THE STRATIGRAPHY OF THE KHOMAS SUBGROUP WEST OF THE SPITZKOPPE, SOUTH WEST AFRICA

by

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ABSTRACT

The Khomas Subgroup along the lower reaches of the Omaruru River overlies the Nosib Group conformably, indicating non-deposition of the Ugab Subgroup. The Khomas sequence can be subdivided into five formations, i.e. a basal Geluk formation consisting of white marble, overlain conformably by the Oberwasser and Hoopverloor formations consisting of immature clastics and impure calcareous rocks, followed conformably by white marble of the Jun-Mon Formation, which in turn is comformably overlain by a monotonous succession of schists of the Rietkuil Formation. A definite change in sedimentary facies, represented by immature clastics and minor calcareous rocks in the west and impure marbles farther eastwards, is present in the lower units of the Khomas Subgroup. The sequence as a whole was subjected to a single, prolonged metamorphism during which the PT conditions reached a minimum of 600 ° at 3,5–5 kb.

CONTENTS

I. INTRODUCTION

During 1975 area 2114D (Fig. 1) was mapped by the junior author (Botha, 1978). This work represents the first detailed geological mapping of this area and it soon became apparent that the stratigraphy of the Damara Sequence in this area differs considerably from that in the Karibib–Swakopmund area or from that in the area west of the Brandberg.

Wagner (1916) was one of the first to give a general description of the Damaraland rocks, while Haughton *et al.* (1939) and Frommurze *et al.* (1942) published maps of the area east and north-east of area 2114D. Gevers (1931, 1936) investigated areas of western Damaraland and specifically mentioned the presence of a tillite in the Damara succession. The area west of the Brandberg was mapped by Jeppe (1952) and that to the north, east and south of the Brandberg by Clifford (1967), Frets (1969), Schoeman (1970), Van Reenen (1970), Tordiffe (1970), Gunter (1970), Koornhof (1970), Miller (1972) and Hodgson (1972); these areas lie north or west of area 2114D. In 1965 Martin described the stratigraphy of the Swakop facies and Smith the geology around the Khan and Swakop Rivers. Nash (1971) completed a detailed study of the metamorphism of an area in the Swakopmund district and Jacob (1974) an investigation of the geology and metamorphic petrology along the lower Swakop River.

II. GEOLOGY

A. Stratigraphic Nomenclature

The Precambrian rocks of area 2114D belong to the Nosib and Swakop Groups of the Damara Sequence which form part of the eugeosynclinal facies of the Damara Orogen. In certain areas an unconformity or paraconformity separates the Nosib and overlying Damara rocks (Smith, 1965; Guj, 1970; Nash, 1971; Jacob, 1974), but a conformable relationship is present in Area 2114D (Botha and Botha, 1978). Martin (1965) has shown, however, that the psammitic rocks of the Nosib Group form part, both sedimentologically and structurally, of the Damara Sequence. The subdivision of the Damara Sequence in the Karibib–Swakopmund area and west of the Brandberg, as proposed by SACS, is presented in Table I; the whole of the succession west of the Brandberg is the equivalent of the Kuiseb Formation of the Karibib–Swakopmund area. The stratigraphic succession along the lower Omaruru River is not in agreement with either of the above and a new, informal subdivision for area 2114D is therefore presented in Fig. 2.

B. Lithostratigraphy

1. General

The major part of area 2114D is underlain by the Rietkuil Formation, which is lithologically similar to the Kuiseb Formation of the Karibib–Swakopmund area but differs considerably from the succession west of the Brandberg. The Jun-Mon, Hoopverloor/Oberwasser and Geluk formations are probably the equivalent of the Karibib Formation of the Swakopmund area. The Chuos Formation is absent along the lower Omaruru River and rocks similar to the Rössing Formation of the Ugab Subgroup have also not been recognised. The succession along the lower Omaruru River therefore very likely forms part of the Khomas Subgroup, indicating non-deposition of the Ugab Subgroup.

