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THE LITHOSTRATIGRAPHY OF THE CHUOS MIXTITE IN PART OF THE SOUTHERN CENTRAL ZONE OF THE DAMARA OROGEN, SOUTH WEST AFRICA

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ABSTRACT

The intraformational stratigraphy of the Chuos Formation varies significantly for four sections measured in the Karibib/Usakos area. Detailed stratigraphic sections on the iron formations provide evidence for glacial activity during the deposition of the mixtite deposits. Clast counts and the study of matrix type in the mixtite and interbedded clastic sediments provide evidence for a mass flow or reworked glacial origin for the bulk of the mixtite deposit.

1. INTRODUCTION

Since the Chuos mixtite was first described by Gevers (1931) from the Chuos Mountains in the southern Central Zone (sCZ), this unit has been widely used as a chronostratigraphic marker in the Damara Orogen. Based on similarities with the Palaeozoic Dwyka tillite, Gevers (1931) interpreted the Chuos Formation as a glaciogenic deposit. Schermerhorn (1974, 1975) was the first to raise objections to the glacial origin for the mixtite based on regional considerations. Subsequent workers have provided evidence gathered over a wide area and from various tectonostratigraphic settings to both support (Hoffmann, 1983; Miller *et al.*, 1983; Henry *et al.*, 1986) and dispute (Miller *et al.*, 1983; Martin *et al.*, 1985) a glacial origin for the Chuos mixtite.

During the mapping of area 2115D, outcrops of the Chuos mixtite were studied at a number of localities around Karibib and Usakos (Fig. 1). The mixtite varies significantly between the different localities with respect to matrix composition, clast assemblage and interbedded sedimentary units. Detailed stratigraphic sections were measured on the farms Okawayo 46, Spes Bona 105, Krantzberg 59 and Navachab 58. Counts of clast type and size in the massive mixtites and detailed profiles of the iron formations were carried out for all measured sections. Plots of clast size vs bed thickness were constructed for the iron formations in order to establish a stratigraphy and source area for the Chuos mixtite in this area.

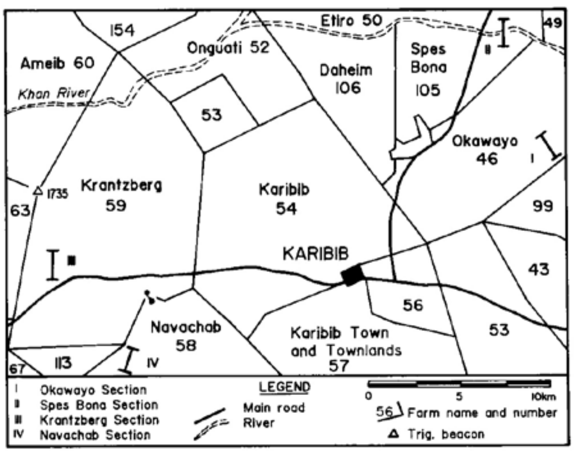

Fig. 1: Locality map of the study area with the position of the four measured sections on Okawayo 46, Spes Bona 105, Krantzberg 59 and Navachab 58.

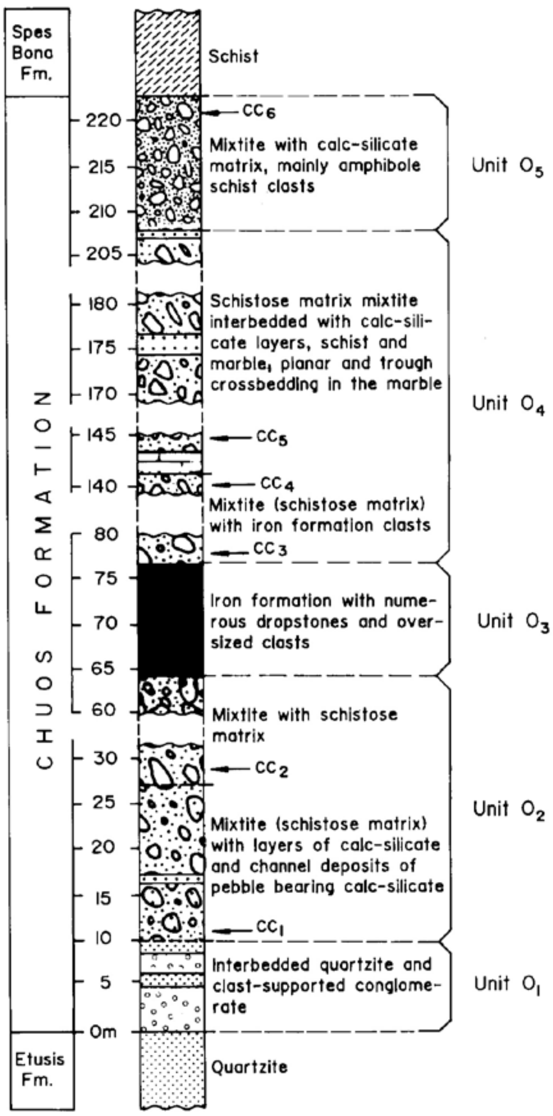

Fig. 2: A stratigraphic profile through the Chuos mixtite on Okawayo 46 showing the different lithological units into which it has been subdivided. The positions where clast counts were done are indicated by cc_1 to cc_6.

