
New aspects of lithostratigraphic subdivision and correlation of late Proterozoic to early Cambrian rocks of the southern Damara Belt and their correlation with the central and northern Damara Belt and the Gariep Belt

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Results from stratigraphic studies in the southern Damara Belt allow detailed correlations between the metamorphic Damara Sequence of the internal Hakos Terrane, and low-grade to non-metamorphic units of the external Naukluft Nappe Complex and foreland succession. The oldest units comprise the Bitterwater, Doornpoort, Klein Aub and Eskadron Formations which were previously included in the pre-Damara Sinclair Sequence, but are now grouped into a new major, lowermost division of the Damara Sequence, the Tsumis Group. They are followed by the Nosib Group, which forms the base of the Damara Sequence elsewhere in the Damara Belt. Metamorphic units of the Kudis and Vaalgras Subgroups (Hakos Group) are shown to represent deep-water facies equivalents of dominantly shallow-water marine carbonate-bearing units of the Naukluft Nappe Complex, the Court and Buschmannsklippe Formations of the new Witvlei Group (Hegenberger, in prep.), and the lower Nama Kuibis Subgroup. Two discrete glaciogenic units, represented by the older Blaubecker Formation and the younger Naos and Blasskrans Formations, are recognized. Stratigraphic evidence from the Gariep Belt indicates correlation of the basal Stinkfontein Group with the Nosib Group and of the overlying Hilda Subgroup and the Holgat Formation with the Kudis Subgroup-Court Formation and the lower Vaalgras Subgroup-Buschmannsklippe Formation and their stratigraphic equivalents in the Naukluft Nappe Complex, respectively. The lower Kaigas Formation tillite occurs in a stratigraphic position corresponding to that of the Blaubecker tillite, while the upper Numees Formation is shown to be a correlate of the Naos and Blasskrans Formations. Correlations between the southern Damara Belt and the central and northern Damara Belt indicate that the Kudis Subgroup and Court Formation are to be correlated with the Khomas Subgroup, comprising the Karibib Formation, the Tinkas Formation, and the older, pre-tectonic parts of the Kuiseb Formation in the Swakop and northern Khomas Terranes, and the Tsumeb Subgroup of the northern foreland and Owambo Basin. The Blaubecker Formation tillite thus corresponds to the Chuos Formation, while the Naos Formation, which has been traditionally equated with the Chuos Formation, is believed to be much younger and to correspond to the regional unconformity which separates the Tsumeb Subgroup from the overlying Mulden Group. Accordingly, it is suggested that the latter is stratigraphically equivalent to the Vaalgras Subgroup and Buschmannsklippe Formation of the upper Witvlei Group and, probably, also the Kuibis Subgroup of the lower Nama Group. Stratigraphic equivalents of these units in the central metamorphic zones of the Damara Belt are believed to be the younger, syn-tectonic parts of the Kuiseb Formation of the Khomas Terrane.

Introduction

The Damara Sequence of the southern Damara thrust belt and adjoining foreland (Fig. 1) is a several thousand metres thick succession of mainly sedimentary and minor volcanic rocks deposited during late Proterozoic to early Cambrian times on the former rifted continental margin of the Kalahari Craton. Slow progress in recognizing the scale and magnitude of thrusting and nappe displacement in the internal metamorphic parts of the belt, coupled with a lack of biostratigraphic and radiometric age constraints, has hindered progress towards resolving problems of correlation between the metamorphic parts of the sequence of the internal zones and the low-grade to essentially non-metamorphic rocks of the external foreland sequence. This is reflected in the persistent uncertainties concerning the relative age and correlation of the local Buschmannsklippe Formation and associated units of the Witvlei-Gobabis area (Martin, 1965), the relationship of the Nama Group to the metamorphic Damara Sequence (Martin, 1965; SACS, 1980; Martin, 1983; Miller, 1983; Porada, 1983, 1985) and the problems of correlation of rocks of the Naukluft Nappe Complex with either parts or all of the metamorphic Damara Sequence or the Nama Group (Korn and Martin, 1959; Martin 1974; Hartnady, 1978; Münch, 1976; Martin *et al.*, 1983).

This paper presents preliminary results from regional stratigraphic studies which have now led to new

insights into problems of correlation in the southern Damara Belt. These are furthermore used to propose a first direct lithostratigraphic correlation with the Gariep Sequence of the Gariep Belt and to present a major re-interpretation of existing lithostratigraphic correlations with the Damara Sequence of the central and northern Damara Belt.

Lithostratigraphy and correlation in the southern Damara Belt

Lithostratigraphic subdivision and correlation of late Proterozoic to early Cambrian rocks of the southern Damara thrust belt and foreland included here in the Damara Sequence are shown in Fig. 2. Column one shows the restored succession of the allochthonous Damara Sequence comprising metamorphic rocks of the Nosib and Hakos Groups of the Hakos Terrane (Fig. 1) based on a revised subdivision and classification by Hoffmann (1983; 1989). Stratigraphic subdivision of rocks of the Naukluft Nappe Complex (Fig. 1) shown in column two, essentially follows the lithostratigraphic nomenclature of Hartnady (1978) but has been rearranged on the basis of reinterpreted age relationships which accept that the entire sequence was deposited prior to any compressional, fabric-forming deformation and thrust displacements and thus rejects the former author's model of syn-tectonic deposition postulated for the younger stratigraphic elements.