Martin (1965, p. 40) states that the upper "Hakos" marble (i.e. upper Karibib Formation) is the first lithostratigraphic unit to be deposited through the whole area of the Damara geosyncline. The subsequent uniformity in depositional conditions is believed to be responsible for the monotony of the overlying schist of the Kuiseb Formation. Martin (1965, p. 38)

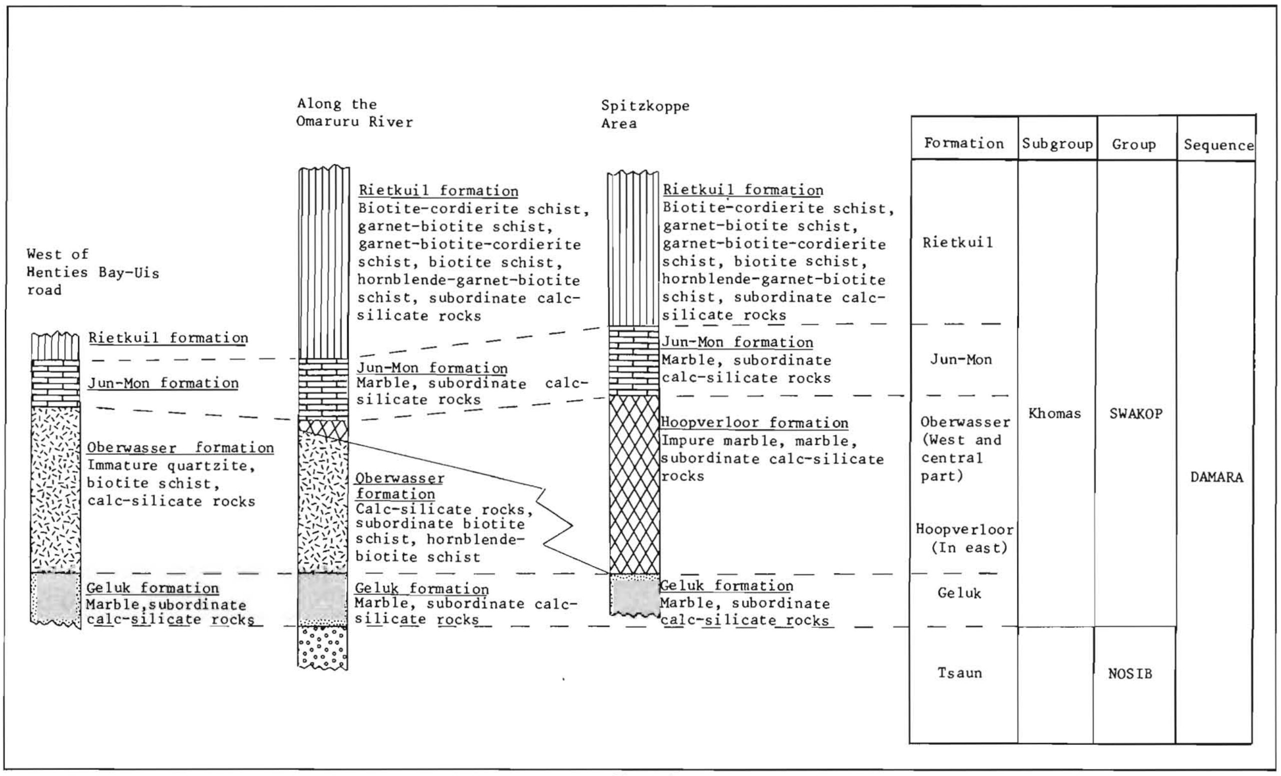

Figure 2

Subdivision of the Khomas Subgroup west of the Spitzkoppe, S.W.A.

points out that the great variety of rock types present below the Karibib Formation reflects continuous changes in the mode of deposition caused by geosynclinal sinking.

A considerable increase in the proportion of calcareous sediments can be observed from west to east in area 2114D: the Oberwasser formation, west of the Henties Bay–Uis road, consists of immature quartzite and minor calc-silicate rocks; along the lower Omaruru River the same formation is comprised of calc-silicate rocks and minor biotite schist and thin marble bands; farther eastwards, in the Spitzkoppe area, the stratigraphic equivalent of the Oberwasser Formation is the Hoopverloor Formation, which consists almost entirely of marble. A definite sedimentary facies change from west to east can therefore be observed in area 2114D (Fig. 2) and this largely explains the differences in the stratigraphic succession from south of the Brandberg to Karibib (Table I).