2. LITHOSTRATIGRAPHY OF THE MIXTITE

The mixtites are subdivided into different lithological units based on both matrix composition and well defined sedimentary units interbedded with the massive mixtite. In addition, clast counts were used to define these lithological units (Fig. 3), clast type and not size being the main criterion.

2.1 Okawayo section

Fig. 2 illustrates a detailed stratigraphic profile through the mixtite on Okawayo 46. The mixtite unit is underlain by Etusis Formation quartzite and overlain by schist of the Spes Bona Formation, previously referred to as the Lower Schist Unit of the Karibib Formation (Badenhorst, 1987). The section is measured through the northern limb of a D_2 anticline and a pervasive s_2 foliation is developed. The clasts in the mixtite are aligned parallel to the s_2 foliation.

2.1.1 Unit O_1

Unit O_1 represents the base of the mixtite unit which has a gradational contact with the quartzites of the Etusis Formation. This gradational contact zone is 9 m thick and consists of fine- to medium-grained, pink muscovite-rich quartzite and matrix-supported pebble conglomerate beds.

Matrix and clasts in the latter are of similar composition and also resemble the interbedded quartzites. Contacts are usually gradational.

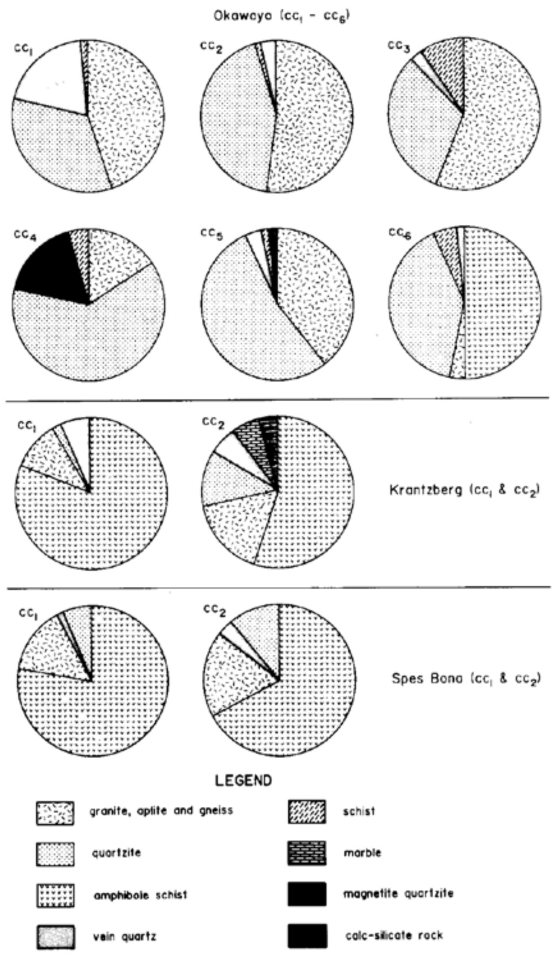

Fig. 3: The results of clast counts done in all four mixtite sections.

2.1.2 Unit O_2

Unit O_2 is about 55 m thick and consists of mixtite with a schistose matrix and interbedded, clast-free calc-silicate layers and lenses of up to 0,5 m in thickness. Individual layers are usually of uniform thickness but lenses are also present. Contacts are sharp and no sedimentary structures were observed. In addition, numerous massive calc-silicate matrix gravels are present (Fig. 4) with clasts being made up predominantly of granitic gneiss and quartzite (Fig. 3, cc_1), schist and vein quartz clasts only representing about 20 % of the population (Fig. 3, cc_1). The gravels are horizontally stratified and inversely graded.

2.1.3 Unit O_3

Unit O_3 is about 12 m thick and is predominantly made up of iron formation. Fig. 5 illustrates a detailed stratigraphic section through this unit which consists of centimetre thick layers of interbedded iron formation, schist, feldspathic quartzite and mixtite. The iron formation can be divided into two distinct rock types, a magnetite quartzite and a magnetite-bearing schist. The magnetite-bearing schist layers only occur interbedded with magnetite quartzite layers and commonly show an increase in magnetite content towards the base and top of the layers. The magnetite-bearing schist layers occasionally contain oversize clasts (Fig. 6), but apart from these the clasts are always restricted to the interbedded mixtite and schist layers and are not found in the magnetite quartzite (Fig. 5). The magnetite quartzite layers vary in thickness from a few millimetres to more than 10 cm and individual layers are laterally persistent for many tens of metres. Contacts are generally sharp and thin parallel laminations are present.

