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A. PAPERS BY THE GEOLOGICAL SURVEY

LITHOSTRATIGRAPHY OF THE DAMARA SEQUENCE IN THE OMARURU AREA OF THE NORTHERN CENTRAL ZONE OF THE DAMARA OROGEN AND A PROPOSED CORRELATION ACROSS THE OMARURU LINEAMENT

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ABSTRACT

A major revision of the presently accepted lithostratigraphic classification of the Swakop Group in the northern Central Zone is presented. The Lower Schist Unit, the Lower Marble Unit, the Upper Schist Unit and the Upper Marble Unit north of the Omaruru Lineament were previously correlated with the Khan Formation, the Rössing Formation, the Chuos Formation and the Karibib Formation respectively. The present investigation shows that the stratigraphic sequence in the northern Central Zone, from the exposed base of the Lower Schist Unit to the top of the Upper Marble Unit, is a stratigraphic unit above the Chuos Formation and thus a facies equivalent of the Karibib Formation. This correlation is based on the assumption that a similar stratigraphic sequence is found above the Chuos mixtite in the southern Central Zone. The suitability of the Chuos mixtite as a chronostratigraphic marker horizon is also discussed.

1. INTRODUCTION

Detailed mapping during the past five years has been aimed at resolving the stratigraphic and structural relationships in the northern parts of the Central Zone. The work has yielded important new information on the lithostratigraphy of the Swakop Group and more specifically of the Karibib Formation. As a result, a major revision of the presently accepted lithostratigraphic classification of the Swakop Group in the northern Central Zone (nCZ), as formally set out by Miller (1983), has become necessary. The purpose of this paper is, therefore, to present a brief account of the lithology of the stratigraphic units in the northern parts of the Central Zone and to propose a revised correlation of stratigraphic units across the Omaruru Lineament. In addition, it includes an outline of facies changes and related tectonostratigraphic subdivisions in the northern Central Zone (nCZ).

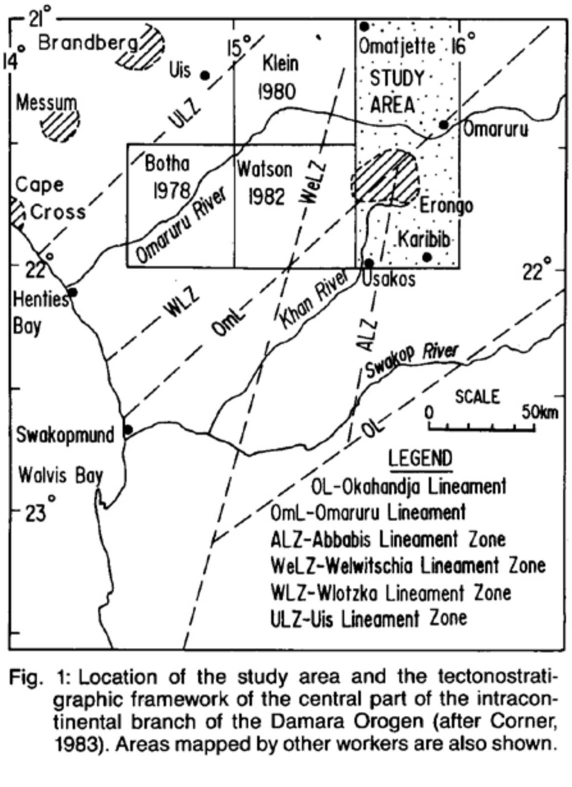

Fig. 1: Location of the study area and the tectonostratigraphic framework of the central part of the intracontinental branch of the Damara Orogen (after Corner, 1983). Areas mapped by other workers are also shown.

The area investigated extends from Omatjette in the north to Karibib and Usakos in the south (Fig. 1). Adjoining areas were mapped by Swart (1986) to the north, Klein (1980) to the west, and Watson (1982) to the south-west. Mapping in the same tectonostratigraphic zone was also carried out by Botha (1978) and Brandt (1985) to the far south-west.

Although the new stratigraphic classification and correlation of the Karibib Formation outlined below is based mainly on observations in the study area, use is also made of reinterpretation and additional mapping in the surrounding areas.