2. *Geluk Formation*

The name "Geluk Formation" is derived from Geluk 123 along the lower Omaruru River (Fig. 1) and the reference stratotype is about 3 km east of the farmhouse on the bank of the Omaruru River. Farther eastwards, approximately 9 km west of the old farmhouse on Marenica 114, the Geluk Formation crops out in the core of a structural dome. A few isolated outcrops are also present west of the Henties Bay–Uis Road.

Due to the intense deformation the thickness of the unit is difficult to determine. On Geluk 123 a figure of 50 metres was obtained, but it is apparently much thicker farther eastwards. The contacts with the underlying Tsaun Formation of the Nosib Group (Botha and Botha, 1978) and with the overlying Oberwasser and Hoopverloor formations are conformable and sharp. Pegmatite bodies are often present along the upper and lower contacts.

TABLE I
Subdivision of the Damara Sequence in the North-Western part of South West Africa (according to SACS)

Karibib and Swakopmund area				
Sequence	Group	Subgroup	Formation	Lithology
DAMARA	SWAKOP	Khomas	Kuiseb	Biotite-rich quartzofeldspathic schist, biotite-garnet-cordierite schist, minor amphibole schist, quartzite, calc-silicate rock and marble
			Karibib	Marble, biotite schist, quartz schist, calc-silicate rock
			Chuos	Diamictite, pebble- and boulder-bearing schist, minor quartzite
		Discordance		
		Ugab	Rössing	Very variable: marble, quartzite, conglomerate, biotite schist, biotite-cordierite schist and gneiss, aluminous gneiss, biotite-hornblende schist, calc-silicate rock
	Unconformity or conformable transition			
	NOSIB		Khan Etusis	Various gneisses, quartzite, schist, conglomerate, minor marble, amphibolite and calc-silicate rock

Area west of Brandberg				
Sequence	Group	Subgroup	Formation	Lithology
DAMARA	SWAKOP	Khomas	Amis River (inland) Hogden Bay (at coast)	Pelitic schist, minor schistose graywacke, sheared quartzite. Porphyroblastic feldspar-biotite schist
			Gemsbok River	Basal yellow limestone, followed by brown and blue limestone
			Brak River	Schistose graywacke, minor pelitic schist and quartzite. Basal limestone (Brandberg West (Member)
			Zebra River	Pelitic schist, minor schistose graywacke

