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THE NOSIB GROUP ALONG THE LOWER REACHES OF THE OMARURU RIVER, SOUTH WEST AFRICA

by

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ABSTRACT

The Tsaun Formation of the Nosib Group exposed along the lower reaches of the Omaruru River is composed of quartz-feldspar gneiss, garnet-biotite and garnet-biotite-cordierite schist and amphibole gneiss, with subordinate amphibolite, calc-silicate rock and marble. The sequence can be divided into a lower psammitic Tsaur Member and an upper, more pelitic and calcareous, Autseib Member. The sequence is conformably overlain by schist and marble of the Swakop Group. Both sequences were deformed and metamorphosed simultaneously.

CONTENTS

I. INTRODUCTION

Based on the work of Gunter (1970), Schoeman (1970) and Van Reenen (1970), Botha *et al.* (1971/72) described a sequence of quartz-feldspar gneisses with subordinate amphibolite and biotite schist in the area south of Brandberg. This succession underlies the old "Damara System" and the name "Tsaun Formation" was assigned to these rocks. It was tentatively suggested that the succession be correlated with other basement rocks such as the Huab and Abbabis Complexes.

During 1975 area 2114 D was mapped in detail by the junior author and it soon became apparent that the Tsaun Formation is in fact the equivalent of the Nosib Group as described by Nash (1971) and Jacob (1974). Jacob and Kröner (1977), after a reconnaissance survey, came to the same conclusion.

II. GEOLOGY

A. General Statement

Particularly fine exposures of the Tsaun Formation are present along the lower reaches of the Omaruru River (Fig. 1) and it was possible to subdivide the formation into an upper Autseib and a lower Tsaur Member; "Autseib" is derived from Autseib 124 along the Omaruru River and "Tsaur" from a trigonometric beacon situated on a prominent hill to the west of the Henties Bay–Uis road. The names "Tsaun" and "Tsaur" are somewhat confusing, but this cannot be avoided due to the absence of other geographical reference points in this area.

The Nosib rocks in area 2114 D are confined to two outcrop areas, separated by the featureless Namib Plain, the one west of the Henties Bay–Uis road and the other along the Omaruru River (Fig. 1). The lithology, especially of the Autseib Member, differs considerably in the two areas (Fig. 2).

Exposures of mainly quartz-feldspar gneiss of the Tsaur Member are found west of the Henties Bay–Uis road, while amphibole and pyroxene-bearing rocks of the Autseib Member are very poorly developed and form a very subordinate part of the succession. Along the Omaruru River exposures of the Tsaun Formation are found mainly in the vicinity of the farm Geluk 123 (Fig. 1) but the Tsaur Member is here subordinate to the Autseib Member. The floor of the Nosib Group is nowhere exposed and this feature, coupled with the intense deformation, makes it impossible to calculate the true thickness of the succession.

Dykes of dolerite are ubiquitous in both areas and have a general northerly strike. In addition a number of dykes of alkaline granite and lamprophyre are also present along the Omaruru River.

B. Tsaur Member

This unit consists of migmatitic quartz-feldspar gneiss with subordinate intercalated lenses of biotite schist and calc-silicate rocks. Two generations of pegmatite, the one parallel to the foliation and deformed and the other discordant and undeformed, are ubiquitous in the gneiss. The latter is characterised by the presence of sub- to euhedral crystals of magnetite.

Quartz-feldspar gneiss. These well-banded reddish to greenish gneisses give rise to a conspicuous flat and rolling topography, in contrast to the rugged character of the surrounding Khomas schists.

A prominent banding is the most outstanding feature of the gneiss. This gives rise to a layered appearance, with alternating grey, red and greenish bands varying from a few millimetres to a few centimetres in thickness (Fig. 3); in rare instances the individual bands are more than a metre thick. The contacts between the individual bands are usually sharp and parallel to interlayers of calc-silicate rock. This indicates that the banding probably represents original sedimentary layering.