At this preliminary stage, no new formal stratigraphic terms are proposed, as work to date has largely been concentrated on synthesising the lithologic framework across the basin. The formal stratigraphy can be revised once a regional framework has been established. Meanwhile, informal terms have been used as a temporary means of identifying and correlating lithologic units and these will simply be referred to as the Lower Schist Unit (LSU), the Lower Marble Unit (LMU), the Upper Schist Unit (USU), the Upper Marble Unit (UMU) and the Kuiseb Formation (KuFm) at the top.

2. TECTONOSTRATIGRAPHIC FRAMEWORK OF THE STUDY AREA

Fig. 2 shows a preliminary subdivision of the study area and adjoining areas in the nCZ into tectonostratigraphic zones. This subdivision is based on differences in stratigraphy, structure, grade of metamorphism, intrusive age of plutonic rocks (Badenhorst, 1986), and also on aeromagnetic and gravity characteristics. From south to north these subzones are simply referred to as nCZ-a, nCZ-b, nCZ-c, nCZ-d, nCZ-e and nCZ-f. Boundaries between subzones form major linear features and are either faults, stratigraphic boundaries, or combinations of these.

The distinctive features of nCZ-a and nCZ-e are that only the higher levels of the Kuiseb Formation crop out, only two phases of deformation are recognised and their metamorphic grade is lower. These two subzones are only intruded by granitoids of the Kawab Igneous Association (Badenhorst, 1986) and the Omaruru granite (in nCZ-a only). In nCZ-b the UMU consists of three thin marble horizons interbedded with schist. Here marble domes are intruded by large volumes of granite. nCZ-c is characterised by pronounced thickness changes in the UMU and the upper member of this unit is not very well developed and the lower member is absent. nCZ-d marks the appearance of the lower member of the UMU and the upper member of this unit is very well developed. The Epako calc-silicate and associated meta-evaporites are only developed in the north-east of this subzone. This subzone is also characterised by large volumes of granite in the dome structures.

3. LITHOSTRATIGRAPHY

The lithostratigraphy of the nCZ is described here, but for the purpose of correlation, a short description of a single section in the southern Central Zone (sCZ) on Okawayo 146 is also included.

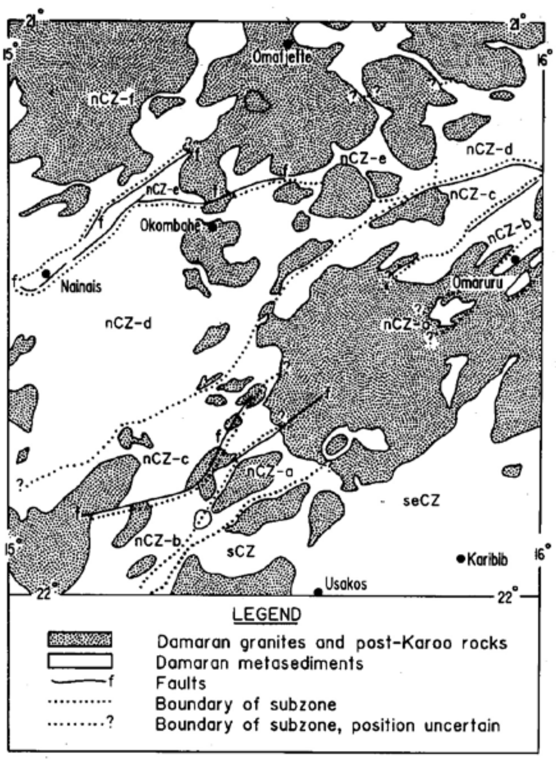

Fig. 2: A preliminary tectonostratigraphic subdivision of the study area and adjoining areas, adapted from Watson (1982).

3.1 Lithostratigraphy of the nCZ

3.1.1 Lower Schist Unit (LSU)

This unit reaches a maximum thickness of 2 500 m. The lower boundary of the unit is not exposed; the upper boundary is at the base of the first pronounced marble horizon.