BOTHA & BOTHA. FIGURE 1

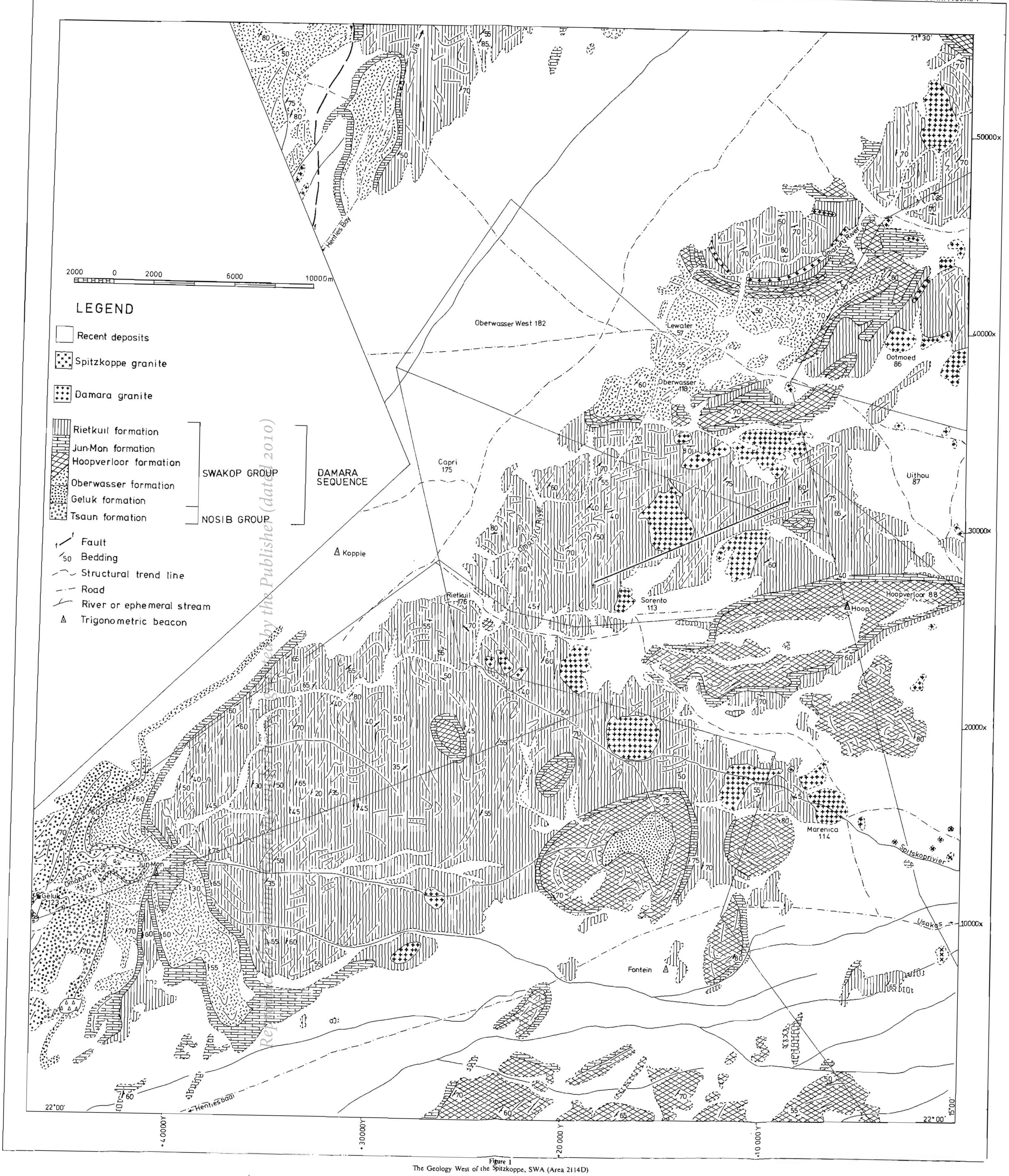

Figure 1
The Geology West of the Spitzkoppe, SWA (Area 2114D)

The Geluk Formation consists of white dolomitic marble, with minor, thin calc-silicate layers (Fig. 3). The marble is medium- to coarse-grained and graphite and phlogopite are visible in some hand specimens. Under the microscope diopside, scapolite and sphene were recognised in the more impure varieties.

The intensely folded and boudinaged calc-silicate layers are normally less than 20 cm in width and up to tens of metres in length. The rocks are medium- to coarse-grained and two or more of the following minerals were recognised together in thin section: quartz, plagioclase, microcline, diopside, cordierite, hornblende, calcite, sphene, clinozoisite and ore minerals.

Figure 3
The general appearance of the white marble of the Geluk Formation. East of Geluk 123.

3. Oberwasser Formation

The name "Oberwasser Formation" is derived from Oberwasser 118 along the lower Omaruru River (Fig. 1). This unit shows considerable facies changes from west to east.

Outcrops west of the Henties Bay–Uis road are extremely poor and consist of immature quartzite with minor schist and calc-silicate rocks. The upper and lower contacts of the unit are not exposed here and the thickness could not be determined. In the area immediately west of area 2114D the Oberwasser Formation follows conformably on the Geluk Formation (Schoeman, 1970). The quartzite consists of quartz, plagioclase (An$_{28}$) and biotite, with one or more of the following minor or accessory minerals: microcline, garnet, muscovite, apatite, tourmaline, sphene and epidote. The immature quartzite grades laterally into biotite schist. The calc-silicates are present as lenses, up to 20 cm in width and 1 metre in length. The main constituents in them are quartz, plagioclase, diopside and hornblende, with accessory garnet, calcite, sphene, epidote and apatite.

