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A preliminary note on a revised subdivision and regional correlation of the Otavi Group 'based on glaciogenic diamictites and associated cap dolostones

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Introduction

The Otavi Group is a thick succession of Neoproterozoic carbonates exposed within the Otavi foreland fold belt of northern Namibia (Fig. 1). It overlies predominantly coarse-grained terrigenous siliciclastic and local volcanic rocks of the Nosib Group and is overlain by fine- to coarse-grained Mulden Group siliciclastic sediments (Hedberg, 1979; Guj, 1970). Lithostratigraphic subdivision and nomenclature presently in use for the Otavi Group (Fig. 2) is based on several decades of regional mapping, mainly in the Otavi Mountainland and eastern Kaokoveld (Fig. 1), and is the classification adopted formally by the South African Committee for Stratigraphy (SACS, 1980).

A key element of this stratigraphic classification is a glaciogenic diamictite horizon, the Chuos Formation, presumed to represent a single time-stratigraphic marker separating lower Otavi (Abenab Subgroup) from upper Otavi (Tsumeb Subgroup) rocks (Fig. 2). However recent field studies along the Fransfontein Ridge flanking the southern margin of the Kamanjab Inlier and within adjoining areas of the metamorphic Damara Belt (Swakop Group) (Fig. 1) have established the presence of two, stratigraphically and lithologically distinct, glacial diamictite intervals (Hoffmann, 1994; Prave and Hoffmann, 1995). The two diamictites are each capped by unique post-glacial dolostone and occupy distinct stratigraphic positions within the Otavi Group (Prave and Hoffmann, 1995). Here we present new field data to further constrain the stratigraphic position and correlation of the two diamictites and associated cap carbonates within the Otavi fold belt and, based on this evidence, propose a substantially revised subdivision and interbasinal correlation of the Otavi Group carbonate sequence.