The LSU consists of graded rhythmites of calc-silicate, metagraywacke and schist which vary from a few centimetres to several metres in thickness. The calc-silicate layers become thinner and less abundant from the exposed base upwards. In general, contacts of thin layers are sharp and those of the thicker calc-silicate layers are gradational. Planar crossbedding and ripple marks are found at many outcrops. The calc-silicate rocks consist of quartz, plagioclase and diopside, with minor amounts of biotite and zircon. The schists consist primarily of quartz, plagioclase and biotite but commonly contain small quantities of diopside.

3.1.2. Lower Marble Unit (LMU)

This unit reaches a maximum thickness of 40 m and the lower and upper boundaries are marked by the appearance and disappearance respectively of the marble horizons.

The LMU can be divided into two separate, but laterally interfingering facies. The first facies is schist-dominated (80 per cent schist, 10 per cent marble and 10 per cent calc-silicate) and the second is marble-dominated (70 per cent marble, 20 per cent schist and 10 per cent calc-silicate). Klein (1980) defined a third facies to the west of the study area where calc-silicate is the dominant rock type but this facies was not observed in the study area. These facies interfinger laterally and therefore their distribution and extent is not well known. On Tjirundu Süd 149 it appears as if the unit is connected with the UMU but this is difficult to verify because of poor outcrop and intense faulting in the area. This possibility was also raised by Watson (1982) in Area 2115c to the south-west.

3.1.3 Upper Schist Unit (USU)

This unit reaches a maximum thickness of 1 000 m. The lower boundary lies just above the uppermost marble layer of the LMU and the upper one just below the lowest marble layer of the UMU.

Quartz-biotite schist and quartz-biotite-plagioclase-diopside schist are the dominant rock types. In the upper portion of the unit, some layers of schist contain accessory cordierite and garnet. Ripple marks, rip-up clasts and loadcasts are commonly found in the schists.

Although schist is the dominant rock type in the unit, other interesting horizons are also present. A few well rounded pebbles and cobbles of calc-silicate ware found in the schists and these are associated with sand-filled channel bodies, even though the pebbles occur outside the channel bodies. Observations on similar pebbles in fold closures of the Kuiseb Formation schists suggest that they could be pseudo-pebbles that formed by shearing and rounding off of a calc-silicate layer in a soft schist matrix. There are also a few iron-rich brecciated quartzite layers in close association with the above mentioned rock types.

The calc-silicate forms thin layers and lenses interbedded in the schist, and is concentrated in the top and bottom portions of the unit. Individual layers are between 1 and 30 cm thick. The most important horizon is the Epako calc-silicate layer, which is 5 to 20 m thick, characterised by stacked climbing ripple laminations, wave ripple laminations and trough crossbedding. Several stromatolites and oncoliths are known from this layer. Evidence for soft sediment deformation was also found, such as convolute laminations, chevron folds in the foresets of crossbeds, flame structures and vertically linked diopside rich layers. Above the Epako calc-silicate layer, a few lenses, several metres in length and consisting of scapolite intergrown with sphene and diopside, were noted. Such rocks occurring elsewhere in the nCZ were believed to be of evaporitic origin (Watson, 1982).

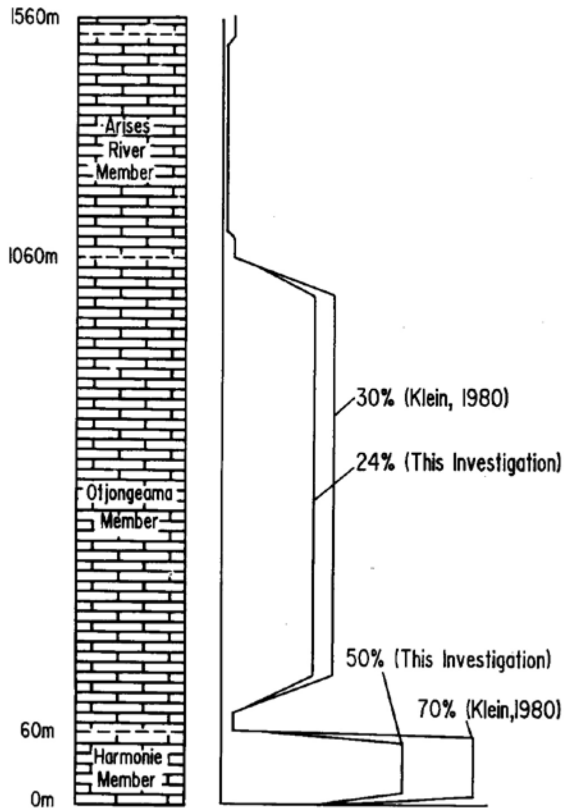

Fig. 3: A schematic profile showing the amount of calcsilicate in the various members of the Upper Marble Unit. Profiles are compiled from data by Klein (1980), and the present investigation. Note the break in calc-silicate sedimentation which defines the boundaries between the three members.