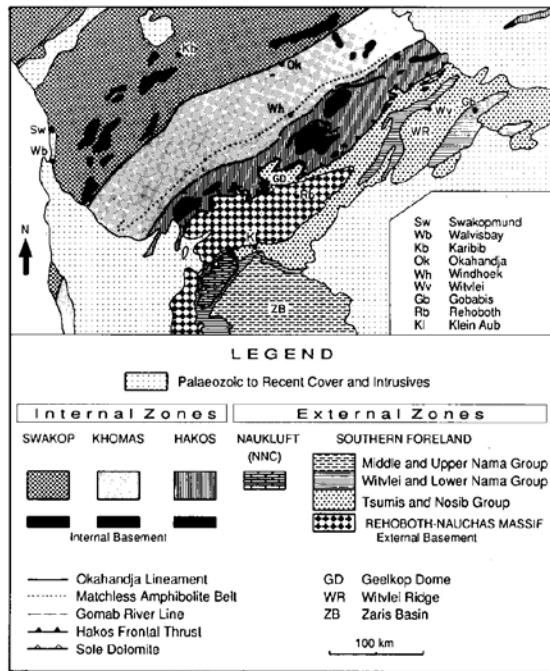


Fig. 1: Tectonostratigraphic terranes of the southern Damara Belt and southern foreland.

The thick autochthonous foreland succession preserved in the Geelkop Dome, the Witvlei Ridge (Hegenberger, in prep.) and the Nama Basin (Fig. 1) shown in column three is a composite, or standard section of different parts of the succession. It comprises the Tsumis and the Nosib Groups in the Klein Aub and the Witvlei areas (Schalk 1970, Hegenberger and Seeger, 1980), the Nosib Group represented by the Duruchaus Formation in the Geelkop Dome area north of Rehoboth (Hoffmann, 1987a), the Court and Buschmannsklippe Formations of the new Witvlei Group (Hegenberger, in prep.) in the Witvlei-Gobabis area, and the Nama Group of the northern Nama, or Zaris, Basin (Germs, 1983).

Lower Damara Sequence

The lower Damara Sequence comprises the Tsumis and Nosib Groups. The Tsumis Group consists of coarse- to fine-grained continental clastic sediments and local intercalated mafic and acid volcanics of the Doornpoort, the Klein Aub and the Eskadron Formations (Schalk, 1970; Hegenberger and Seeger, 1980; Ruxton, 1981; Borg and Maiden, 1986). A local thick basaltic volcanic sequence, the Bitterwater Formation (Williams-Jones, 1984; Schalk, 1988) occurs at the base of the succession in the eastern Dordabis area. The Aubures Formation represents the stratigraphic equivalent of these units of the Tsumis Group in the Sinclair area.

All or parts of the Tsumis Group as defined here were first regarded to be of post-Sinclair and pre-Damara, or pre-Nama, age (Martin, 1950, 1965; Korn and Martin, 1959; Geological Map of SWA, 1963; Handley, 1965; Schalk, 1970) but have since come to be included in

the pre-Damara age Sinclair Sequence (Watters, 1974, 1977; SACS, 1980; Geological Map of SWA/Namibia, 1980; Ruxton, 1981; Miller, 1983; Borg and Maiden 1986; Borg, 1988). They are now believed to be younger than the approximately 1000 Ma old regional deformation which has affected the Sinclair Sequence and associated plutonic intrusives in the Rehoboth-Nauchas Massif (Fig. 1) and are, therefore, incorporated into the Damara Sequence. The term Tsumis Group is adapted from 'Tsumis Formation' which is the name first introduced for these rocks by Martin (1950). It differs from the original definition in that it now includes the Bitterwater Formation volcanic rocks, and excludes older quartzite and conglomerate of the Grauwater Formation of the Sinclair Sequence and the younger Kamtsas Formation quartzites of the Nosib Group.

The Nosib Group comprises similar but more widely developed, coarse- to fine-grained continental clastic sediments belonging to the Kamtsas and Duruchaus Formations and occurring in the internal metamorphic as well as the external parts of the southern Damara Belt. In the Witvlei Ridge and northern side of the Nama Basin, the Nosib Group is represented only by the Kamtsas Formation which overlies the Tsumis Group rocks either paraconformably or, locally, with a marked angular discordance. In the Geelkop Dome on the north side of the Rehoboth-Nauchas Massif, it consists of the Duruchaus Formation directly overlying basement and interfingering with the Kamtsas Formation to the north-east (Hälbich, 1970; Hoffmann, 1987a). Metamorphosed equivalents of both the Duruchaus Formation, containing local mafic metavolcanics, and the Kamtsas Formation present within the nappes of the Hakos Terrane are closely associated with transported metamorphic and granitic basement which they overlie with partly preserved angular unconformity (Hoffmann, 1989). Rocks of the Tsumis and Nosib Group are not represented in the Naukluft Nappe Complex.

Middle Damara Sequence

Rocks belonging to the middle Damara Sequence overlie the Nosib and Tsumis Groups, or where absent, older crystalline basement, and consist of carbonates and mainly fine-grained clastics deposited in diverse shallow-water shelf to deep-water continental slope depositional environments. They include the metamorphic Hakos Group of the Hakos Terrane, all units of the Naukluft Nappe Complex, the Witvlei Group and the Kuibis Subgroup of the lower Nama Group (Fig. 2). The Hakos Group comprises rocks formerly grouped within the lower and middle Swakop Group in the southern Damara Belt (SACS, 1980) which have now been redefined on the basis of distinct differences of lithology, sedimentary facies as well as stratigraphic age (Hoffmann, 1989). The Witvlei Group (Hegenberger, in prep.) is a major new division of the Damara Sequence consisting of the Court and Buschmannsklippe Forma-