The mixtite and gritty layers often show inverse grad-

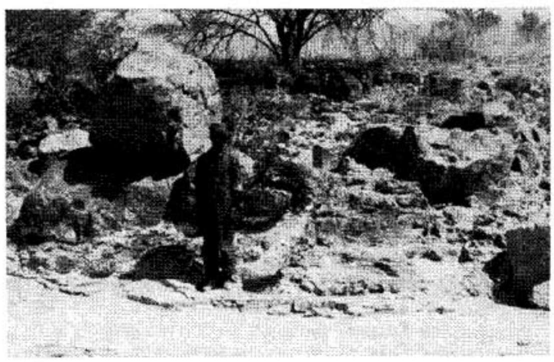

Fig. 4: Clast-bearing channel deposits with a calc-silicate matrix interbedded with mixtite with a schistose matrix.

ing (Fig. 7) and contain numerous oversize clasts (Figs 6 and 8) and dropstones (Fig. 9). Granite and quartzite make up more than 90 % of the clasts, although the percentage of clasts is much lower than in other units.

2.1.4 Unit O_4

Unit O_4 is about 130 m thick and consists of mixtite with a schistose matrix and interbedded clast-free calc-silicate layers 0,3 to 0,5 m thick, thin clast-free schist layers and a single 2 m thick marble layer. Granite and quartzite constitute about 85 % of the clast population

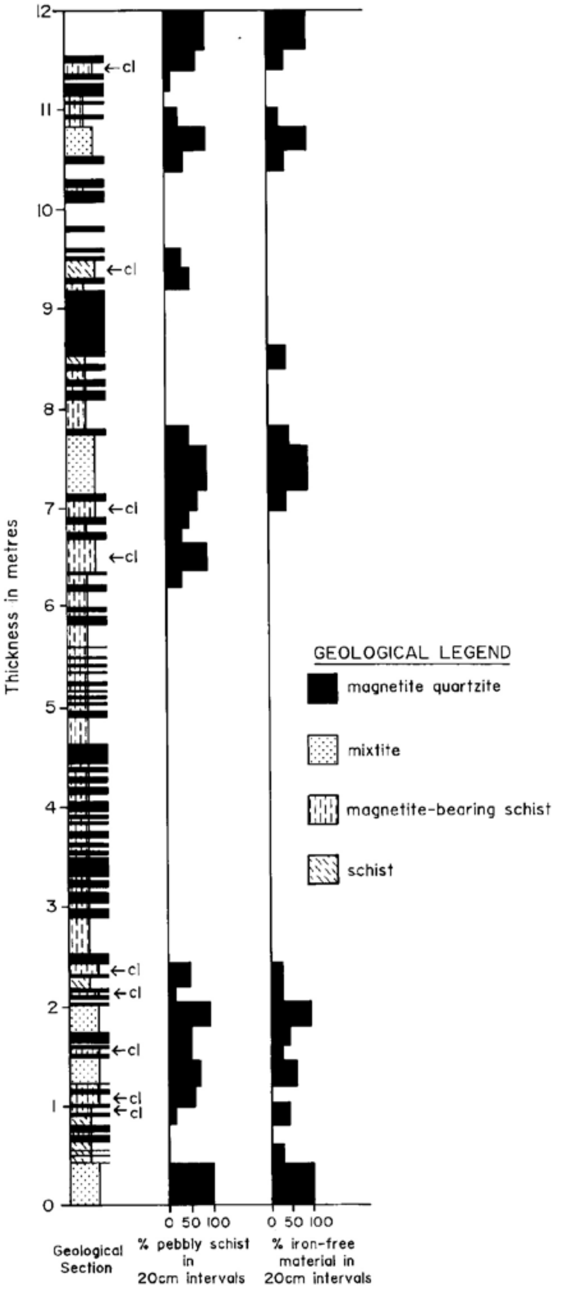

Fig. 5: A detailed stratigraphic profile of Unit O_3 in the Chuos mixtite on Okawayo 46. The position of clasts in the interbedded schist layers are indicated by cl. Also illustrated are plots (in 20 cm intervals) of percentage iron-free sedimentary layers and percentage clast-bearing layers.

with granite boulders reaching 2,5 x 2,5 x 1,5 m in size (Fig. 3, cc_5). The remainder of the clasts are made up of magnetite quartzite, schist, calc-silicate rock and vein quartz. The first appearance of iron formation clasts in the massive mixtite also occurs in this unit. Most of the iron formation clasts are tabular in shape and not well rounded.