Particularly fine outcrops of the Oberwasser Formation are present along the Omaruru River, especially in the vicinity of Lêwater 57 and east of Geluk 123. In the latter area the unit follows conformably on the Geluk Formation and is conformably overlain by the Jun-Mon Formation; the contacts are sharp. The reference stratotype is along the Omaruru River, approximately 6 km east of Geluk 123, where a thickness of 700 metres was determined. On Lêwater 57 some 100 metres of brown marble of the Hoopverloor Formation is present between the Oberwasser and Jun-Mon formations (Fig. 1). The Oberwasser formation along the Omaruru River consists mainly of calc-silicate rocks with minor biotite or hornblende-biotite schist and thin bands of marble. These calc-silicate rocks have a green or brown colour and weather in a typical tombstone manner on the Namib Plain (Fig. 4). The rock has a massive appearance, except where biotite becomes a main constituent in which case an excellent foliation is developed. The main constituents are quartz, plagioclase (An$_{30-50}$) and diopside with or without microcline, hornblende, biotite, muscovite, scapolite, sphene, calcite and clinozoisite as minor or accessory minerals. The schist bands vary from a few centimetres to a few metres in width and the contact between the calc-silicate and the biotite schist is always sharp; the contact between the calc-silicate and the hornblende-biotite schist is normally gradational. The minerals in the schist are the same as those in the calc-silicate rock except that diopside is absent or only very minor.

Figure 4
Tombstone weathering in the calc-silicate rocks of the Oberwasser Formation. On the Namib Plain east of the Omaruru River.

4. Hoopverloor Formation

The name "Hoopverloor Formation" is derived from Hoopverloor 88 (Fig. 1). Outcrops are confined mainly to the eastern part of area 2114D and are nearly always exposed in structural domes, i.e. in the vicinity of Marenica 144 and on Lêwater 57. At Lêwater the unit is approximately 100 metres and 250 metres in the dome north of the Fontein trigonometric beacon (Fig. 2) the latter locality is taken as the reference stratotype. The contacts with the overlying Jun-Mon Formation and the underlying Geluk Formation are sharp and conformable, except at Lêwater where the unit follows conformably on the calc-silicate rocks of the Oberwasser Formation (Fig. 2). The Oberwasser and Hoopverloor formations are time-stratigraphic equivalents and indicate a change in sedimentary facies from west to east.

The Hoopverloor Formation consists of brown marble with thin, continuous calc-silicate layers (Fig. 5). The mineralogy is similar to that of the Geluk Formation.

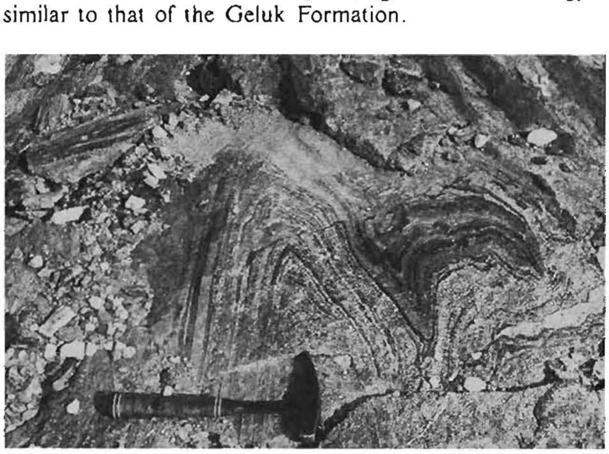

Figure 5
Thin calc-silicate layers in the brown marble of the Hoopverloor Formation. East of Lêwater 57.

5. Jun-Mon Formation

The name "Jun-Mon Formation" is derived from the trigonometric beacon Jun-Mon, which is located on a prominent marble hill approximately 6 km east of Geluk 123. This unit represents the top of the calcareous metasediments of the Swakop Group and is present both east and west of the Omaruru River.

The thickness is approximately 200 metres and the contacts with the overlying Rietkuil Formation and the underlying Oberwasser/Hoopverloor formation are conformable and sharp. The reference stratotype is at the Jun-Mon beacon.