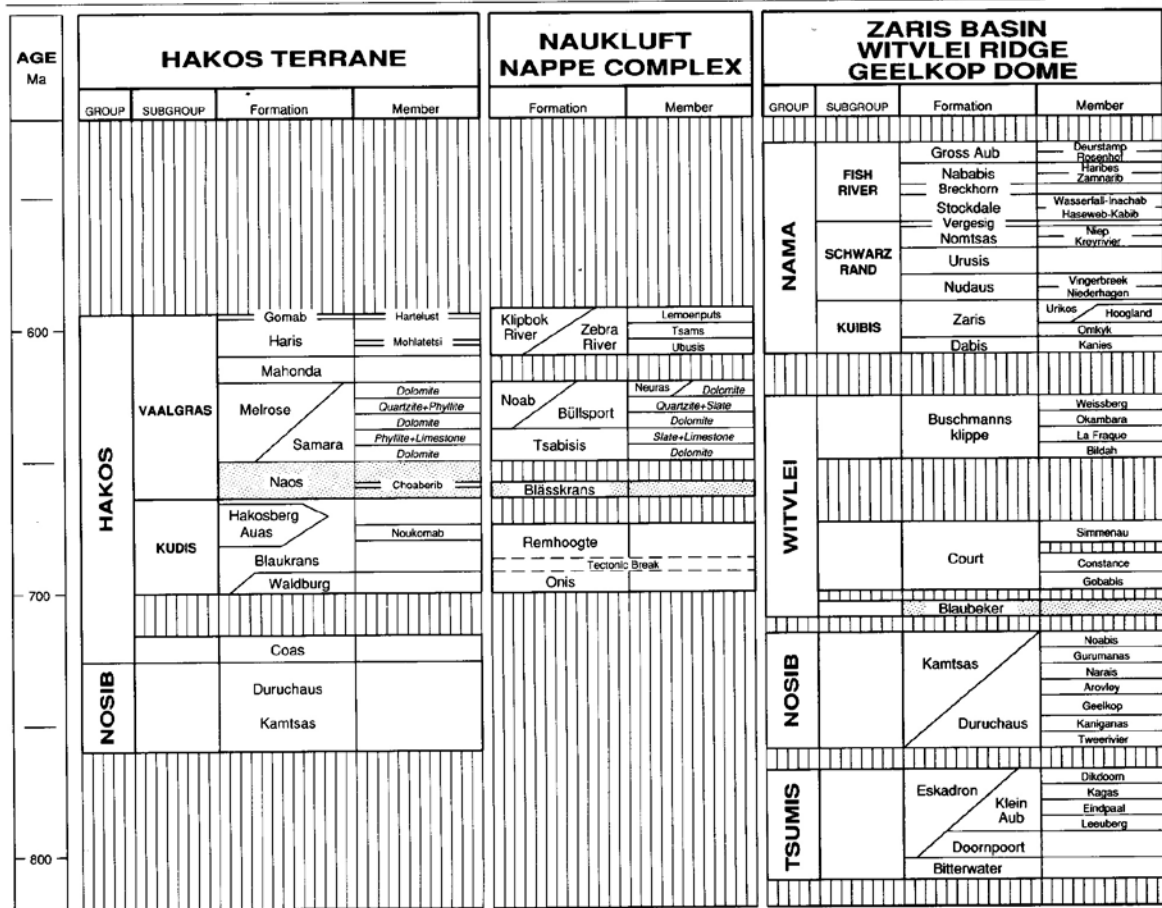


Fig. 2: Lithostratigraphic subdivision and correlation of the Damara Sequence in the southern Damara Thrust Belt and southern foreland. Unconformities within the middle and upper Nama Group are not shown because of scale.

tions which were formerly included as a local facies in the lowermost part of the overlying Nama Group (SACS, 1980; Hegenberger and Seeger, 1980).

The Coas Formation represents a first cycle of major marine carbonate deposition at the base of the Hakos Group. It consists of local, thick light -coloured dolomites and minor marble which follow conformably and transitionally on fine-grained clastics of the Duruchaus Formation. Their inclusion in the Hakos Group, rather than the Nosib Group, is done in order to conform with the general practice, followed throughout the Damara Belt, of placing the stratigraphic top of the Nosib Group at the first appearance of carbonates (Martin, 1965; SACS, 1980).

The Blaubeker Formation consists of local diamictite interpreted as tillite which overlies the Kamtsas Formation paraconformably (Hegenberger and Seeger, 1980) to unconformably (Schalk, 1970). It has not been recognized in the Hakos Terrane where it is probably missing at the regional discordance associated with the base of the Kudis Subgroup.

The Kudis Subgroup usually starts with dark grey to bluish grey or white dolomitic marble of the Waldburg Formation which is correlated with similar dark carbonates of the basal Gobabis Member of the Court Formation (Fig. 2). Both show lateral and vertical interfinger-

ing with mainly fine-grained clastics represented by the graphitic schists of the Blaukrans Formation and shales and siltstones of the Constance Member respectively. The thick succession of deep-water turbidites of the Auas and the Hakosberg Formations are the dominant facies units of the Kudis Subgroup in the upper nappes. Both are located in a stratigraphic position in the upper part of the Kudis Subgroup which suggests correlation with local prominent quartzite of the Simmenau Member of the upper Court Formation (Fig. 2).

Stratigraphic equivalents of the Kudis Subgroup and the Court Formation in the Naukluft nappes are believed to be the dark grey to black dolomite and limestone of the Onis Formation and the Remhoogte Formation, which consists of thick fine-grained clastics and local interbedded black limestone (Fig. 2). Correlation of the Onis Formation, which was included as a member in the younger Zebra River Formation by Hartnady (1978), is proposed on the basis of its similar lithology to the dark carbonates of the Waldburg Formation and the Gobabis Member and the fact that it overlies lower units of the Zebra River Formation with marked structural discordance (Münch, 1976; Hartnady, 1978), thus implying that it may be older than the latter. No stratigraphic equivalents of the Auas and Hakosberg Formations or the Simmenau Member quartzites are present,

which may be due to either non-deposition or removal by erosion associated with the Blässkrans unconformity (Fig. 2).