Fransfontein Ridge

The Fransfontein Ridge comprises a well-exposed

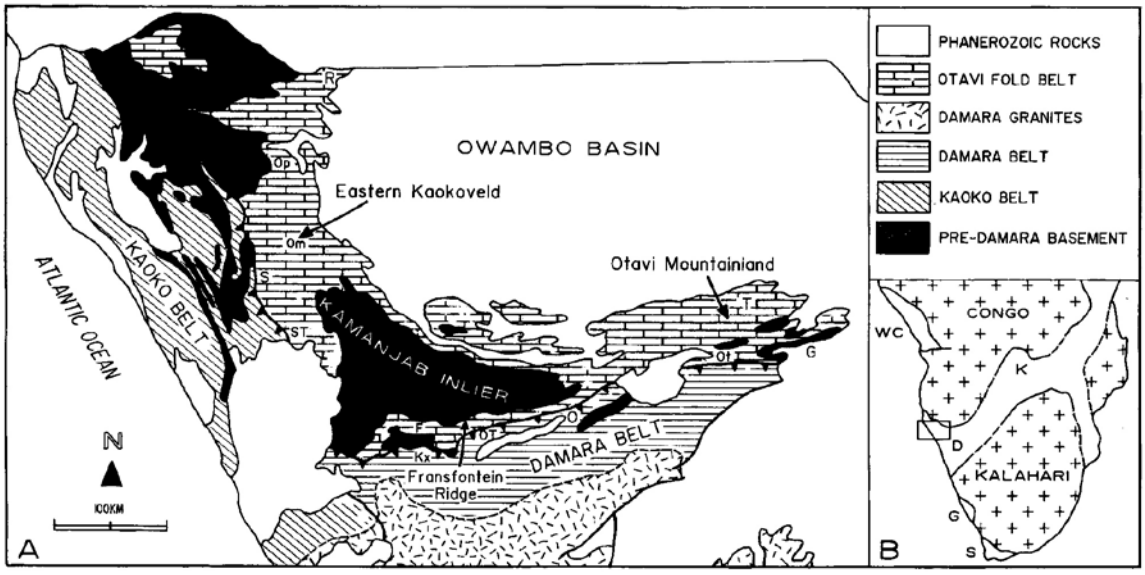

Figure 1: A. Sketch map of northern Namibia showing the distribution of the Otavi Group within the Otavi Mountainland, the north and south flanks of the Kamanjab Inlier and the eastern Kaokoveld (G - Grootfontein, T - Tsumeb, Ot - Otavi, Kx - Khorixas, F -Fransfontein, S - Sesfontein, Om - Ombambo, Op - Opuwa; OT - Outjo Thrust, ST - Sesfontein Thrust). **B.** Inset map showing Pan-African belts in central and southern Africa. D - Damara Belt, WC - West Congo Belt, G - Gariep Belt, S - Saldhania Belt, K - Katangan.

succession of Otavi Group carbonates along the southern flank of the Kamanjab Inlier between Outjo and Fransfontein village (Fig. 1). The lower diamictite occurs as locally preserved lenses, up to 80 m thick and 3.5 km in strike length, at the base of the Otavi succession on farms Malta 7 and Duurwater 66 (15 km E of Fransfontein), directly north of Fransfontein, and again on farms Bethanie 514 and Austerlitz 515 (70 km W of Fransfontein). The diamictite rests either directly on crystalline basement or, locally, on Nosib Group rocks (Fig. 3). It consists mostly of angular pebbles and boulders (up to 30 cm in diameter) of granite, gneiss, schist, quartzite and rare carbonate enclosed in a dark unsorted, iron-rich matrix. On the farm Malta, iron-formation and laminated mudstones interbedded with the diamictite contain dropstones which indicate glacial conditions of sedimentation (Prave and Hoffmann, 1995).

At the base of the Otavi carbonate succession is a prominent unit of dark grey, very finely laminated dolostone that varies from 15 to 30 m in thickness (Fig. 3). It is characterised by a complex lateral interfingering of wavy-parallel laminites, convoluted and slumped microbial laminites, and mm- to cm-thick finely graded beds. This dolostone invariably displays a sharp base where it caps the diamictite, or rests directly on Nosib Group rocks or basement. Upwards, it is conformably overlain by a heterolithic unit, 30 to 450 m thick, dominated by uniform light grey traction-bedded dolostone and subordinate variegated limestone and shale.

The upper glacial interval is composed of massive carbonate-clast diamictite developed at the base of the upper, main part of the Otavi succession (Fig. 3). It varies from a few metres up to 375 m in thickness and consists almost entirely of unsorted, highly angular clasts and blocks of dolostone and limestone in a fine-grained carbonate matrix. Previous workers inferred a non-glacial, sediment gravity-flow origin for the diamictite (Frets, 1969; Guj, 1974; Hedberg, 1979). However, the presence of well-preserved drops tones within the rare lenses of dolostone rhythmite enclosed by the diamictite and in a 5 to 10m thick interval of bedded dolostone present locally at the top of the diamictite, is unequivocal evidence of ice-rafting and, hence, glaciomarine sedimentation (Prave and Hoffmann, 1995). The diamictite pinches out on the western part of farm Kranspoort, about 30 km east of Fransfontein, and with the exception of a few local occurrences noted by Guj (1974), appears to be mostly absent eastward as far as Outjo. It is present in most places along the western extension of the Fransfontein Ridge and in the Bethanie area west of Khorixas (Frets, 1969).

The carbonate-clast diamictite is capped by a thin (3-25 m) light grey to cream or pink, laminated and slumped dolostone (Fig. 3). The basal contact defines a sharp, transgressive (flooding) surface whereas at the top it passes gradationally into a limestone-dolostone rhythmite unit, typically 30 to 50 m in thickness. The remainder of the succession consists mainly of light grey medium-bedded to laminated dolostone, with minor limestone rhythmites and shales, up to 1200 m in total thickness.