The gneiss is a fine- to medium-grained, usually inequigranular rock. It shows a well-developed foliation parallel to the banding due to the presence of orientated biotite. A more massive quartz-feldspar rock with a granoblastic texture is also present, but grades laterally into banded types with a well-developed foliation. The biotite varies in abundance and proportion and is responsible for the differences in overall mineral content and texture. The main

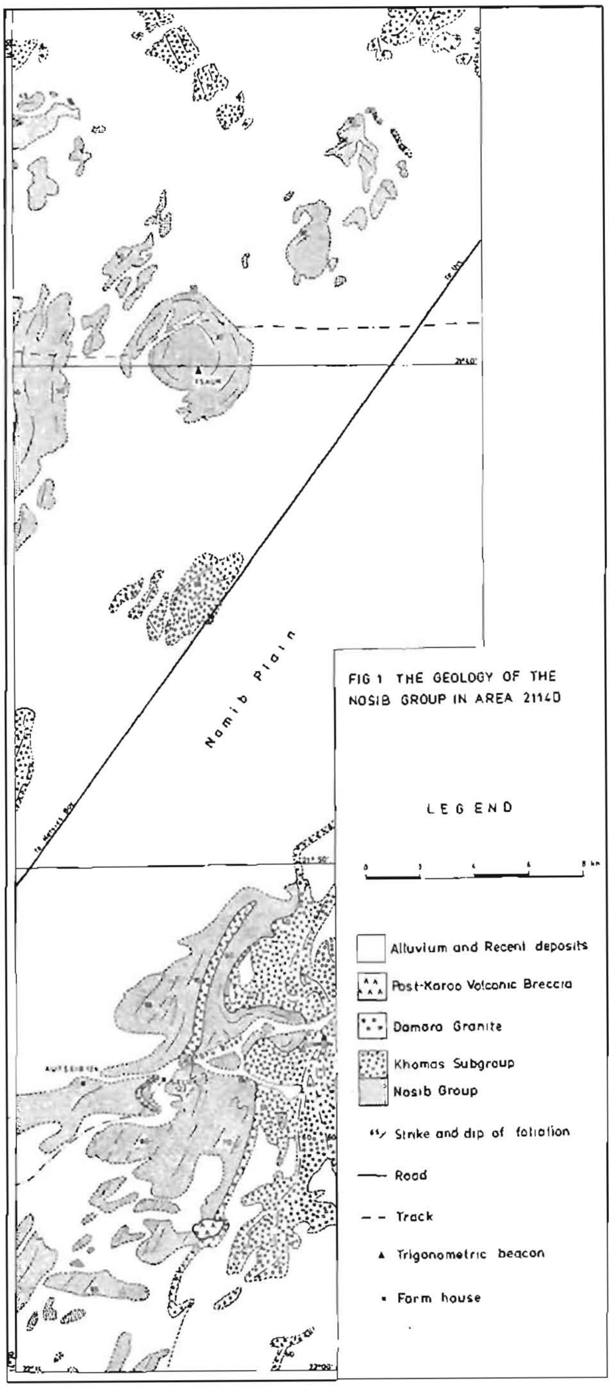

Figure 1
The geology of the Nosib Group in area 2114D.

constituents are xenoblastic quartz, plagioclase (An_{28-32}, with more albite-rich rims), microcline and subordinate reddish-brown biotite and muscovite. The accessory minerals include sphene (also present as a minor constituent), calcite, zircon, apatite and secondary chlorite, sericite and iron ore. Rounded inclusions of quartz and plagioclase are present in the microcline and alteration of biotite to chlorite and iron ore can be seen in some thin sections. Muscovite, when present, is found together with biotite. Garnet and sometimes sillimanite are also present in the gneiss along the Omaruru River.