The Naos Formation of the lower Vaalgras Subgroup consists of the extensive glaciogenic pebbly schist unit formerly correlated with Chuos Formation metatillite of the central and northern Damara Belt (Martin, 1965; SACS, 1980). It conformably overlies either Blaukrans or Auas and Hakosberg Formation and is itself overlain conformably by the Melrose Formation. It appears to be absent at the regional discordance separating the Court and Buschmannsklippe Formations in the Witvlei Ridge. Correlation of the Blässkrans Formation diamictites of the Naukluft Nappe Complex with the Naos Formation is indicated on the basis of sedimentological evidence for a glacial origin and similar stratigraphic position. The much younger age of the Naos-Blässkrans glacial diamictites than the Blaubeker tillite implied by these correlations relies on the fact that the latter underlies the Court Formation, while the Naos and Blässkrans Formations overlie and contain clasts derived from stratigraphically equivalent dark carbonate bearing units of the Court Formation in the Kudis Subgroup and the Naukluft Nappe Complex.

The Samara Formation in the extreme south-western portions of the Hakos Terrane, the Büllsport and Noab Formations, which are the main carbonate-bearing units of the Naukluft Nappe Complex, and the Buschmannsklippe Formation of the upper Witvlei Group, represent renewed major carbonate deposition following the Naos-Blässkrans glaciation. All comprise characteristic light-coloured carbonates, mainly dolomite, and display a distinct five-fold vertical subdivision consisting of: (1) a lower, or basal dolomite; (2) a lower fine-grained clastic unit; (3) a middle dolomite unit; (4) a middle coarse- to fine-grained clastic unit, and (5) an upper dolomite unit. The most complete section appears to be preserved in parts of the Naukluft Nappe Complex where the uppermost portion, represented by the Neuras Member, was included in the overlying Zebra River Formation by Hartnady (1978). Only the lower and middle parts of the succession appear to be preserved in the Buschmannsklippe Formation, indicating the presence of a major regional discordance separating it from the overlying Kuibis Subgroup of the lower Nama Group. The Samara Formation shows a progressive north-eastward facies change accompanied by pronounced stratigraphic thinning and lateral interfingering with pelitic schists. The latter are in turn correlated on lithologic grounds with the thick metapelite succession of the Melrose Formation, which represents the middle Vaalgras Subgroup in the upper nappes of the Hakos Terrane.

Thick black limestone of the Zaris Formation of the lower Nama Kuibis Subgroup (Martin 1965; Germs, 1983) and its probable stratigraphic equivalent in the Naukluft Nappe Complex, the Tsams Member dolomite of the Zebra River Formation (Hartnady, 1978), rep-

resent a final cycle of extensive carbonate deposition. Both are preceded by thin basal transgressive quartzite and conglomerate of the Dabis Formation and Ubusis Member respectively, and are overlain, or pass laterally, into fine-grained clastic rocks of the Urikos and Lemoenputs Members (Fig. 2). Fine-grained clastics with thick intercalated carbonate debris flow units of the Klipbok River Formation in the northern Naukluft Nappe Complex (Hartnady, 1978) represent probable deepwater facies of the Tsams and Zaris Formations. Assuming that the correlation of the Melrose Formation, which represents the middle part of the Vaalgras Subgroup in the Hakos Terrane with the Samara, the Büllsport - Noab and the Buschmannsklippe Formations is correct, this suggests that these units of the Kuibis Subgroup and the Naukluft nappes are correlates of the upper Vaalgras Subgroup, consisting of quartzites and schists of the Mahonda and the Haris Formations (Fig. 2). This would imply stratigraphic equivalence of the lower Nama Group with upper parts of the metamorphic Damara Sequence.

Upper Damara Sequence

The Schwarzrand and Fish River Subgroups of the middle and upper Nama Group are entirely confined to the Nama Basin and comprise clastic rocks in the north interfingering with carbonates of the middle Schwarzrand Subgroup in the southern Nama Basin (Germs, 1983). The clastic rocks have been shown to be derived from early uplift in the internal metamorphic zones of the Damara Belt (Germs, 1983; Horstmann, 1987), which is in accordance with biostratigraphic evidence for an altogether younger, latest Proterozoic to early Cambrian, age of deposition in a foreland basin (Germs, 1983).

Lithostratigraphic correlation with the Gariiep Belt

Lithostratigraphic subdivision and correlation of late Proterozoic units in different parts of the Gariiep Belt (Fig. 3) and their correlation with the Damara Sequence of the southern Damara Belt are illustrated in Fig. 4. The sequence consists of autochthonous, mildly folded to undeformed sediments of the southern Nama, or Witputs, Basin (Germs, 1983) in the east, and folded and thrust-emplaced metasedimentary and metavolcanic rocks of the Port Nolloth Terrane which forms the eastern marginal part of the internal Gariiep Belt (Von Veh, 1988). Allochthonous units of the western Marmora Terrane (Davies and Coward, 1982) are not considered here, due to a lack of reliable evidence for correlating these largely metavolcanic units with those in the east.