Together with the overlying limestone-dolostone rhythmite interval, the cap dolostone makes an excellent, continuous marker bed. Where the diamictite is present, the cap dolostone averages only a few metres in thickness and typically consists of the characteristic thinly bedded to laminated or slumped, cream or pink lithofacies. Where the diamictite is absent, or very thin and impersistent (such as at Bothashof, 35 km east of Fransfontein), the cap is thicker, by as much as 25 m, and grades laterally into a light-grey dolostone which contains enigmatic, but highly distinctive, subvertical tubular structures (from a few centimetres to

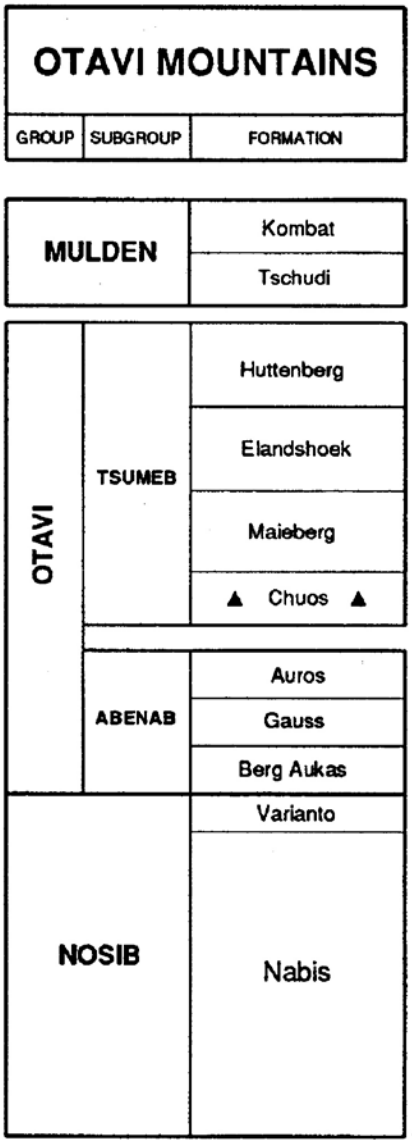

Figure 2: Lithostratigraphic subdivision and nomenclature of the Otavi Group in the Otavi Mountainland, after the South African Committee for Stratigraphy (SACS, 1980).

several decimetres in length and up to 15 mm in diameter) filled with quartz and dolomite spar. On detailed 1:25 000 scale exploration company maps of an area half-way between Fransfontein and Outjo (Thirion, 1969), this unit has been equated with a lithologically identical dolomite marker bed, "the quartz-cluster dolomite", at the top of the Abenab Subgroup in the Otavi Mountains.

Otavi Mountainland

In the Otavi Mountainland, the lower glacial interval is represented by local "diamictite and associated iron-formation of the upper Nosib Varianto Formation (Figs. 2 and 3). The diamictite attains a maximum thickness of 130 m where it unconformably overlies Nabis Formation (lower Nosib Group) feldspathic quartzite and conglomerate in the central and western Otavi Mountainland, but is absent in the southern and eastern Otavi Mountains. It consists of massive or crudely stratified diamictite containing dispersed, rounded, pebble- to boulder-sized basement clasts derived from the unconformably underlying Nabis Formation. The matrix is typically dark, feldspathic to iron-rich muddy sandstone. Lenticular intervals of laminated iron-formation have been observed to contain isolated drops tones