The volumetric composition of 12 gneisses is given in Table I. The gneisses are granitic to granodioritic in composition. The quartz content is fairly constant, but the plagioclase and K-feldspar content varies considerably. Several thin sections were chemically stained and showed that the light-coloured bands consist mainly of quartz and plagioclase, the reddish bands of microcline and quartz and the greenish ones of biotite, quartz and microcline.

Calc-silicate rocks. These weather positively and have a green colour due to the presence of pyribole. Individual bands are seldom more than one metre thick, but are nevertheless of considerable lateral extent. Aggregates of dark green amphibole give a speckled appearance to the rock. No foliation is visible in outcrop.

The calc-silicate rock is medium- to coarse-grained and inequigranular. The main constituent is diopside which encloses quartz, plagioclase, hornblende (usually idiomorphic) and sphene poikiloblastically. Fractures in the diopside are filled with calcite. Occasional aggregates of unorientated hornblende, which encloses quartz and plagioclase poikiloblastically are also dispersed throughout the rock. Fine- to medium-grained quartz and labradorite (An_{62}) are subordinate to pyribole. Sphene is an important accessory mineral and is commonly found as euhedral crystals.

Biotite schist. This rock is very soft and weathers negatively. The lenses are seldom more than a metre in thickness and have a lateral extent of a few metres.

The schist consists of brown, orientated biotite and subordinate cordierite, quartz and plagioclase. The quartz and cordierite are elongated parallel to the foliation defined by biotite. Sphene and iron ore are the main accessory minerals.

C. Autseib Member

This member is developed mainly along the Omaruru River and consists of migmatitic garnet-biotite schist and garnet-biotite-cordierite schist (Fig. 4) which occur as alternating bands, a few centimetres to a few metres in thickness, and containing occasional parallel lenses of calc-silicate rock. Thin lenses and larger bodies of pegmatite are often present and have an orientation parallel to the foliation of the schist. The banding is parallel to the foliation and the contacts between individual bands are

TABLE I
Volumetric Analysis of the Tsaur Gneiss

Mineral	Sample											
	B2	B3	B4	B5	B6	B7	B13	B28	B31	B36	B39	B328
N	1 737	1 177	1 176	826	1 196	1 468	2 409	715	1 140	1 422	1 289	1 644
Quartz	26,66	29,31	37,20	32,61	33,70	35,05	41,09	31,65	37,79	33,34	32,75	37,96
Plagioclase	30,50	35,08	37,85	25,68	21,37	18,34	36,83	26,98	47,79	34,14	30,20	29,68
Microcline	33,86	30,22	15,11	35,21	39,54	40,06	16,01	34,27	8,66	27,25	35,78	24,82
Biotite	5,84	2,46	3,06	2,53	2,72	3,65	3,57	3,77	3,63	1,34		1,22
Muscovite			3,38	1,52				1,23		1,80		4,62
Accessory minerals*	3,14	2,93	3,40	2,45	2,67	2,90	2,50	2,10	2,13	2,13	1,27	1,70

N: Number of point counts
*Zircon, calcite, chlorite, epidote, iron ore, apatite and sphene