The autochthonous eastern succession of the Witputs Basin comprises a relatively thin and very impersistent lower sequence, defined here as the Witputs Group, which is exposed in the escarpment area around Witputs and further south in the Namuskluft area east of

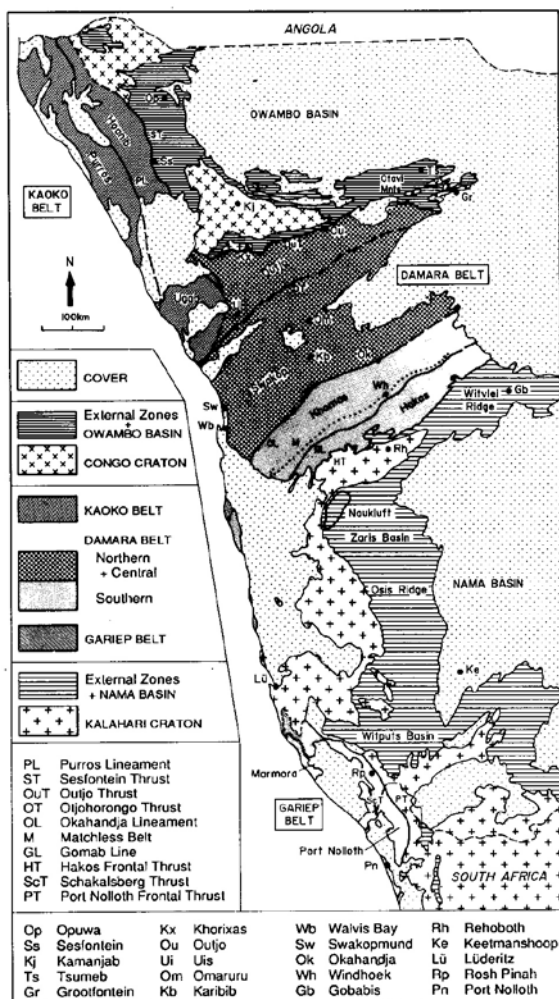


Fig. 3: Tectonostratigraphic terranes of the Damara Orogenic Province and cratonic basins of the adjacent Congo and Kalahari Cratons (adapted from Miller, 1983; Hoffmann, 1987b; Von Veh, 1988).

Rosh Pinah, and a very thick and extensive upper succession representing the Nama Group. The Witputs Group comprises four, as yet unnamed, informal units separated by major unconformities and considered to represent stratigraphic equivalents of parts of the folded Gariep Group in the Port Nolloth Terrane in the west. The complete succession of the Witputs Group is equivalent to McMillan's (1968) 'Numees Formation' which he considered to be altogether younger than the Gariep Group.

Subdivision and nomenclature of the restored sequence of the Port Nolloth Terrane is adapted from the recently proposed new subdivision of the Gariep Group by Von Veh (1988) in the north-western Richtersveld south of the Orange River, and field evidence from the Rosh Pinah-Witputs area to the north (Hoffmann, 1972; and the writer's unpublished data). The main features of the sequence are a thick but mostly local, basal succession of clastic and volcanic rocks belonging to the Stinkfontein Group and an unconformably overlying extensive mixed clastic-carbonate sequence, the Gariep

Group. As in the Damara Belt, the sequence contains two discrete glacial units present in both the Gariep Group of the Port Nolloth Terrane as well as in the autochthonous Witputs Group.

The basal Stinkfontein Group is developed mainly in the Richtersveld and comprises feldspathic, cross-bedded quartzite and conglomerate and minor intercalated acid to intermediate volcanic rocks (Von Veh, 1988). These continental clastics and volcanics are virtually identical to the Nosib Group in the southern Damara Belt and elsewhere in the central and northern Damara Belt. In the area east of Rosh Pinah, Stinkfontein quartzites are conformably overlain by a local succession of mainly fine-grained clastics and interbedded dolomite and limestone (Hoffmann, 1972). Like the Coas Formation of the southern Damara Belt, these appear to represent the first major carbonate-bearing rocks and are therefore taken to define the base of the Gariep Group. Both the Stinkfontein Formation and this lower carbonate-bearing succession of the Numais Formation are missing at the sharp basal Witputs unconformity in the east.

Diamictite of the Kaigas Formation, which unconformably overlies the Stinkfontein Group quartzites in the Richtersveld (Von Veh, 1988), and the mostly thin, impermanent 'Basal Tillite' unit present at the base of the Witputs Group directly overlying basement, represent the lower one of the two tillite-bearing units in the Gariep Belt and are therefore correlated with the Blaubecker Formation in the southern Damara Belt.

The Hilda Subgroup comprises dark carbonates and mixed clastic sediments deposited in shallow-water shelf and mainly intermediate to deep-water slope environments. In the Richtersveld area, these have been subdivided by Von Veh (1988) into three formations consisting of, in ascending order: (1) dark blue-grey dolomitic limestone, minor interbedded arkose and phyllite of the Pickelhaube Formation; (2) dominantly coarse- to fine-grained clastics, represented by feldspathic quartzite, grit and conglomerate and minor graphitic phyllite or schist of the Wallekraal Formation; and (3) again local dark blue-grey dolomite of the Dabie River Formation. Stratigraphic evidence north of the Orange River shows that the local mixed clastic-volcanic succession of the Rosh Pinah Formation, which was formerly considered to be either older than the Gariep sequence (McMillan, 1968), or a facies of the Stinkfontein Group (SACS, 1980), is in fact a local turbidite sequence occurring either at the base of the Hilda Subgroup, or as a facies of the middle Wallekraal Formation. In the former case it is considered equivalent to Von Veh's (1988) Gumchavib Formation which he included as a distal, western facies in the Stinkfontein Group. It is equivalent to identical turbidites of the middle 'Greywacke' unit of the lower Witputs Group, with younger stratigraphic equivalents of the Hilda Subgroup being absent and thus indicating the presence of a major erosional unconformity with the overlying 'Upper Tillite' unit of the upper Witputs