The Jun-Mon Formation consists of coarse-grained white marble with very minor calc-silicate rocks. The marble often weathers positively, thus forming low ridges which contrast sharply with the overlying dark schists of the Rietkuil Formation. The mineralogy of the unit is similar to that of the Geluk Formation.

6. Rietkuil Formation

The name "Rietkuil Formation" is derived from Rietkuil 176 along the Omaruru River. The unit follows conformably on the Jun-Mon Formation and is disconformably overlain by recent deposits. The reference stratotype is along the Omaruru River, north-east of the Jun-Mon trigonometric beacon. Due to intense folding the true thickness cannot be determined, but it is probably in excess of 1 000 metres.

The Rietkuil Formation underlies most of area 2114D and consists of a monotonous succession of biotite schists with very minor calc-silicate lenses. The softness of the rocks is responsible for the extreme ruggedness of the terrain along the Omaruru River. This feature is enhanced by the presence of numerous small and large bodies of pegmatite; some of these bodies measure 3× 2 km and contain numerous remnants of schist. Most of the bodies of intrusive Salem granite are also confined to the Rietkuil Formation.

The following types of schist were recognised: biotite, garnet-biotite, hornblende-garnet-biotite, biotite-cordierite and garnet-biotite-cordierite schist. The main constituents are quartz, plagioclase and biotite, with or without microcline, cordierite and garnet and with minor or accessory hornblende, muscovite, sillimanite, calcite and zircon. Elliptical glomeroporphyroblasts of cordierite with minor quartz, microcline, biotite and sillimanite are common. The schist consists of parallel layers, a few centimetres to tens of metres thick, of different mineralogical composition (Fig. 6). The rock is often migmatitic in character and it is conspicuous that the leucosome is always surrounded by a melanosome of biotite. According to the classification of Mehnert (1971) these migmatites are venites which form *in situ* by partial mobilisation; stromatic, surreitic, ptygmatic, stictolithic and nebulitic structures were recognised.

The calc-silicate lenses consist of quartz and plagioclase, with minor diopside, hornblende, garnet and calcite and accessory sphene.

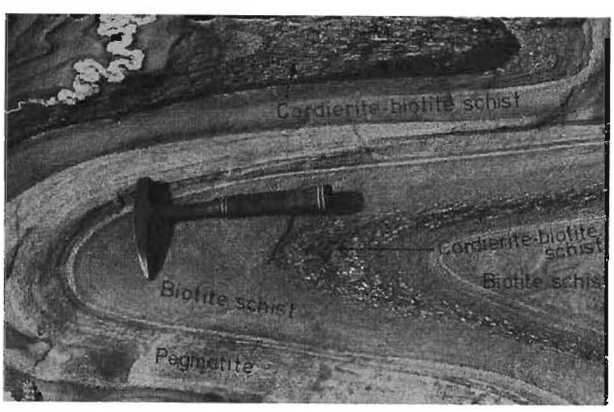

Figure 6
Alternating layers of cordierite-biotite and biotite schist in the Rietkuil Formation. Near the confluence of the Omaruru and Spitskop Rivers.

C. Metamorphism

The metamorphic grade along the lower Omaruru River is that of the amphibolite facies. Evidence of retrograde metamorphism in the form of chloritisation is found throughout the area but is not very common. During the present study attention was given mainly to the semi-pelitic and pelitic rocks of the Rietkuil Formation and to the calc-silicate rocks of all the lithostratigraphic units.