3.1.4 Upper Marble Unit (UMU)

This unit is characterised by a decrease of the pelitic and fine clastic sediment fraction from the base upwards. The boundaries between the three members into which the unit is subdivided mark a break in this trend (Fig. 3). These units were defined by Klein (1980), whose nomenclature is retained because it is generally accepted and used in the present Damara literature, e.g. Miller (1983) and Swart (1986). From bottom to top, these are the Harmonie Member, the Otjongeama Member and the Arises River Member.

The *Harmonie (or C) Member* in the study area is a calc-silicate dominated unit with about 50 per cent calc-silicate, 40 to 45 per cent calcitic marble and 5 to 10 per cent schist. This member reaches a maximum thickness of 60 m in the study area. The lower boundary coincides with that of the first marble horizon following upon the USU. Individual calc-silicate layers are commonly between 3 and 5 m thick and occasionally show crossbedding, while individual marble beds only reach a thickness of 1,5 m. Composition of the calc-silicate and schist is the same as in the USU. The marble of this member resembles that of the Otjongeama rather than the Arises River type.

The marble-dominated *Otjongeama (or B) Member* as a maximum thickness of 1 000 m, but the absence of a marker horizon makes it difficult to decide if this is the result of tectonic thickening. The member consists of 75 per cent calcitic marble and 25 per cent calc-silicate with occasional biotite schist layers. The calc-silicate layers were deposited in cyclic units 0,5 to 2 m thick, and these cycles thicken upwards. These cycles are defined by a decrease of calc-silicate from the base upwards. Some stromatolites were seen in this member. The composition of the calc-silicate is the same as that of the Harmonie Member. The medium-grained calcitic marble contains a few per cent diopside, and biotite is rarely seen as an accessory.

The *Arises River (or A) Member* does not contain any calc-silicate except for a few thin layers in the upper 20 m of the member. The member reaches a maximum thickness of 500 m. The upper boundary of the member is the top of the marble band below the first schist or quartzite layer of the overlying formation. Sedimentary breccias and chert layers and lenses were found at a few localities. The calcitic marble is very coarse-grained and accessory minerals such as graphite, muscovite, chondrodite and diopside are found.

3.1.5 Kuiseb Formation

Although this formation is lithologically very complex, distinction will only be made between the upper more quartzitic and phyllitic unit and the lower schistose unit. The boundary between these two horizons is generally not well defined but is usually a fault or, as in the study area, a horizon of tourmaline schists marks the base of the upper unit. The metamorphic indicator minerals can also be used to decide where the boundary lies; the upper unit has a lower metamorphic grade and is characterised by cordierite and sillimanite and the lower unit by garnet. There is nowhere a complete section through the formation but it is known to have a minimum thicknes of between 3 000 and 5 000 m. The lower boundary of the formation is at the base of the first schist horizon above the Arises River marble. This means that a few Further thin marble layers are included in the lower Kuiseb Formation.

The schists interbedded with the Arises River marble are quartz-biotite schist, quartz-biotite-feldspar schist and biotite-cordierite schist. Quartzite layers rich in sulphides and iron oxides, are interbedded in the marble. Similar schists are found above the marble horizons. The feldspathic schists contain porphyroblastic plagioclase and alkali feldspar in the matrix. Partial melting of the schist has been observed in the vicinity of large granite plutons.