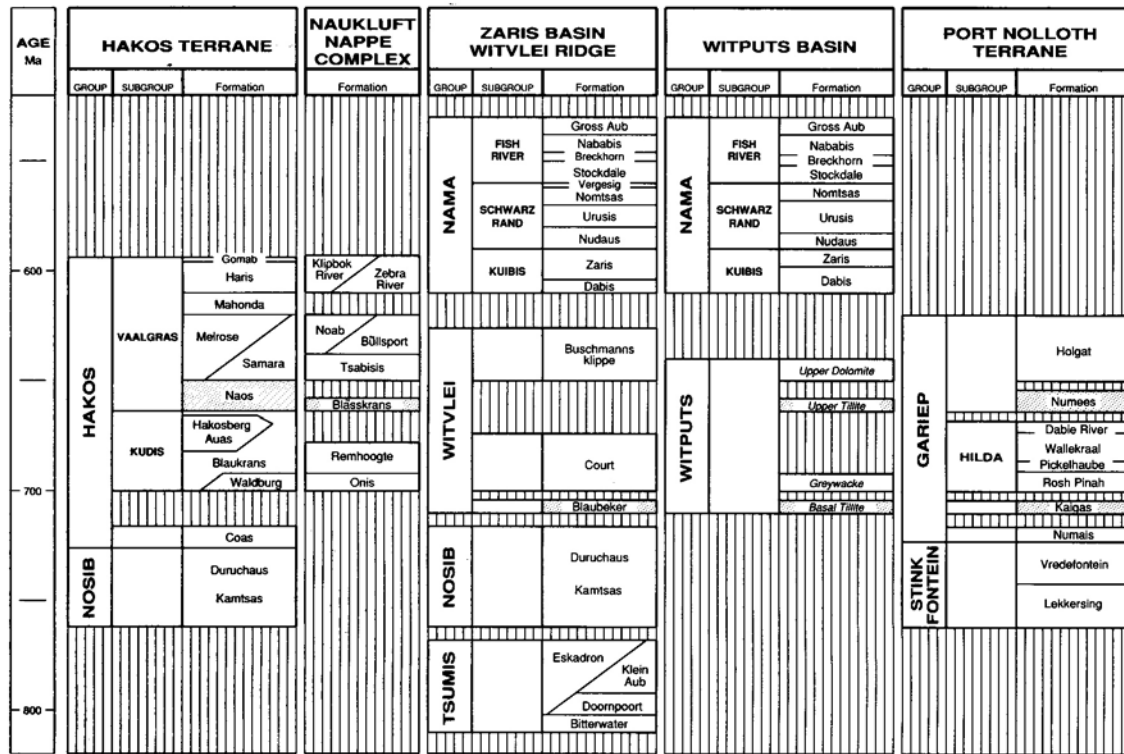


Fig. 4: Lithostratigraphic subdivision and correlation between the southern Damara Belt and the Gariep Belt.

Group. With the exception of the local Rosh Pinah Formation, all the rocks of the Hilda Subgroup closely resemble various units of the Kudis Subgroup which is consistent with their proposed correlation on the basis of inferred stratigraphic position between the two glacial units recognized in each area.

In the Witputs escarpment, the 'Upper Tillite' unit is itself unconformably overlain by the 'Upper Dolomite' unit which comprises very characteristic cream or pink dolomite at the base, followed by green phyllite with minor interbedded quartzites and carbonate. The pink dolomite is identical to the basal Bildah Member dolomite of the Buschmannsklippe Formation and pink dolomite occurring at the base of the Tsabisis to Bülisport Formations of the Naukluft nappes and the Samara Formation in the south-western part of the Hakos Terrane. Stratigraphic equivalents of the 'Upper Tillite' and the 'Upper Dolomite' units of the upper Witputs Group in the Port Nolloth Terrane consist of thick extensive diamictite of the redefined Numees Formation of

Von Veh (1988), which overlies the Hilda rocks conformably or with only slight unconformity, and the Holgat Formation which is made up of impersistent basal dolomite overlain by schist and interbedded gritty, arkosic quartzite and thin carbonate. Correlation of the Holgat Formation with the 'Upper Dolomite' which occurs in a stratigraphic context below unconformably overlying basal Dabis Formation quartzite of the Kuibis Subgroup in the Witputs escarpment, implies a definite pre-Nama age for the Holgat Formation, thus disprov-

ing a Holgat-lower Nama correlation suggested by Von Veh (1988).

Lithostratigraphic correlation with the central and northern Damara Belt

Fig. 5 illustrates a proposed new regional correlation of the Damara Sequence of the southern Damara Belt discussed above with that of the Swakop and Khomas Terranes of the central and northern internal metamorphic zones of the Damara Belt (Fig. 3), and the low-grade to non-metamorphic succession in the Otavi Mountains and Owambo Basin of the northern Damara foreland. As in the southern Damara Belt, basal continental clastics and associated volcanic suites of the Nosib Group unconformably overlie crystalline basement in both the northern external and the internal metamorphic zones of the Damara Belt (Miller, 1983). However, no stratigraphic equivalents of the older Tsumis Group clastic sediments, which are a product of initial rift sedimentation at an early stage on the Kalahari Craton margin, are known from the central and northern Damara Belt.

The absence of a regional unconformity associated with entirely local diamictite of the Varianto Formation at the top of the Nosib Group in the Otavi Mountains implies that it is unrelated to continent-wide glaciation and, therefore, argues against its chronostratigraphic correlation with the Blaubeker Formation tillite of the southern Damara Belt (SACS, 1980; Geological Map SWA/Namibia, 1980; Miller 1983).