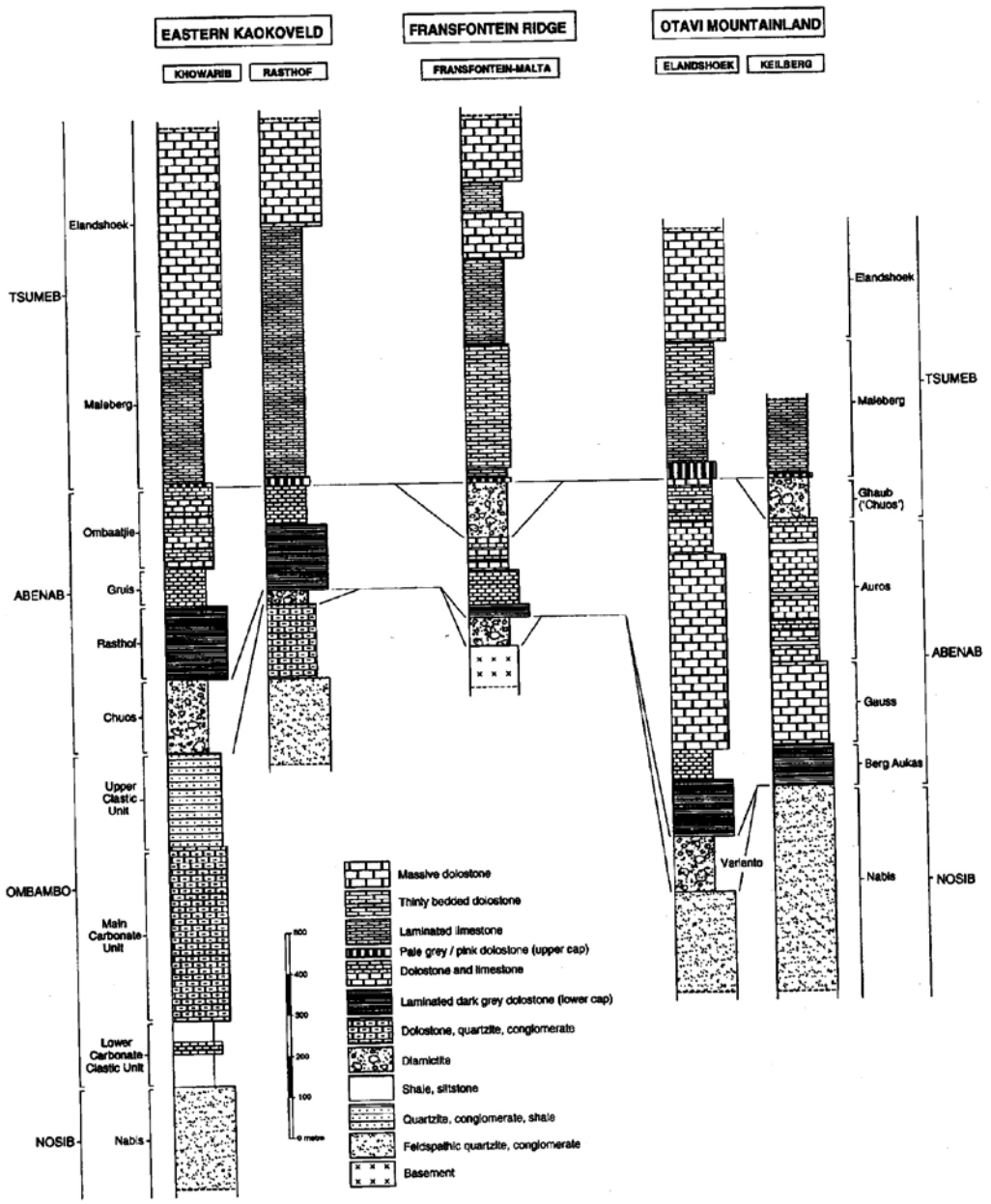

Figure 3: Generalised composite stratigraphic sections of the lower to middle Otavi Group in parts of eastern Kaokoveld, the south flank of Kamanjab Inlier and the Otavi Mountainland. Sections compiled from Hedberg (1979); Beukes (1986); King (1994); A.R. Prave and K.H. Hoffmann (unpubl. data); P.F. Hoffman (pers. comm. 1995).

and provide clear evidence for a glacial origin of the diamictite.

The overlying Abenab Subgroup consists upward of the Berg Aukas, Gauss and Auros Formations (Figs. 2 and 3). The base of this subgroup is a sharp, unconformable contact above which follows medium grey, very finely parallel laminated and mm-thick graded dolostone. This dolostone shows widespread small-scale convolute bedding and slumping, identical to the dark laminated basal dolomite of the Otavi succession along the Fransfontein Ridge. The upper part of the Berg Aukas and the overlying Gauss and Auros Formations amount to as much as 730 m in thickness and comprise a succession of shoaling cycles made up of grey traction-bedded dolostone, microbial laminites and stromatolitic and oolitic beds (Beukes, 1986; King, 1994).