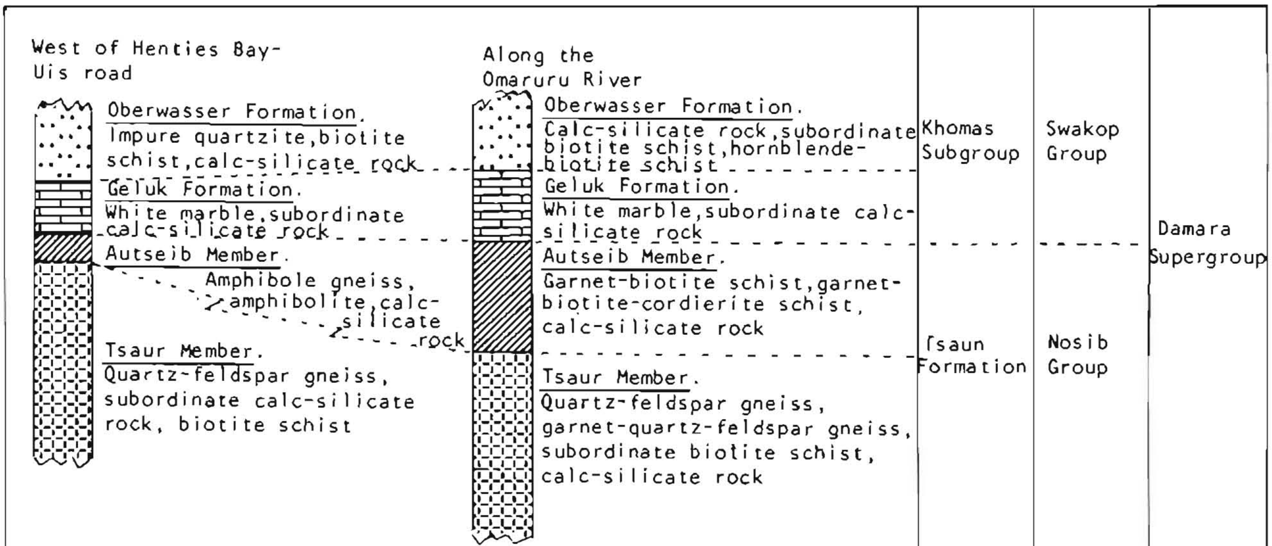

Fig.2 The subdivision of the Nosib Group along the lower reaches of the Omaruru River

Figure 2
The subdivision of the Nosib Group along the lower reaches of the Omaruru River.

Figure 3
Banding in the Tsaur gneiss. West of the Henties Bay — Uis road.

usually sharp. This unit follows conformably on the Tsaur Member and is in turn conformably overlain by the Geluk Formation of the Swakop Group (Botha, 1978, p. 35). No evidence of pre-Swakop erosion is present and the layers in all the stratigraphic units are parallel.

The Autseib Member west of the Henties Bay–Uis road consists of a few isolated outcrops of thin alternating bands of amphibole gneiss, amphibolite, calc-silicate rock and occasional thin bands of marble. The outcrops seldom measure more than 3–5 metres across. The bands are usually a few millimetres to a few centimetres in width and the contacts are usually sharp. These outcrops lie in the same stratigraphic position as those of the Autseib Member along the Omaruru River and resemble the calc-silicate rocks present in the latter, hence the correlation. The contact relationships with the overlying Geluk Formation and the underlying Tsaur Member could, however, not be studied here due to poor exposures.

The *garnet-biotite schist* consists of quartz and plagioclase (An_{26}) with subordinate biotite and garnet, and accessory zircon. The quartz, feldspar and biotite are poikiloblastically enclosed by the garnet and some rotation of the garnet has occurred during a later phase of deformation.

The *garnet-biotite-cordierite schist* consists of K-feldspar and coarse-grained cordierite, with subordinate quartz, garnet and biotite and accessory sillimanite and zircon. The cordierite is elongated parallel to the foliation, is often twinned and encloses quartz, feldspar, biotite and sillimanite poikiloblastically. Secondary pinite is present along fractures in the cordierite, around inclusions and on the contact between cordierite and the other minerals.

Two types of *amphibole gneiss*, one dark green to black and the other pinkish, could be distinguished macroscopically. The former occurs as bands between amphibolite and calc-silicate rock. It is medium-grained and consists of quartz, plagioclase (An_{60-70}) and hornblende, the latter constituting up to 40 per cent of the rock. A good foliation is developed due to the preferred orientation of the amphibole. The pink variety is similar to the quartz-feldspar gneiss of the Tsaur Member except that it has hornblende instead of biotite. The rock consists of quartz, microcline, plagioclase and hornblende, with accessory sphene, zircon and iron ore. The hornblende has a good preferred orientation, resulting in the foliated appearance of the rock.