The important mineral parageneses in the semi-pelitic rocks are the following:
quartz + plagioclase + biotite ± K-feldspar ± muscovite
quartz + plagioclase + muscovite
quartz + K-feldspar + biotite + almandine
quartz + K-feldspar + biotite + sillimanite

The metapelites are composed of up to eight mineral phases and as quartz and plagioclase are common to all of them, these minerals are omitted from the following parageneses:
K-feldspar + cordierite + biotite + sillimanite
K-feldspar + cordierite + biotite + almandine
K-feldspar + cordierite + almandine ± sillimanite

The first four parageneses reflect the progressive breakdown of muscovite with increasing metamorphic grade (Winkler, 1974, pp. 81–86, 273–310). Muscovite is present in minor or accessory quantities and always coexists with quartz and plagioclase, thus defining the change from medium to high-grade metamorphism (Winkler, 1974, p. 81). The schists of the Rietkuil Formation are often migmatitic in character, indicating minimum PT conditions of 650 °C at P_{H_2O} greater than 3,5 kb. This high-grade metamorphism is confirmed by the presence of myrmekitic and perthitic textures (Spry, 1974, pp. 104 and 181) in the semi-pelitic rocks.

Sillimanite is widespread in the metapelitic schists of the Rietkuil Formation and equilibrium curves established by Althaus (1967) and Richardson *et al.* (1969) for the Al_2SiO_5 species provide a minimum temperature of 595 °C and 625 °C respectively. Muscovite is again present in minor or accessory quantities in most specimens. Although cordierite or almandine are present in most specimens, they were found to coexist in only one. As the FeO/(MgO + FeO) ratio of this rock lies between 0,5 and 0,6 (Botha, 1978) the coexistence of cordierite and almandine indicates a minimum temperature of 630 °C at 5 kb (Hirschberg and Winkler, 1968).

The important mineral parageneses in the calc-silicate rocks are:
quartz + hornblende + plagioclase ± diopside ± garnet ± sphene
quartz + plagioclase + diopside ± calcite ± scapolite ± sphene
quartz + diopside + scapolite + calcite

Diopside is present as a stable phase throughout the area and according to Winkler (1974, pp. 119–120) it will most likely form from the reaction tremolite + calcite + quartz. As no tremolite is present in area 2114D, and if P_f = 5 kb is assumed, a temperature of 600 °C must have been exceeded. Forsterite was not noticed in any of the specimens examined and it is possible that unsuitable rock compositions have prevented its formation.

To summarise: the metamorphic mineral parageneses present in area 2114D indicate the stability of diopside and of sillimanite and the coexistence of quartz, plagioclase and muscovite, of cordierite and biotite and of cordierite and almandine. The PT conditions are estimated at a minimum of 600 °C at 3,5–5 kb. Cordierite is one of the most common and widespread minerals in the pelitic schist. It is often found in elliptical glomeroporphyroblasts which are orientated parallel to S_2 surfaces (Botha, 1978). Migmatites are common in the Tsaun Formation (Botha and Botha, 1978), but less so in the Rietkuil formation. Nash (1971) postulated two episodes of high-grade metamorphism for the Damara Orogen, but evidence for only a single, prolonged episode is present in area 2114D (Botha, 1978). Different metamorphic isograds cannot be distinguished in area 2114D and the same PT conditions existed for the area as a whole.

The schists of the Rietkuil Formation do not show any signs of contact metamorphism. The Salem granite in area 2114D has the characteristics of late or post-tectonic intrusions (Botha, 1978), indicating that the prevailing temperatures in the schist were still high at a fairly late stage in the tectonic evolution of the orogen.

D. Conclusions

The Damara Sequence west of the Spitzkoppe is represented by the Tsaun Formation (Nosib Group), conformably overlain by the Khomas Subgroup. A subdivision of the latter into five lithostratigraphic units, i.e. Geluk, Oberwasser, Hoopverloor, Jun-Mon and Rietkuil formations, is possible, although the second and third represent time-stratigraphic equivalents. A change in sedimentary facies from west to east could be established in the lower units, i.e. immature quartzite and calc-silicate rocks of the Oberwasser Formation are represented by impure marble of the Hoopverloor Formation farther eastwards. The Jun-Mon and Rietkuil formations indicate a stable and uniform depositional environment without change in sedimentary facies. The Swakop Group along the lower Omaruru River thus represents an intermediate facies between that exposed around the Brandberg and that present along the lower Swakop River. The rocks of the Damara Sequence west of the Spitzkoppe were subjected to a single, prolonged metamorphism and the PT conditions for the area as a whole are estimated at a minimum of 600 °C and 3,5–5 kb.

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