The upper glacial interval recognised in the Otavi Mountains is the 'Otavi tillite', or 'Chuos Formation' (Fig. 2), which marks the base of the upper Otavi Tsumeb Subgroup. A maximum thickness of approximately 2000 m has been reported from the western and southern Otavi Mountainlands (Grobler, 1961), whereas it is thin or absent in most of the eastern Otavi Mountains. It consists of variously shaped, mixed carbonate and basement clasts in an orange-brown weathering carbonate-rich (dolarenitic to micritic) matrix.

A sharp transgressive surface separates the diamictite from a light coloured dolostone unit at the base of the overlying Maieberg Formation (Fig. 3). The basal dolostone displays the same lateral facies change as the thin dolostone which caps the carbonate diamictite along the Fransfontein Ridge. Where the diamictite is present, the dolostone is buff- to pink-coloured, thinly bedded to laminated and locally slumped, on average a few metres in thickness (e.g. Keilberg section in Fig. 3). In areas where the diamictite is absent (e.g Elandshoek section in Fig. 3), it is up to 40 metres thick, takes on a generally light grey colour and contains the same quartz-dolomite filled tubular structures observed on Bothashof near Fransfontein. Field evidence reveals that this unit is equivalent to a regional marker known as the 'quartz-cluster dolomite' and included as the uppermost unit in the Auros Formation of the upper Abenab Subgroup (SACS, 1980; Beukes, 1986; King, 1994). This unit was described in detail by Hegenberger (1987) who interpreted the tube structures as possible gas- or fluid-escape features.

The remainder of the Maieberg Formation comprises several hundred metres of uniform limestone-marl rhythmite passing upward into thinly bedded and