The marble layer grades from a fine-grained white marble at the base to a medium-grained brownish ferruginous marble at the top. Cross-bedding with set heights of 0,4 m and trough cross-bedding (Fig. 10) are well preserved in the medium-grained part of this layer. The calc-silicate rock layers are fine- to medium-grained and contacts are generally sharp. Layers vary in thickness from a few millimetres to tens of centimetres and the thin layers are often interbedded with clast-free schist layers. No sedimentary structures were observed in this rock type.

2.1.5 Unit O_5

Unit O_5 follows directly above the uppermost calc-silicate layer of Unit O_4 and represents the top of the Chuos mixtite in this section. This unit consists of massive-mixtite only but may be separated from the other mixtites on the basis of matrix type and the occurrence of unique amphibole schist clasts which make up about 50 % of the clast population. Quartzite constitutes about 40 % of the clasts and schist, aplite and vein quartz make up the remainder (Fig. 3, cc_6). Rare small clasts of a green-white calc-silicate assemblage may represent altered marble clasts.

2.2 Spes Bona section

A stratigraphic profile through the mixtite deposit on Spes Bona 105 was measured through the southern limb of a D_2 anticline. A pervasive s_2 foliation is developed and the clasts are aligned parallel to this foliation. The base of the section is intruded by a granite and thus only part of the Chuos mixtite is exposed here (Fig. 11). The mixtite is overlain by schist of the Spes Bona Formation.

2.2.1 Unit s_1

This unit comprises massive mixtite which has a light green calc-silicate matrix and makes up about 60 % of the section. Amphibole schist constitutes about 70 % of all clasts (Fig. 3, cc_1 and cc_2) with granite, quartzite and vein quartz making up the remainder.

2.3 Krantzberg section

The Chuos Formation in the Krantzberg section is very thin compared with the other sections (Fig. 12) and a detailed profile was measured on the farm Krantzberg 59 on the southern limb of the same D_2 anticline as the

Spes Bona section. The Chuos mixtite is underlain by the Rossing Formation marble and overlain by schist of the Spes Bona Formation or marble of the Okawayo Formation, previously referred to as the Lower Marble Unit of the Karibib Formation (Badenhorst, 1987).

2.3.1 Unit K_1

Unit K_1 is about 30 m thick and consists of massive mixtite with a calc-silicate rock matrix and interbeds of dark grey schist. A wide variety of clast types are present with the amphibole schist clasts making up be-

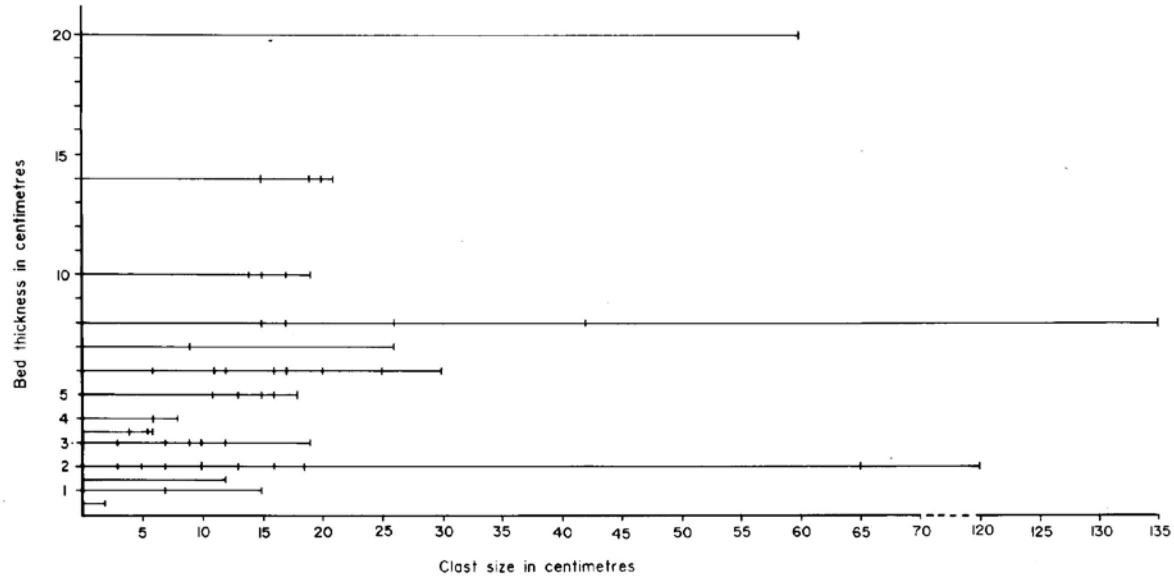

Fig. 6: Clast size *vs* bed thickness of oversize clasts in the iron formations on Okawayo and Krantzberg.

