and compositional variety.

Smith (1965) observed at one place augen gneiss underlying sillimanite gneiss of metasedimentary origin and because he did not find any indications for the intrusive character of these augen gneisses, he placed them below the metasediments of the Naob Formation, ascribing an autochthonous character to them. The supposed unconformity between the augen gneiss and the underlying sillimanite gneiss mentioned by Smith (1965) has been reinvestigated by Marlow (1981), who found that both units have a vertical foliation and are separated by a flat surface caused by a Karoo Sequence dolerite sill. Marlow (1981) also found that most of the gneisses on Naob 69 and Tsawisis 16 contain small and large xenoliths (up to a few hundred metres long) of the AC metasediments (mainly schist and calc-silicate rock) and metavolcanic rocks, and that they locally show intrusive relationships with those rocks. It is therefore more likely that the AC gneisses are orthogneisses and are younger than the metasedimentary and metavolcanic rocks of the Naob Formation.

In the present study, all ortho-(augen) gneisses and granitic rocks of the AC have been grouped together in the Narubis Granitoid Complex, named after Narubis 67, where there are excellent exposures of several (but not all) of the granitoids. The word 'complex' has been preferred above 'suite' because no genetic relation between the granitoids has been proved yet. The Habis granite (see later section), is also a member of this granitoid complex and has been studied in more detail because it formed part of the granitoid study mentioned earlier.

Because of the large number of intrusive bodies and their relatively small size (in many cases only veins), it is very difficult to bring order in their succession. Mapping of the terrain underlain by the Tsawisis Formation and the Narubis Granitoid Complex will be time-consuming and was not the scope of the present study. Both rock

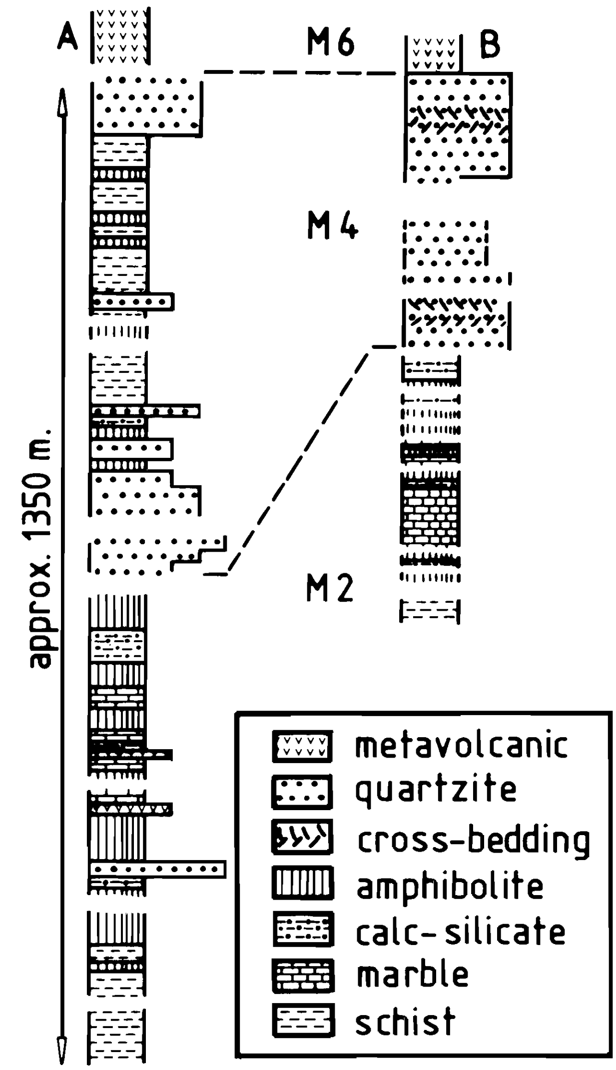


Figure 6 Two southeast to northwest sections through the northwestern limb of the Black Mountain–Gamgamichabberg syncline. The location of the sections (A and B) is indicated in Figure 2. No complete section through the southeastern limb of the structure is available. Modified after Marlow (1981).

units have been given the same symbol in Figure 2. Furthermore, Damaran plutonic rocks occur in the AC terrain. They include pegmatites, cutting the Abbabis–Damara contact (e.g. north of the Naob River on Naob 69) and the Kubas granite, which intruded rocks of the AC at several localities on Ubib 76. In higher grade metamorphic rocks to the west of the present area, remobilization of the basement rocks during Damaran time has given rise to several migmatites and intrusives (Jacob, 1974; Berning *et al.*, 1976; Marlow, 1981; Sawyer, 1981).