Dolomite and marble of the local Coas Formation, the Rössing Formation and the more extensive and in part very thick carbonate succession of the Abenab Subgroup, all follow conformably or with slight discordance on the Nosib Group (Smith, 1965; Hedberg, 1979; Hoffmann, 1989) indicating that these carbonates reflect the earliest, albeit probably highly diachronous, shallow marine transgression preceding continent-wide glaciation recorded by the unconformably overlying glacial diamictites of the Chuos and the Blaubecker Formations. Chronostratigraphic equivalence of the Chuos tillite with the Blaubecker tillite, instead of the younger pebbly schists of the Naos Formation (Martin, 1965; Geological Map SWA/Namibia, 1980; SACS, 1980; Miller, 1983), implies that the extensive and very thick platform carbonates of the Tsumeb Subgroup and the mixed clastic-carbonate succession of the lower Khomas Subgroup should be correlated with the Kudis Subgroup and Court Formation (Fig. 5). This is supported by the presence of a major regional unconformity and sedimentological and stratigraphic evidence for rapid subsidence, maximum regional transgression and widespread basin anoxia which characterize the deposition of these rocks on both former continent margins.

In the southern part of the Swakop Terrane, the Karibib Formation carbonates have been shown to pass through upward and lateral facies transition into mixed carbonate-siliciclastic turbidites of the Tinkas Formation and, further south, across the Okahandja Lineament, into metagreywacke and metapelite of the lower Kuiseb Formation (Jacob, 1974; Sawyer, 1981) repre-

senting the older, pre-tectonic part of the thick metagreywacke turbidite succession of the northern Khomas Terrane (De Kock, 1989; Kasch, 1988). These stratigraphic relationships contrast with those in the southern Damara Belt where the Kuiseb Formation of the southern Khomas Terrane forms a thick tectonic package of intensely transposed schist and local amphibolite of the Matchless Member with no recognizable internal stratigraphy and structurally overlying transported units of the Hakos Terrane (Hoffmann, 1983; 1989). No lateral or vertical interfingering of the Kuiseb Formation with the deep-water facies units of the Kudis Subgroup, consisting of the Blaukrans Formation graphitic schists and the quartzose turbidites of the Auas and Hakosberg Formations, is observed. Instead, these units are conformably overlain by the glaciogenic diamictites of the Naos Formation, followed by middle and upper units of the Vaalgras Subgroup. The Naos Formation and its equivalent in the Gariep Belt, the Numees Formation, which clearly represent a second major glacial event on the Kalahari Craton, therefore must post-date the deposition of the entire Tsumeb Subgroup and lower parts of the Khomas Subgroup consisting of the Karibib Formation and pre-tectonic parts of the Kuiseb Formation. Its apparent absence on the Congo continent margin may be due either to non-deposition or, more likely, removal by erosion associated with the unconformity at the base of the Mulden Group in the Otavi Mountains and Owambo Basin. Both interpretations are consistent with structural and geochronological evidence indicating that deposition of the Mulden Group represents

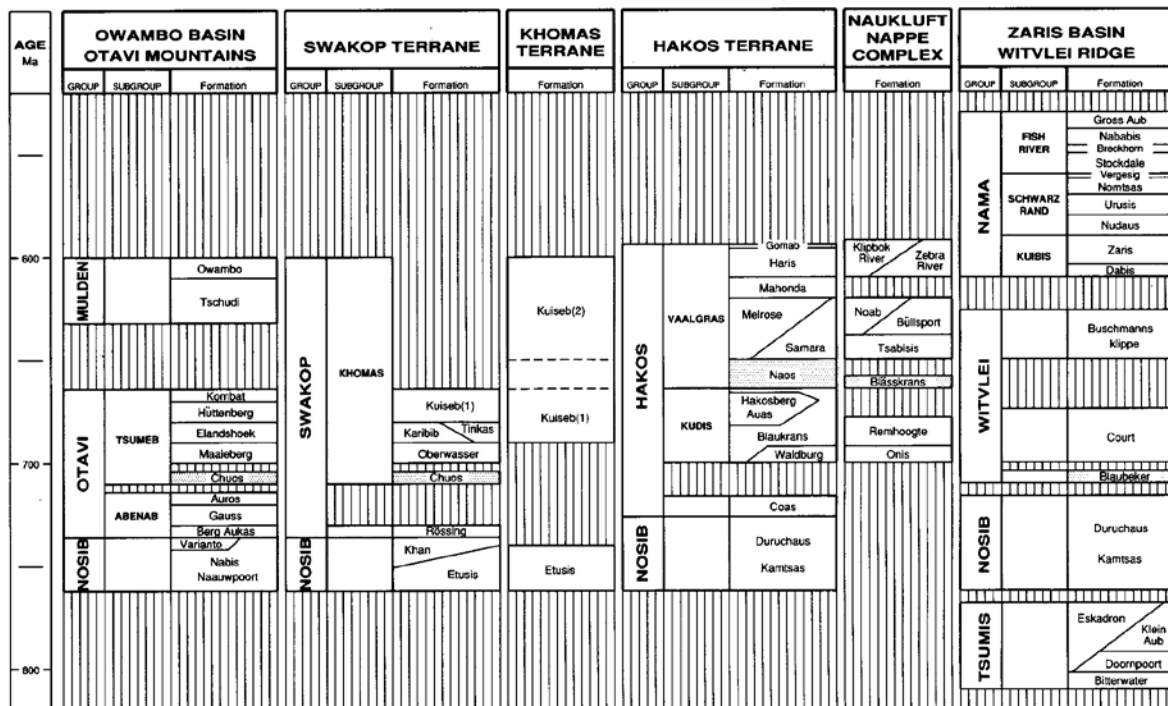


Fig. 5: Lithostratigraphic subdivision and correlation between the southern Damara Belt and the central and northern Damara Belt. Kuiseb (1) and Kuiseb (2) represent pre- and syn-tectonic parts of the Kuiseb Formation in the northern and southern Khomas Terrane, respectively.