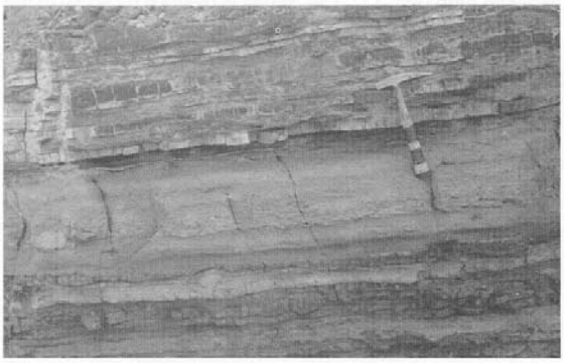

Fig. 7: Typical iron formation showing alternating layers of magnetite quartzite, schist and gritty schist. Note the inverse grading in the gritty layer.

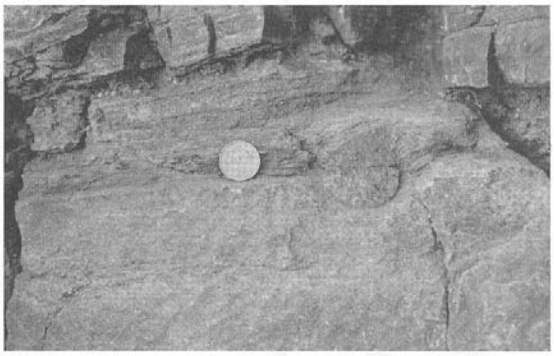

Fig. 9: A small faceted quartzite pebble (dropstone) embedded in a feldspar-bearing quartzite layer. Note how some of the muddy material (now schist) from the top layer has been pushed into the underlying quartzite layer.

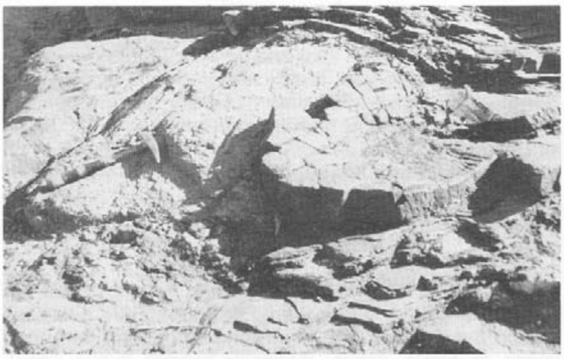

Fig. 8: A large granite clast (120 × 90 × 25 cm) interpreted as a dropstone in a 3 cm thick magnetite-bearing schist layer.

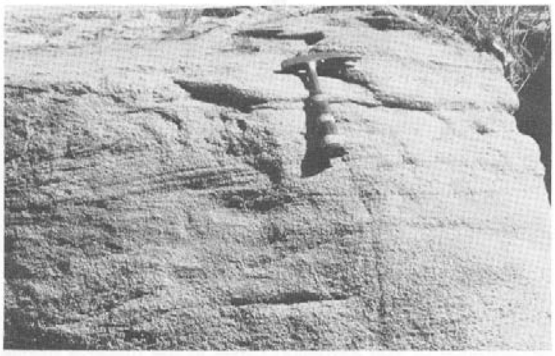

Fig. 10: Cross-bedding in a 2 m thick marble bed in the mixtite on Okawayo 46.

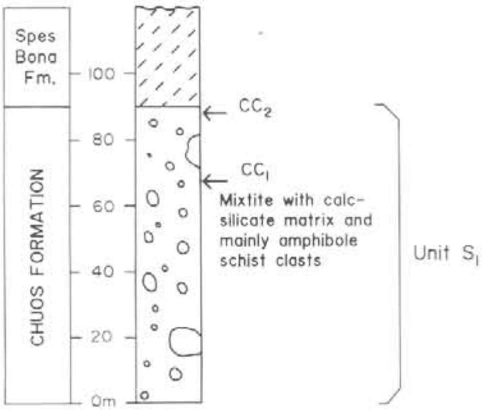

Fig. 11: A stratigraphic profile through the mixtite unit on Spes Bona 105. cc_1 and cc_2 indicate the position where clast counts were done.