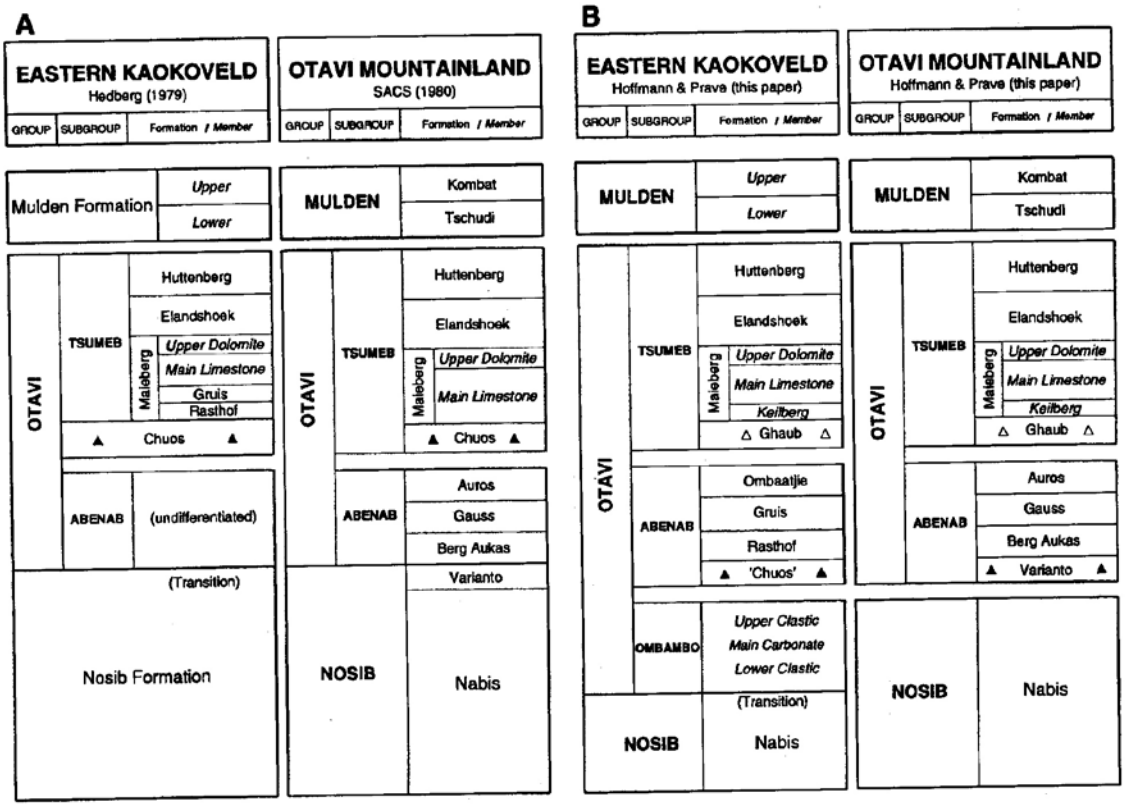

Figure 4: A. Lithostratigraphic subdivision and correlation of the Otavi Group in the Otavi Mountainland and the eastern Kaokoveld by SACS (1980) and Hedberg (1979). Two additional informal units of the Maieberg Formation in the Kaokoveld by Hedberg (1979), the local arkosic carbonate member and the arenaceous member, have been omitted for clarity. **B.** Proposed new lithostratigraphic subdivision and correlation of the Otavi Group.

laminated dolostone (Fig. 3). These are overlain by the monotonous succession of grey, traction-bedded, commonly cherty and stromatolitic, dolostones of the Elandshoek and Huttenberg Formations.

Eastern Kaokoveld

In the eastern Kaokoveld, the lower glacial interval is represented by the thick (up to several hundred metres) and laterally continuous diamictite (Fig. 3) mapped as 'Chuos Formation' by Guj (1970), Hedberg (1979) and Hoffman *et al.* (1994) (Fig. 4A). In contrast, the upper glacial interval is only very locally present, in the form of thin lenses (generally less than a few metres) recognised only recently through detailed mapping (P.F. Hoffman, A.R. Prave and Hu Guowei - unpublished data).

The lower interval ('Chuos') is made up of massive to crudely stratified diamictite with clasts (up to several metres in size) derived from older carbonate rocks and basement, set in a typically iron-rich matrix. It unconformably overlies lower Otavi Group strata consisting of carbonates and fine to coarse grained siliciclastics. A total thickness in excess of 2000 m is present in the Ombambo area south of Opuwa (Hedberg, 1979). This sequence follows conformably on Nosib Group quartzites (up to 1250 m thick) with no evidence for an intervening unconformity (Guj, 1970; Hedberg, 1979; Hoffman *et al.*, 1974). Based on mapping by P.P. Hoffman, Hu Guowei and one of the present authors (ARP), it consists of a lower fine-grained clastic-carbonate unit, a middle or main carbonate unit of mainly well-bedded dolostone and minor limestone, and an upper clastic unit (Fig. 3).

Resting with an invariably sharp contact on the lower diamictite is a dark grey, finely flat -laminated dolostone, less than two metres thick, and up to 200 m of slumped, microbial laminated, and traction-bedded dark to medium grey dolostone (Fig. 3). This unit, named the Rasthof Member and included by Hedberg (1979) as a local facies unit in the Maieberg Formation (Fig. 4A), is a continuous marker horizon throughout the eastern Kaokoveld. However, in contrast to Hedberg (1979), we regard this unit as identical to the finely laminated dark basal dolostone of the Berg Aukas Formation and the basal Otavi Group in the Fransfontein Ridge.

Above the Rasthof Member, the Gruis Member (Fig. 3) consists of very light-coloured (buff and pink) laminated and medium bedded, cherty dolostones, up to several tens of metres in thickness (Hedberg, 1979). In the Khowarib area, the Gruis Member is followed by grey to dark grey, laminated to nodular limestone and traction-bedded dolostone and limestone, up to 200 m thick, named the Ombaatjie Member by P.P. Hoffman (*pers. comm.* 1995).