major clastic sedimentation following early compressional orogenic and magmatic activity in parts of the central Damara Belt (Frets, 1969; Miller, 1983). Within the internal zones of central and southern Damara Belt, structural evidence similarly indicates a younger age for the deposition of the main, upper syn-tectonic parts of the Kuiseb Formation in a fore-arc basin in the northern Khomas Terrane (Blaine, 1977; Kasch, 1988; De Kock, 1989) and a trench-accretionary prism setting in the southern Khomas Terrane (Hoffmann, 1983; 1989), thus suggesting approximate chronostratigraphic equivalence of these younger components of the Kuiseb Formation with all or, at least parts, of the Mulden Group. Stratigraphic equivalents of the Mulden Group and the younger, syn-tectonic parts of the Kuiseb Formation in the southern Damara Belt are believed to consist of the largely clastic Vaalgras Subgroup, the carbonate-bearing units of the Buschmannsklippe Formation of the upper Witvlei Group, and probably also the Kuibis Subgroup of the lower Nama Group. A prominent, basin-wide black shale horizon, which marks the basal part of the Owambo Formation of the upper Mulden Group (Hedberg, 1979), is considered to be related to marine transgression following the continental clastic deposition of the lower Mulden Tschudi Formation. Possible correlation of this transgressive event on the Congo Craton with the sharp basal Kuibis transgression on the Kalahari margin would indicate stratigraphic equivalence of the coarse, fluviatile clastics of the Tschudi Formation, with the light-coloured dolomites and minor interbedded clastic sediments of the Buschmannsklippe Formation, the Noab- Büllsport Formation of the Naukluft Nappe Complex and the Samara-Melrose Formation of the middle Vaalgras Subgroup. These successions were deposited during relatively low sea-level stands prior to the transgression, while the mostly fine-grained clastics and upward interbedded minor dolomites of the Owambo Formation of the upper Mulden Group and the Kuibis Subgroup carbonates were deposited during rising sea-levels.

Summary and conclusions

Results from regional stratigraphic studies in the southern Damara Belt provide a basis for detailed correlations between the metamorphic Damara Sequence of the internal Hakos Terrane, and low-grade to non-metamorphic units of the Naukluft Nappe Complex, the Witvlei Ridge and northern Nama Basin of the southern foreland.

The oldest rocks consist of continental clastics and volcanics of the Bitterwater, Doornpoort, Klein Aub and Eskadron Formations. These units, which were previously included in the pre-Damara Sinclair Sequence, are now grouped into a new major division, the Tsumis Group, representing the lowermost part of Damara Sequence. They are paraconformably to disconformably overlain by similar clastic rocks of the Nosib Group,

which forms the base of the Damara Sequence in the Hakos Terrane and elsewhere in the Damara Belt.

The Hakos Group comprises mainly clastic meta-sedimentary and minor metavolcanic rocks formerly grouped within the lower and middle Swakop Group. These represent deep-water facies equivalents of the dominantly shallow-water marine carbonate-bearing units of the Naukluft Nappe Complex, the Court and Buschmannsklippe Formations of the Witvlei Group, and possibly also the Kuibis Subgroup of the lower Nama Group. Glaciogenic rocks within these units are related to two discrete events of glacial deposition, represented by the older Blaubeker Formation and the younger Naos and Blässkrans Formations.

Stratigraphic evidence from the Gariiep Belt, which also includes the presence of two distinct glacial units, indicates direct correlation of the basal volcanoclastic Stinkfontein Group with the Nosib Group and of the overlying Hilda Subgroup and the Holgat Formation with the Kudis and lower Vaalgras Subgroup and their stratigraphic equivalents in the Naukluft Nappe Complex and foreland sequence, respectively. The older Kaigas Formation tillite occurs in a stratigraphic position corresponding to that of the Blaubeker tillite, while the younger Numees Formation is shown to be a correlate of the Naos and Blässkrans Formations.

Evidence for the correlation between the Damara Sequence of the southern Damara Belt and that of the central and northern Damara Belt, indicate that the Blaubeker tillite corresponds to the Chuos Formation, and that the Kudis Subgroup and Court Formation are stratigraphic equivalents of the Khomas Subgroup, comprising the Karibib Formation, the Tinkas Formation and the older, pre-tectonic parts of the Kuiseb Formation in the Swakop Terrane and northern Khomas Terrane, and the Tsumeb Subgroup of the northern foreland and Owambo Basin. Glaciogenic rocks related to the Naos-Numees glaciation, which were previously equated with the Chuos Formation, are therefore believed to be much younger and to probably correspond to the regional unconformity which separates the Tsumeb Subgroup from the overlying Mulden Group. The latter must, therefore, be stratigraphically equivalent to all or at least parts of the Vaalgras Subgroup and the Buschmannsklippe Formation and probably also the lower Nama Kuibis Subgroup. Stratigraphic equivalents of these units in the central metamorphic zones of the Damara Belt are believed to consist of the younger syn-tectonic, fore-arc and accretionary prism sediments of the Kuiseb Formation of the southern and northern Khomas Terrane respectively.

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