The *amphibolite* is a homogeneous, dark green, well-foliated rock forming irregular, discontinuous bands which contain thin bands of calc-silicate or marble in places (Fig. 5). The amphibolite is a medium- to coarse-grained, inequigranular rock with a hornblende content of more than 80 per cent; diopside, plagioclase, quartz, sphene and calcite are present as minor or accessory constituents and epidote and chlorite are secondary minerals.

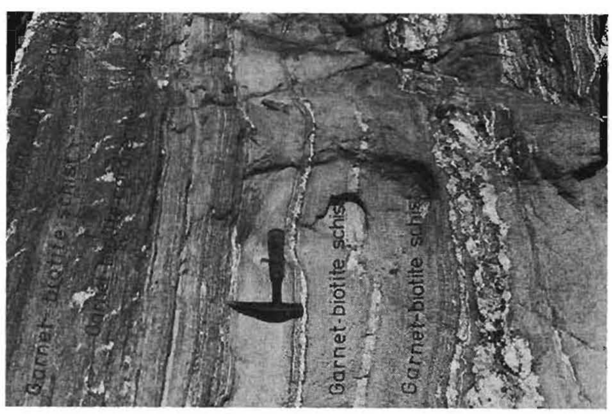

Figure 4
Migmatitic character of the schist of the Autseib Member. East of Geluk 123.

Figure 5
Outcrop of calc-silicate rock with interbands of marble and amphibolite. Autseib Member. West of Henties Bay — Uis road.

The *calc-silicate rocks* are petrographically similar to the calc-silicate bands in the gneiss of the Tsaur Member. Along the Omaruru River an unusual mineral assemblage of quartz, calcite, clinozoisite, piedmontite, epidote and sphene was found.

D. Metamorphism

The metamorphic grade along the lower reaches of the Omaruru River is confined to the change from medium- to high-grade or to the beginning of the high-grade as defined by Winkler (1976, pp. 82–88). The following mineral associations in the Tsaun gneiss, the amphibolite and in the calc-silicate rocks were found:

Quartz + Plagioclase + Biotite ± K-feldspar ± Muscovite
Quartz + Plagioclase + Muscovite
Quartz + K-feldspar + Biotite + Garnet
Quartz + K-feldspar + Biotite + Sillimanite
Quartz + K-feldspar + Cordierite + Garnet
Quartz + K-feldspar + Cordierite + Sillimanite + Garnet
K-feldspar + Sillimanite + Cordierite + Spinel
Diopside + Calcite ± Quartz ± Sphene ± Hornblende
Diopside + Quartz ± Sphene ± Hornblende
Zoisite + Quartz + Calcite

The presence of myrmekitic and perthitic textures in the migmatitic quartz-feldspar gneiss of the Tsaur Member indicates that these rocks were subjected to a high grade of metamorphism (Spry, 1974, pp. 104 and 181). Muscovite is a very minor constituent in the Tsaur gneisses and according to Winkler (1976, pp. 82–87) and Althaus *et al.* (1970, p. 331) it will break down at 4 kbar and 650 °C during prograde metamorphism to form K-feldspar, sillimanite and almandine-rich garnet or a granitic melt is formed producing migmatitic gneisses (Winkler, 1976, p. 246). The mineral composition and textures of the Tsaur gneisses show that these PT conditions were, in effect, attained.

The colour of hornblende for Z shows a relatively regular change during prograde metamorphism (Miyashiro, 1973, p. 254). The colour of the mineral in the Tsaun rocks varies from green to greenish-brown and this feature, together with the mineral associations, suggest that the [cordierite-almandine]-high grade of metamorphism (Winkler, 1976, p. 250) was attained. Hornblende and diopside intergrowths are very common in the amphibolite of the Autseib Member and the texture reveals that the diopside was formed from hornblende during prograde metamorphism. According to Jackson (1976, p. 142) this takes place during the transition of green to brown hornblende, which again is indicative of a high grade of metamorphism.