Petrography

Gevers (1931) described coarsely crystalline grey (augen) gneiss on Abbabis 70, Navachab 58, Habis 71, Tsawisis 16, and Tsawisis Suid 95, and considered it to be biotite-muscovite-plagioclase granite, which has been altered. These rocks contain biotite and muscovite in equal quantities, whereas plagioclase is more abundant than microcline. Typical augen gneiss with large plagioclase augen are as common as gneisses with scattered augen of quartz-feldspar aggregates. From Tsawisis 16, Gevers (1931) reported the occurrence of a very biotite-rich variety of this augen gneiss, a cataclastic gneiss with quartz-microcline augen and various other gneissic rocks.

Smith (1965) distinguished in the Abbabis Inlier 'quartzofeldspathic biotite augen gneiss and plagioclase-rich biotite gneiss'.

Marlow (1981) found, in that part of the Abbabis Inlier he studied (Naob 69, Tsawisis 16), muscovite-bearing granitic gneisses, biotite-bearing dioritic gneisses, and a granodioritic gneiss. The latter is probably the oldest of the pre-Damaran plutonic rocks and is intrusive into the metasediments and metavolcanic rocks of the AC (Marlow, 1981). This gneiss is probably the same as Gevers's grey (augen) gneiss. Because of reverse intrusive relationships and their intimate association, Marlow (1981) concluded that the other two types of intrusives he recognized were probably emplaced synchronously.

A large variety of descriptive terms has been used to characterize the (augen) gneisses in other AC occurrences in the SW Central Zone, (e.g. Jacob, 1974; Marlow, 1981; Sawyer, 1981; Downing, 1982). Without comparative geochemistry it is at this stage impossible to correlate the different (augen) gneisses of the AC.

The present author studied the Habis granite, the augen gneiss, and the biotite diorite on the western part of Habis 71 in more detail to compare them geochemically with granitic rocks of Damaran age. This comparison does not form part of the present publication.

Habis granite

This granite, named by Gevers (1931) occurs in the Abbabis Inlier on the western part of Habis 71, where it forms some prominent hills in an otherwise flat country underlain by augen gneiss.

According to Gevers (1931), who found the granite intrusive into Damaran marbles of the Karibib Formation, it represents an early post-Damaran intrusion. The present author cannot confirm the intrusive relationship, but found at Aroab on Habis 71 (Figure 1) that the granite not only lies below but, at one place, also above what is presumed to be Karibib Formation marble of the Damara Sequence. The same situation occurs on the extreme southern part of Goas 79 (outside the present area, where the main Karibib–Anschluss road crosses the Karibib Formation marble and AC augen gneiss), where lenses of augen gneiss occur within the marble. It is believed that the granite is of pre-Damaran age and that its position above and in the marble is due to thrusting. The pre-Damaran age was deduced from the presence of boulders of this granite in a channel fill of Etusis Formation on the Otjipateraberg on Abbabis 70 (Martin, pers. comm.) and from its occurrence as boulders in the Chuos Formation at the Taghubberg on Kubas 77.

Macroscopically the Habis granite is a grey to buff, in places gneissose, porphyritic granite with whitish K-feldspar phenocrysts scattered throughout the rock. Xenoliths of biotite granite (with scattered K-feldspar phenocrysts), biotite schist, hornblende schist, and hornblende-rich rock are present, the last locally as an aggregate of xenoliths. Epidote lenses occur at some localities.

A foliation is caused mainly by the planar orientation of biotites in the matrix, especially in higher strain areas such as around xenoliths or K-feldspar phenocrysts. The latter are up to 8 cm long and in many cases broken or flattened. The fabric in some inclusions is not related to that of the host rock.

Microscopically the Habis granite is characterized by a biotite-quartz-feldspar foliation, which is not very planar but rather bends around microcline phenocrysts, enclosing smaller microcline, muscovite, partly or completely chloritized biotite and quartz. Andesine is partly or completely replaced by sericite and in some cases by muscovite. Most feldspars have serrated rims (Figure 7), probably due to renewed crystal grow during late AC or Damaran metamorphism. Non-undulating muscovite is poikiloblastic or replaces other minerals. Accessories such as apatite, zircon, and opaque minerals are present as well.