A thin (typically less than several tens of metres) laminated, buff-coloured cap dolostone with abundant quartz-dolomite filled tubular structures sharply overlies the Ombaatjie Member and patchily preserved, thin (upper) diamictite lenses. The cap dolostone is the stratigraphic equivalent of the light-coloured, pink, laminated and grey tubular (or 'quartz-cluster') dolostone described above from the Fransfontein Ridge and the Otavi Mountainland. It passes upwards into pink and grey limestone laminites and rhythmites, and thinly bedded dolostones, of the main and upper Maieberg Formation respectively. These are followed by the thick dolostone succession of the Elandshoek Formation.

Proposed stratigraphic revision of the Otavi Group

Two distinct stratigraphic couplets, each consisting of diamictite and cap dolostone, are recognised throughout the Otavi foreland in northern Namibia. The lower couplet consists of iron-rich diamictite, dominated by basement-derived clasts, sharply overlain by dark grey, finely laminated dolostone. The upper couplet is a carbonate-matrix diamictite, dominated by carbonate clasts, sharply overlain by light-coloured carbonate that changes laterally from thin buff or pink, laminated and slumped, dolostone to thicker light grey dolomite characterised by quartz-dolomite filled tubular structures. Both the lower and upper diamictite vary greatly in thickness and are absent from large areas. In contrast, the cap dolostones both define regionally persistent stratigraphic markers recognizable throughout the Otavi fold belt. Furthermore, stable isotope studies in progress have revealed that the two cap units have distinct carbon isotope signatures (Kaufman *et al.*, 1996; A.R. Prave and M.J.Kennedy, unpublished data)

Correlation of the two diamictites and associated cap dolostone units presented here requires a substantially revised lithostratigraphic subdivision and correlation of lower and middle Otavi Group units, as follows:

1. The local Varianto Formation of the Otavi Mountainland, previously included in the upper Nosib Group (Fig. 4A), is stratigraphically equivalent to the thick and regionally extensive, main diamictite mapped in the past as 'Chuos Formation' in the eastern Kaokoveld (Fig. 4B). Both units are separated from underlying rocks by a regional unconformity and should therefore be included in the lower Otavi Abenab Subgroup.
2. Dark grey, finely laminated cap dolostone of the basal Berg Aukas Formation is lithologically correlative to the Rasthof cap dolostone in the eastern Kaokoveld (Fig. 4B). This implies that the Rasthof and Gruis Members (including the newly defined Ombaatjie Member of P.F. Hoffman, *pers. comm.* 1995), which Hedberg (1979) interpreted as local facies members of the lower Maieberg Formation (Fig. 4A), are in fact stratigraphic equivalents of the Abenab Subgroup.
3. The thick succession of mixed carbonates and siliciclastics, which follows conformably on

Nosib Group rocks in eastern Kaokoveld and which has been traditionally correlated with the Abenab Subgroup in the Otavi Mountainland (Fig. 4A), is an entirely older marine carbonate sequence for which the name Ombambo Subgroup is proposed (Fig. 4B). Rocks equivalent to the Ombambo Subgroup appear to be entirely absent from both the northern and southern flanks of the Kamanjab Inlier, as well as from the Otavi Mountainland.

4. The well-known carbonate clast-rich diamictite, the 'Otavi tillite' - or Chuos Formation in the nomenclature of SACS (1980) and other stratigraphers (Fig. 4A) developed at the base of the Tsumeb Subgroup in the Otavi Mountains and along the Fransfontein Ridge, is renamed the Ghaub Formation (Fig. 4B) after the farm Ghaub 47 near the area from which it was first described by Le Roex (1941). It is absent, with few local exceptions, throughout most of the eastern Kaokoveld.
5. The Maieberg Formation of the lower Tsumeb Subgroup comprises three units, consisting of the basal light grey to buff or pink cap dolostone overlying the Ghaub Formation, a main limestone member and an upper dolomite member (Fig. 4B). The name 'Keilberg Member' is proposed for the basal Maieberg Formation cap dolostone which incorporates the so-called 'quartz-cluster dolomite' formerly mapped as part of the uppermost Auros Formation.

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