The higher stratigraphic levels of the formation (informally called the Uis Formation by Klein, 1980) are confined to the Sandamap and Omaruru tin belts. The maximum thickness of these upper stratigraphic levels is 2000 m. The most common rock types are quartz-biotite-muscovite phyllite ± cordierite ± sillimanite. Quartzite layers occur at lower levels of the unit. These layers have thin, graded beds which are laterally persistent on outcrop scale. The tourmaline schist is composed of thin, (1 cm) graded sequences with rip-up clasts. Scheelite, malachite, chalcocite, chalcopyrite and pyrite are common in these rocks. The unit is believed to be a turbiditic sequence, containing tourmaline-bearing rocks of exhalative origin (Baden horst, 1986b).

3.2 Okawayo Section

Fig. 4 shows a stratigraphic section measured on the farm Okawayo 146 in the Karibib District.

The *Etusis Formation* consists mainly of a light pink to white quartzite, in which sedimentary structures are rarely preserved. The succession was intruded by a red medium-grained granite, and the base is therefore not exposed. The upper boundary of the formation is gradational and consists of interbedded muscovite quartzite and matrix supported conglomerate beds where the cobbles and matrix are similar in composition.

The *Khan Formation* in this section is not well-defined but is present as metre thick lenses of calc-silicate and calc-silicate filled channel deposits containing gravel size clasts. These deposits occur near the base of the Chuos Formation and are interbedded with mixtite. A few hundred metres to the west the formation

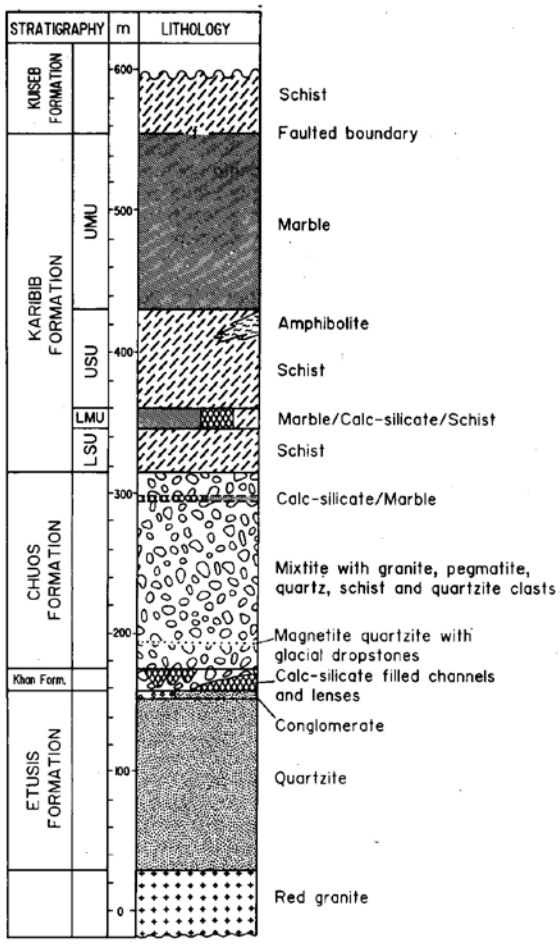

Fig. 4: A simplified stratigraphic column of the Damara Sequence on Okawayo 146 (Karibib District) in the sCZ. The subdivision of the Karibib Formation is explained in section 1, paragraph 4.

consists of well-bedded calc-silicate layers interbedded with Etusis quartzite and conglomerate layers.

The *Chuos Formation* consists mainly of a matrix-supported mixtite with schist, quartzite, granite and pegmatite clasts in a greenish calc-silicate bearing schist. All the clasts except the granite and pegmatite seem to be intrabasinal. In the lower third of the formation a 3 to 5 m thick unit of interbedded mixtite and magnetite-rich quartzite occurs. A few pebbles which are possibly dropstones, were noted. Some of the clasts show poorly-developed striations. Towards the top of the formation several metre thick layers of calcsilicate and marble are interbedded.

The *Lower Schist Unit (LSU)* in this section is only 50 m thick. The layers are graded and are 1 to 2 cm in thickness. The more typical lithotypes of the Lower Schist Unit are developed in a corresponding stratigraphic position 10 km to the north on Spes Bona 105.

The *Lower Marble Unit (LMU)* consist of thinly layered white and gray marble containing pyrite cubes up to 0,5 cm across. The lower 5 m of the unit is free of calc-silicate, but upwards more interbedded calc-silicate occurs.