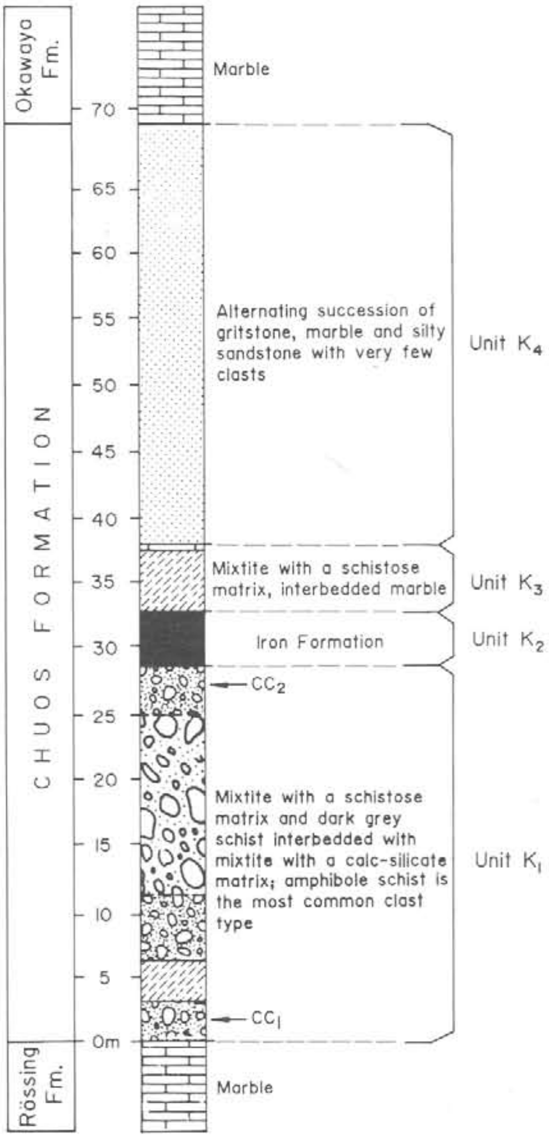

Fig. 12: A stratigraphic section through the mixtite unit on Krantzberg 59 showing the division into different lithological units and the localities where clast counts were done (cc_1 and cc_2).

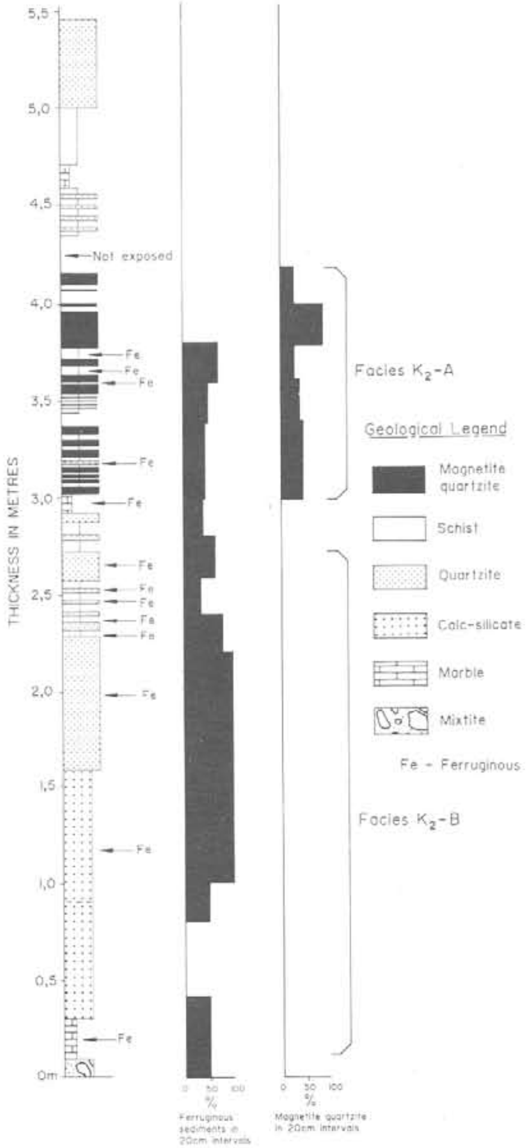

Fig. 13: A detailed stratigraphic profile through the iron formation in the mixtite on Krantzberg 59 showing the two facies of iron formation present.

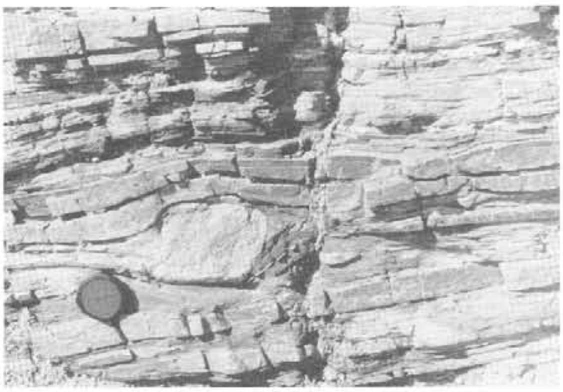

Fig. 14: An angular clast of red quartzite (10 × 10 cm) in a 2 cm thick magnetite-bearing schist layer interbedded with magnetite quartzite layers. Note the broken up appearance of the thin magnetite quartzite layer underneath the clast.

tween 50 and 80 % of all clasts (Fig. 3, cc_1 and cc_2). Granite, aplite, gneiss, vein quartz, marble and calc-silicate make up the remainder of the clasts. Marble clasts are unique to both this unit and section.