The Habis granite was intruded by pegmatites, containing large (up to 10 cm) K-feldspar crystals, quartz, and muscovite, and by grey, fine crystalline biotite granite. Both intrusives also occur in Damara Sequence rocks and are probably of Damaran age.

Augen gneiss

The augen gneiss underlies most of the western part of Habis 71. On outcrop scale it is a uniform rock with quartz-feldspar augen and schlieren (Figure 8), but on a regional scale it varies in colour (red, dark or light grey, buff) and grain size. Between Aroab (Habis 71) and the diorite koppie (3,7 km south of Aroab, marked 3 in Figure 1), it occurs mainly as grey augen gneiss with abundant K-feldspar augen. South of the diorite koppie the rock is much darker and has a finely crystalline, almost black matrix with scattered K-feldspar phenocrysts, whereas to the east of it red K-feldspar augen are embedded in a reddish, muscovite-bearing matrix. Locally the augen consist of microcline, which might be myrmekitic. Partly sericitized andesine and partly, or completely, chloritized biotite occur together with weakly undulose muscovite and quartz. A second generation of strain-free muscovite grew over most of the other minerals and is probably of Damaran age.

Biotite diorite

The biotite diorite forms two boulder-covered hills on Habis 71, one partly consisting of marble (marked 3 in Figure 1).

Intrusive relationships with the surrounding augen gneiss could not be established due to scree cover and the strong weathering of a probably cataclastic contact zone.

It is a very dark-grey to black, massive, and unfoliated rock, consisting mainly of andesine and green biotite. The feldspar is zoned and strongly sericitized (in many cases more than 50 per cent). Biotite is partly chloritized or contains muscovite along its main crystal cleavage planes. No quartz has been found. Several large, anhedral sphene crystals and interstitial carbonate are present. Apatite, epidote, and opaque minerals occur as accessories.

Most Damaran granodiorites, tonalites, and diorites in the present area and its immediate surroundings are hornblende-bearing rocks with brown biotite and a far lower degree of sericitization and chloritization than found in the biotite-diorite under discussion. It is therefore thought that this biotite-diorite is an AC igneous rock.

Amphibolite dykes of the Abbabis Complex

At several localities in the Abbabis Inlier and elsewhere

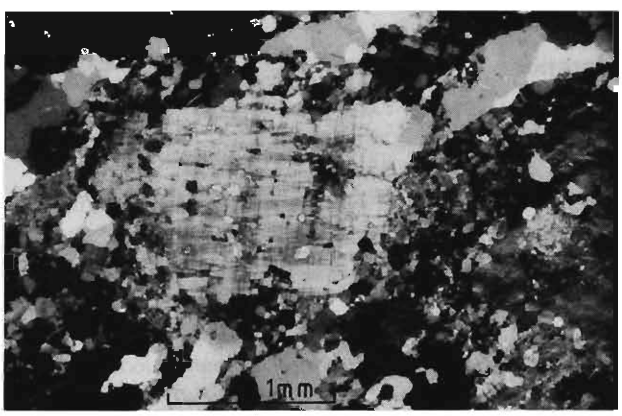


Figure 7 Serrated edge of feldspar phenocrysts in the Habis granite. These phenocrysts overgrow with a reaction rim an older generation of sericitized feldspar. The serrated edge probably indicates renewed crystal growth during late AC or Damaran times. Habis 71.

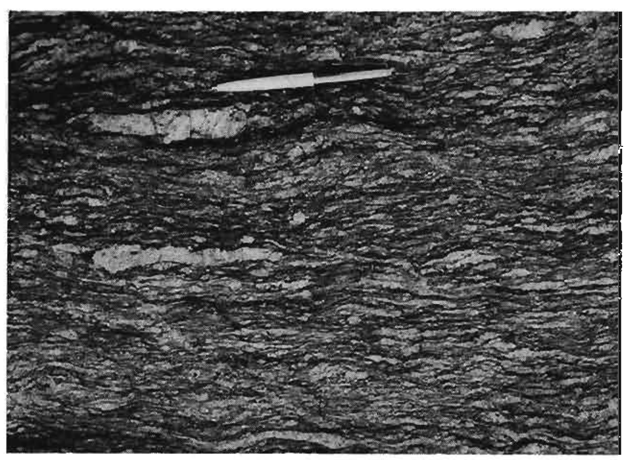


Figure 8 Augen gneiss with quartz-feldspar augen and schlieren (light) and biotite-rich schlieren (dark) of the Narubis Granitoid Complex of the Abbabis Complex. Habis 71.

outside the study area (at Swakopmund, and south of the Rössing and Arandis railway sidings, and in the lower Khan gorge; see also Jacob, 1974) rocks of the AC have been intruded by basic dykes, cross-cutting the sedimentary layering and schistosity or foliation of the country rock. The dykes can be followed in the field for distances of up to 3,5 km (Narubis 67, Figure 2), but in most cases are shorter, probably due to offsetting and boudinage during Damaran deformation.