The *Upper Schist Unit (USU)* is a monotonous succession of dark gray schist. The abundance of interbedded calc-silicate layers increases towards the top of the unit. In the upper 30 m of the unit a horizon of medium- to fine-grained ortho-amphibolite occurs. Marble and calc-silicate xenoliths are present in this rock type, as are pillow structures.

The *Upper Marble Unit (UMU)* resembles the Arises River type marble but the rocks are finer-grained and different accessory minerals are present. The upper few metres of the unit has large quantities of tremolite and fine sugary quartz.

The boundary between the UMU and the *Kuiseb Formation* is faulted in this section. However in the Spes Bona section 10 km to the north, this boundary consists of interbedded schist and marble. This transitional zone can reach up to 800 m in thickness.

4. STRATIGRAPHIC CORRELATION ACROSS THE OMARURU LINEAMENT

The Chuos Formation, or Chuos tillite, as first described by Gevers (1931), has been widely used as a stratigraphic marker horizon throughout the Damara Orogen. Because of the apparent absence of the Chuos mixtite in the nCZ, correlation was a major problem. Klein (1980) subdivided the Damara sequence in the northern parts of the Central Zone in accordance with the Damara stratigraphy established in the Khan-Swakop Area (Smith, 1965). Klein (1980) based his correlation on similarities in the bulk stratigraphic column, for example the presence of two marble units, which in the present report are referred to as the Upper and Lower Marble Units. The UMU was correlated with the Karibib Formation and the LMU with the Rössing Formation (Fig. 5). The calc-silicate rich LSU was correlated with the Khan Formation and the USU was interpreted as being a facies equivalent of the Chuos Formation mixtites (Fig. 5). Miller (1983), Porada (1985) and Martin *et al.* (1985) adopted this correlation in their interpretation of the development of the Damara basin. Other workers such as Watson (1982), Brandt (1985) and Botha (1978) grouped the LSU, the LMU and the USU together and called it the Oberwasser Formation, maintaining that there is no stratigraphic equivalent in the Khan-Swakop area (Fig. 5).

<table>
<tr><th>nCZ
STRATIGRAPHY</th><th>Klein, 1980
Miller, 1983</th><th>Watson, 1982
Brandt, 1985</th><th>This
Paper</th></tr>
<tr><td>Kuiseb Fm.</td><td>Kuiseb Fm.</td><td>Kuiseb Fm.</td><td>Kuiseb Fm.</td></tr>
<tr><td>UMU</td><td>Karibib Fm.</td><td>Karibib Fm.</td><td rowspan="4">Karibib Fm.</td></tr>
<tr><td>USU</td><td>Chuos Fm.</td><td rowspan="3">Oberwasser Fm.</td></tr>
<tr><td>LMU</td><td>Rössing Fm.</td></tr>
<tr><td>LSU</td><td>Khan Fm.</td></tr>
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Fig. 5: Correlation of stratigraphic units in the nCZ with those defined by previous workers in the sCZ. Abbreviations of the stratigraphic subdivision are explained in section 1, paragraph 4.

The present investigation has shown that the whole stratigraphic sequence from the exposed base of the LSU to the top of the UMU in the nCZ is a stratigraphic unit above the Chuos Formation and thus a facies equivalent of the Karibib Formation. The correlation is proposed under the assumption that a similar stratigraphic sequence is found above the Chuos mixtite in the sCZ on Okawayo 146 (Fig. 6). In this section both the LMU and the UMU occur above the Chuos mixtites, and thus the LMU cannot be a stratigraphic equivalent of the Rössing Formation. This suggests that the Chuos mixtites are not in fact absent in the nCZ, but do not crop out. This is to some extent confirmed in Area 2114C (Tsaun) where there is a small outcrop of a pebbly schist below the LMU (Diehl, pers. comm., 1987).

Apart from the use of the bulk stratigraphic column and the mixtite for correlation across the Omaruru Lineament, the boundary between the Arises River Member and the Otjongeama Member of the UMU and the Arises River Member itself were found to be useful markers on a limited scale in the nCZ.