2.3.2 Unit K_2

This unit is only about 4 m thick and is made up predominantly of iron formation. Fig. 13 illustrates a detailed section through this unit which consists of centimetre thick layers of biotite schist, magnetite-bearing biotite schist, marble, gritty schist, whitish quartzite and magnetite quartzite. There are numerous oversize quartzite clasts in the biotite schist layers that are interpreted as dropstones (Fig. 14). The iron formation can be divided into two distinct types, the ferruginous sedimentary layers (Facies K_2-B) and the magnetite quartzite (Facies K_2-A). The iron deposition in Facies K_2-B is not restricted to any particular rock type but overprints biotite schist, marble, calc-silicate and quartzite and these are all interbedded with iron-free sedimentary layers. Facies K_2-A consists of interbedded magnetite quartzite, ferruginous sedimentary layers and iron-free layers. Clasts occur only in schist and magnetite-bearing schist in both facies.

2.3.3 Unit K_3

This unit is about 5 m thick and consist of schistose mixtite with poorly defined bedding and interbedded marble and gritstone layers. There are very few clasts in this unit and they are restricted to the schistose mixtite.

2.3.4 Unit K_4

This unit is about 40 m thick and displays a poorly defined and gradational boundary with Unit K_3. Unit K_4 consists of interbedded ferruginous gritstone, thin marble and clastbearing fine silty sandstone.

2.4 Navachab section

The Navachab section (Fig. 15) is a composite section which was measured on the western limb of a D_2 structure on the boundary between Navachab 58 and Mon Repos. The Chuos Formation is underlain by the Etusis Formation quartzite and overlain by schist of the Spes Bona Formation.

2.4.1 Unit N_1

Unit N_1 is about 10m thick and consists of mixtite with a dark grey biotite schist matrix with small (≤ 1 cm) white and pink muscovite quartzite clasts. Some of these clasts show a concentric internal structure which suggests that they may be metamorphosed pseudomorphs of early evaporitic crystals (Fig. 16). Elsewhere these clasts have an irregular form and appear to have disrupted and deformed bedding. A few large granitic clasts were also observed. The contact between this unit and unit N_2 is poorly defined.

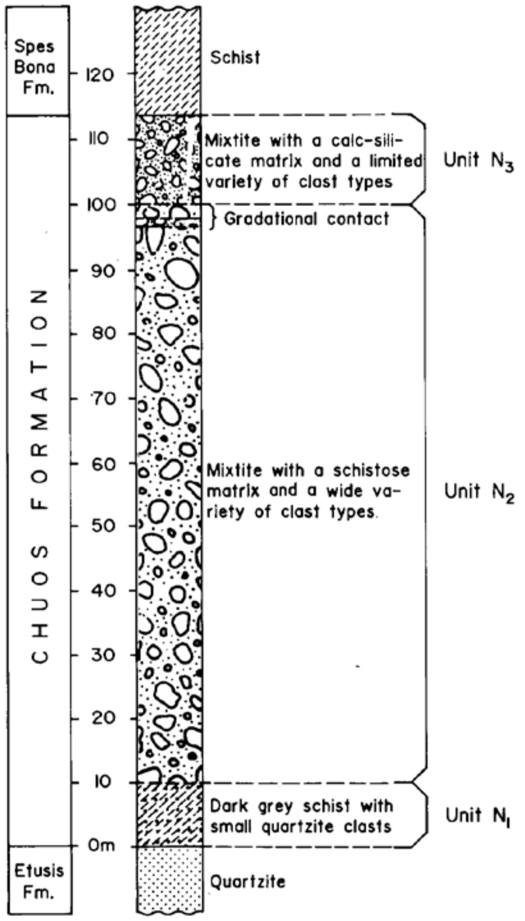

Fig. 15: A stratigraphic section through the Chuos mixtite on Navachab 58 showing the different facies of the mixtite unit.

2.4.2 Unit N_2

This unit is about 90 m thick and consists of a mixtite with a light grey schistose matrix and a wide variety of clast types. The contact between this unit and Unit N_3

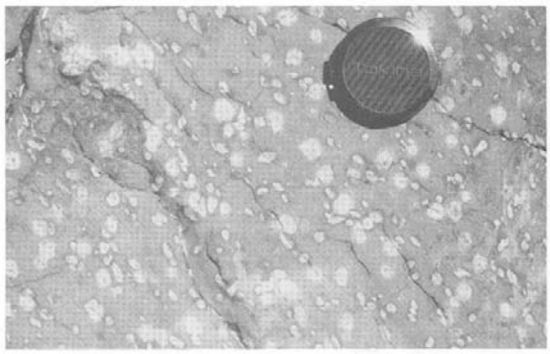

Fig. 16: Dark grey schist with small clasts of pink and white muscovite quartzite at the base of the mixtite unit on Navachab 58.