Botha (1978, pp. 117–135) has investigated the mineral parageneses in the Tsaun Formation and in the overlying Khomas Subgroup and concludes that both were subjected to the same PT conditions of 3, 5–6, 5 kbar and 600–700 °C.

E. Structure

Outcrops to the west of the Henties Bay–Uis road are generally very poor, so that structural interpretation in this area is very difficult. All that can be said is that the Tsaun Formation here crops out in a dome-like structure as defined by the foliation (Fig. 1). Outcrops are considerably better along the Omaruru River and Botha (1978, pp. 136–142) makes the following general conclusions for area 2114 D:

1. Conspicuous dome and basin structures are present, especially in the marble and schist of the overlying Swakop Group. The domes are elongated in a northerly direction.
2. The rocks exhibit a well-developed folded foliation.
3. Overfolding to the north-west is present throughout.
4. The Tsaun and Swakop rocks were deformed and metamorphosed simultaneously.

The following folding events can be distinguished:

F_1 Event. This event is characterised by isoclinal folds and was accompanied by high-grade metamorphism and migmatisation. This resulted in a regional foliation, mostly parallel to the original bedding. The orientation of F_1 axial planes could not be established with certainty, but it probably had a westerly to north-westerly strike.

F_2 Event. This event caused the general north-easterly structural grain so well displayed in area 2114 D, and north-east-trending isoclinal folds with overfolding to the north-west came into being. A very prominent north-east-trending *b*-lineation formed during this phase, but no regional foliation is associated with the event. The rotation of garnet occurred during this event. The interference of F_2 and F_1 structures gave rise to the conspicuous dome and basin structures. A study of minor folds indicates that the flow direction (A_2) of the F_2 folds are orientated close to the axial surfaces of the F_1 folds, hence the drop- and oval-shaped outlines of the domes (Ramsay, 1967 pp. 520–525).

F_3 Event. This event can only be seen in the schists and marbles of the Swakop Group. The folding was open and the axial traces have a general north-westerly trend.

III. CONCLUSIONS

The succession of gneisses and other rock-types of the Tsaun Formation forms part of the eugeosynclinal portion of the Late-Precambrian Damara Orogen. The Tsaun strata and overlying Swakop rocks show the same structural features and have suffered the same degree of metamorphism.

A subdivision of the Tsaun Formation into a lower Tsaur and an upper Autseib Member is possible. The Tsaur Member represents an original sequence of arkosic or feldspathic sandstones (now quartz-feldspar gneiss), with very minor interlayers of shale (now biotite schist) and calcareous sandstone or shale (now calc-silicate rock).

The massive, reddish quartz-feldspar gneiss is interpreted by Jacob and Kröner (1977, p. 77) as felsic metavolcanics similar to the lava flows in the Naauwpoort Formation of the Summas Mountains (Miller, 1972, 1974). No proof for this deduction could be found as these massive units grade laterally into banded types with interbands of schist and calc-silicate rock.

The Autseib Member originally consisted of a more pelitic and calcareous sequence now represented by garnet- and biotite-bearing schist, amphibole gneiss, amphibolite and minor calc-silicate rocks and marble. This member, therefore, probably represents a transition to the more schistose and calcareous units of the overlying Swakop Group. Sedimentation was thus continuous from the Nosib to the Swakop sequence and no break in the sedimentation could be established. The parallelism of the layers in the Tsaun Formation and Swakop Group is further proof for this conclusion.

The Nosib sequence along the lower reaches of the Omaruru River has many characteristics in common with the basal unit in the Khan–Swakop area (Nash, 1971; Jacob, 1974). Here the Nosib Group is subdivided into a lower Etusis Formation (quartzite, conglomerate, quartzo-feldspathic gneiss, migmatite, pelitic schist and minor marble) and an upper Khan Formation (hornblende-biotite schist and gneiss; migmatitic banded and mottled gneiss). The resemblance between the Tsaun and Etusis Formation is apparent, although the Autseib Member has some features in common with the Khan Formation.

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