The correlation of facies equivalent units relies heavily on the suitability of the Chuos mixtite as a chronostratigraphic marker horizon, which has been questioned by several workers (Martin *et al.*, 1985; Schermerhorn, 1974). They argue that the mixtite is not of glacial origin but is rather a mass flow deposit. However, Henry (1986) has recorded the occurrence of a dropstone in iron formations interbedded in Chuos mixtite on the farm Valencia 122. Similar features have been observed in the iron formation interbedded with the Chuos mixtite in the Okawayo section. The origin of the Chuos mixtite is not discussed here, but it's reliability as a chronostratigraphic marker is, however, questioned. Henry (1986) provided convincing evidence for the assumption that the Chuos mixtites in the Khan-Swakop area are reworked glacial sediments laid down on an unstable slope of a tectonically-active basin margin. Martin *et al.* (1985) speculated that the unstable conditions prevailing on the shelf on which the mixtites accumulated might have resulted from the effects of glacial conditions elsewhere, so that, although not deposited by ice, the mixtites would still have originated during a worldwide cold period. This therefore implies a roughly coeval deposition of all mixtite deposits in the Southern Zone and the Central Zone of the Damara Orogen.

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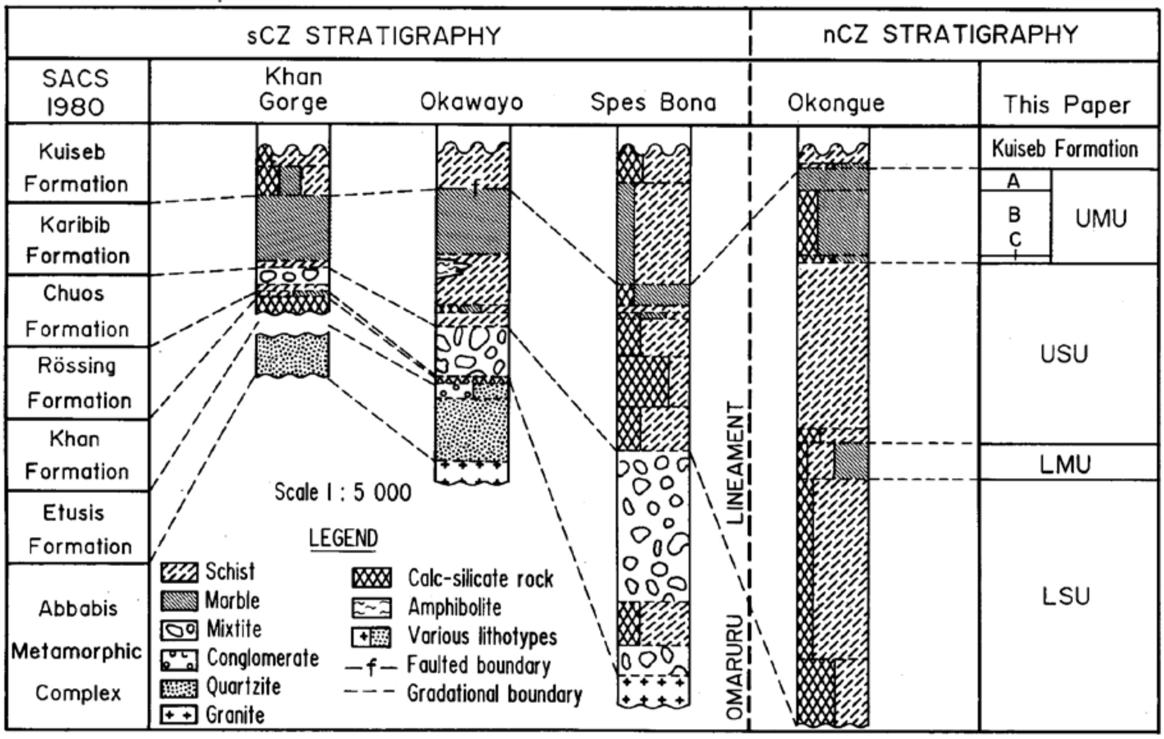

Fig. 6: Simplified stratigraphic columns showing the present stratigraphic correlation across the Omaruru Lineament. The Khan Gorge profile is included as a type section for the sCZ stratigraphy as defined by SACS (1980).

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