Fig. 17: Mixtite with a light green calc-silicate matrix and abundant clasts of white aplite at the top of the mixtite unit on Navachab 58.

is gradational and layers of Unit N_3-type mixtite occur in the top 10m of this unit. These layers of Unit N_3-type mixtite show inverse grading.

2.4.3 Unit N_3

Unit N_3 is about 15 m thick and comprises mixtite with a green calc-silicate matrix and a limited clast variety. The most common clast types are medium-grained leucocratic gneiss and white aplite with very few calc-silicate and schist clasts (Fig. 17). This lithological unit of the mixtite was named the Kubas Formation by Brandt (1985), and De Kock (1984) speculated that this rock type could be volcanic in origin.

3. CORRELATION OF LITHOSTRATIGRAPHIC UNITS

Although an intraformational stratigraphy could be established for the four measured sections, correlation between sections is difficult at this stage because of the wide lithological variation in the study area. The main similarity between the two southern sections (Okawayo and Navachab) is that they both grade from a schistose matrix at the base to a calc-silicate matrix towards the top. The stratigraphic units above and below the mixtite units in these two sections are also very similar.

In the Krantzberg section, the mixtite has a calc-silicate matrix at the base and is schistose above the iron formation. The only similarity between the two northern sections (Spes Bona and Krantzberg) is that clasts of amphibole schist are common to both, whereas the only similarity between the northern sections and the Okawayo section is the presence of amphibole schist clasts associated with the calc-silicate matrix unit. If the above criteria are used as a basis for correlation, then the mixtites to the north correlate with the top unit of the mixtites in the south. The schistose matrix unit of the southern sections possibly never developed towards the north or was subsequently eroded. A major problem with this correlation is the relative stratigraphic position of the iron formations in the southern and northern sections. In the Krantzberg section the iron formation is above the calc-silicate matrix unit, but in the Okawayo section it is well below the calc-silicate matrix unit which contains the amphibole schist clasts.

Further correlation can only be attempted once more detailed information exists on the following aspects:

(a) The stratigraphy of the Chuos mixtite deposits to the immediate south of the study area and the distribution of the various lithological units.

(b) The distribution and lithological associations of the schistose units above and below the mixtite deposits.

(c) The spatial and stratigraphic distribution of the metavolcanic succession in the sequence and its association, if any, with the iron formations.

4. SOME THOUGHTS ON THE ORIGIN OF THE MIXTITE DEPOSITS

Martin *et al.* (1985) used the palaeogeographical configuration of the Chuos Formation as a strong argument against its speculated glacial origin. They argued that if the marine depository in the Central Zone had been fringed in the Northern Zone and the southern Central Zone (sCZ) by shelves on which glacial and glaciomarine deposition occurred, then dropstones should be present in the intervening part of the basin as well, i.e. the northern Central Zone (nCZ). This is, however, not the case, but their argument is based on the correlation of two marble horizons in the nCZ with the Rossing and Karibib Formations in the sCZ. The interbedded schist and calc-silicate rock unit was assumed by Martin *et al.* (1985) to be equivalent to the Chuos Formation, but this correlation is incorrect and does not exclude the presence of dropstone-bearing Chuos mixtites in the nCZ (Badenhorst, 1987).

Ice rafting is indicated by dropstones in all the sections where iron formations were deposited as well as the large exotic clasts in the thin interbedded mixtites. The very good correlation between clast-bearing layers and iron-free sediments in the iron formation on Okawayo (Fig. 5) suggests glacial influence since the clast-free iron formation could be the result of very cold periods when no icebergs formed and suitable Eh and pH conditions existed for iron and silica to precipitate from iron-rich sea water (Yeo, 1978). In a rifting environment, iron-rich sea water could form at spreading centres and drift with bottom currents to the shelf edge (Yeo, 1978). A possible explanation for the evaporite-type minerals at the base of the Navachab section is that they formed as a result of the concentration of solutes by freezing of a large volume of sea water (Young, 1976).

If we assume a glacial origin for the iron formations, then at least part of the massive mixtite must also be glacial in origin. This assumption is supported by inversely graded calc-silicate matrix mixtites at the base of the Okawayo section which may represent channel gravels that accumulated in steep-sided channels in a submarine ice-contact fan. The bulk of the massive mixtite must, however, have been reworked since iron formation clasts only occur in the mixtite above the layered iron formations in the Okawayo section. The many interbedded calc-silicate, schist and even cross-bedded marble layers in the mixtite also indicate either reworking of glacial deposits or mass flow deposits. Marble clasts do, however, only occur in the Krantzberg section, the only section where there is a major marble unit below the mixtite, and consequently favour a mass flow process.

In conclusion, I consider the most likely origin for the mixtite deposit to be glaciomarine, where moraine till was reworked in a submarine environment during warmer intervals and also moved deeper into the basin by mass flow processes.

5. ACKNOWLEDGEMENTS

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