According to Marlow (1981) the main constituents of these dark green to black rocks are hornblende and feldspar. Subordinate amounts of green biotite, epidote, sphene, opaque minerals, and zircon are also present. These rocks are considered to be altered AC dolerite dykes, metamorphosed during the Damara Orogeny.

Naob Alkali Complex

An alkali complex along one of the tributaries of the Naob River on Naob 69 (Figure 2) has been indicated on one of Marlow's maps (Marlow, 1981). In the legend to the map it is referred to as 'syenite and feldspar-ilmenite rock' of Damaran age, but in the text this complex is not mentioned.

The complex measures about 360 m by 150 m and is cut by a Karoo-age dolerite dyke.

A large variety of rock types is exposed, such as light green hornblende-bearing syenite, biotite magnetite schist, white, sugary syenite with abundant hematite (diameter up to 5 cm), nodular syenite with a groundmass composed of feldspar and hematite, several other light-coloured rocks, veins consisting almost purely of feldspar, as well as buff magnetite aplite veins. No thin sections of these rocks have been studied. In many cases, hematite is concentrated in veins, which locally seem to be brecciated. There is also a pink biotite augen syenite, with augen consisting of relatively coarse orthoclase and plagioclase (oligoclase-andesine) with accessory muscovite, sericite and polygonal quartz, surrounded by a finer matrix of biotite, plagioclase, and hematite. Accessory zircon and quartz are present in the matrix. In the highest strain area, where the matrix bends around the augen, the biotite is replaced by chlorite.

The augen texture of the syenite, attesting to intense deformation, suggests that this complex of alkali rocks is of pre-Damaran and probably AC age.

Pegmatites in the Abbabis Complex

In the present area, fragments of pegmatite, feldspar, and quartz are present in the basal conglomerate of the Damara Sequence (Abbabis 70), in the mixtite of the Chuos Formation (several localities), and in the rock and mineral fragment-bearing member of the Karibib Formation (several localities). These fragments must have been derived from AC pegmatites.

Non-gneissose, coarse, reddish pegmatite is present ubiquitously in the rocks of the AC. Apart from red feldspar (from 0,5 to 20 cm and on average 5 cm), quartz, schorl, and muscovite are abundant. Some of these pegmatites are restricted to the AC, but others have been found cross-cutting the AC–Damara contact. Locally they are abundant in these rocks and in the Damara intrusives. Some of these pegmatites therefore must be of Damaran age. In the field it has not been possible to distinguish mineralogically between pre-Damara and Damara pegmatites in the Abbabis Inlier. The AC pegmatites are deformed however. The same applies to the small quartz or quartz-feldspar veins, parallel to or cross-cutting the foliation or schistosity of the AC rocks.

In general, rocks of the AC seem to be intruded more intensely by pegmatite veins than those of the Damara Sequence.

Conclusions

The presence of the Black Mountain–Ubib Mine syncline of the Abbabis Complex rocks in the Abbabis Inlier is supported by the dip of the bedding, the orientation of the fold axes and mineral lineations, and the younging direction indicated by cross-bedding structures in both limbs of the syncline. The moderately northeast dipping, 20-km long fold axis of the syncline runs from the fold closure at the Black Mountain to the Gamgamichabberg, where the structure stops against Damara Sequence metasediments. The northwestern limb of the syncline is well preserved, but the southeastern one is obliterated for a great deal by an intrusive Damaran granite (Kubas granite).

The proposed stratigraphy of the Abbabis Complex starts with gneiss and metasediment of the Tsawisis Formation, overlain by schist, metabasite and marble (M2 Member), quartzite, marble and calc-silicate (M4 Member), and metavolcanic rock (M6 Member) of the Naob Formation, which in turn is overlain by a large variety of granitic rocks of the Narubis Granitoid Complex. The whole sequence is intruded by dolerite dykes, which are now amphibolites.

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