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The geological history of the Awasib Mountain terrain and its relationship to the Sinclair Sequence and Namaqualand Metamorphic Complex

B.G. Hoal
Geological Survey of Namibia

The middle to late Proterozoic Awasib Mountain terrain (AMT) comprises two major crustal components that are correlated with the Namaqualand Metamorphic Complex (NMC) and Sinclair Sequence, respectively. The Kairab Complex forms an important constituent of the early-stage crust of the AMT and comprises a mixed gneiss and amphibolite terrain. Volcano-sedimentary rocks within the latter have similar counterparts in the Garub Sequence of the NMC, while the younger AMT granitoid gneisses (Aunis Tonalite Gneiss and Khorasib Granite Gneiss) resemble several of the later NMC granitoids. In addition to lithostratigraphic similarities to the NMC, the early-stage crust of the AMT has undergone at least three episodes of deformation, the earliest of these being characterised by amphibolite grade metamorphism and migmatisation. The late-stage crust of the AMT is characterised by trough-hosted volcano-sedimentary successions (Urusib, Haiber Flats and Barby Formations) and a host of high-level intrusive rocks (Saffier and Haisib Intrusive Suites, Bushman Hill Quartz Diorite, and Awasib and Chowachasib Granites) which together bear a strong resemblance to lithologies in the middle part, or second cycle, of the Sinclair Sequence. In comparison to the Sinclair Sequence, late-stage AMT rocks are strongly deformed (four episodes of deformation) and metamorphosed (greenschist facies) as a result of events which pre-dated the Pan-African orogeny and appear to be closely related to tectonic (and possibly also magmatic) activity in the adjacent Central Zone of the NMC. South-west of the AMT, the even more highly deformed and metamorphosed Konipberg Formation may lie close to a palaeomargin of the Sinclair Sequence. Late bimodal dyke swarms represent the youngest magmatism in the AMT and may be correlated with similar dyke swarms in the Sinclair Sequence. The Aubures Formation, formerly part of the Sinclair Sequence, post-dates this late magmatism and therefore probably formed during early Pan-African rifting.

Introduction

The middle to late Proterozoic Awasib Mountain terrain (AMT) is situated within the Namib Desert to the south-west of Maltahöhe and is bounded by latitudes 25°00'S and 26°00'S, and longitudes 15°00'E and 16°00'E (Fig. 1). The area is approximately 11 200 km^2 in extent but outcrop is concentrated largely in the central-eastern portion and makes up a relatively small part of the total area. The topography of the study area is characterised by rugged inselbergs which rise steeply above sand- and scree-covered plains.

Initial mapping of the AMT was carried out in 1963 by geologists of Consolidated Diamond Mines, but these maps remain unpublished. Martin (1965) identified several rock types within the AMT which he correlated with lithologic units of the Sinclair "Series" in the neighbouring region. Amongst these were felsites of the Nagatis Formation, reddish Tumuab Granite and sediments of the Kunjas Formation.

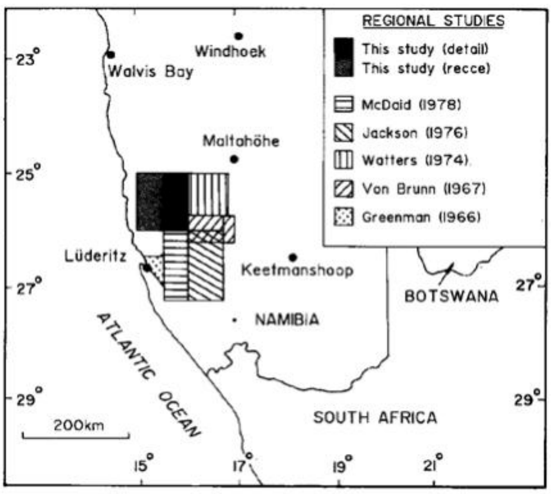

Fig. 1: Locality map of regional geological studies undertaken in southern Namibia.

Watters (1974), after completing a regional study to the east of the AMT, produced a generalised geological map of the Sinclair, Helmeringhausen and Awasib areas in which he depicted the AMT as underlain almost entirely by the Sinclair Sequence. While this depiction was largely corroborated by the reconnaissance work of Harrison (1979), SACS (1980) has shown that a larger portion of the AMT is underlain by pre-Sinclair metamorphic basement than previously indicated.

Areas adjacent to the AMT have been subject to several major regional mapping projects which have been undertaken since the mid-sixties (Fig. 1). Studies which dealt mainly with the cover rocks and high-level intrusions of the Sinclair Sequence are those of Von Brunn (1967) and Watters (1974), while the neighbouring, largely underlying, Namaqualand Metamorphic Complex (NMC) has been studied by Greenman (1966), Jackson (1976) and McDaid (1976, 1978). Details of earlier work carried out in these areas is contained in Range (1910, 1912), Beetz (1923, 1924), Kaiser (1926) and Martin (1965).

Regional geology

Regional setting

The major tectonic provinces and subprovinces of southern Africa are illustrated in Fig. 2 (after Harnady *et al*., 1985). The situation of the AMT across the proposed boundary between the Rehoboth and Gordonia

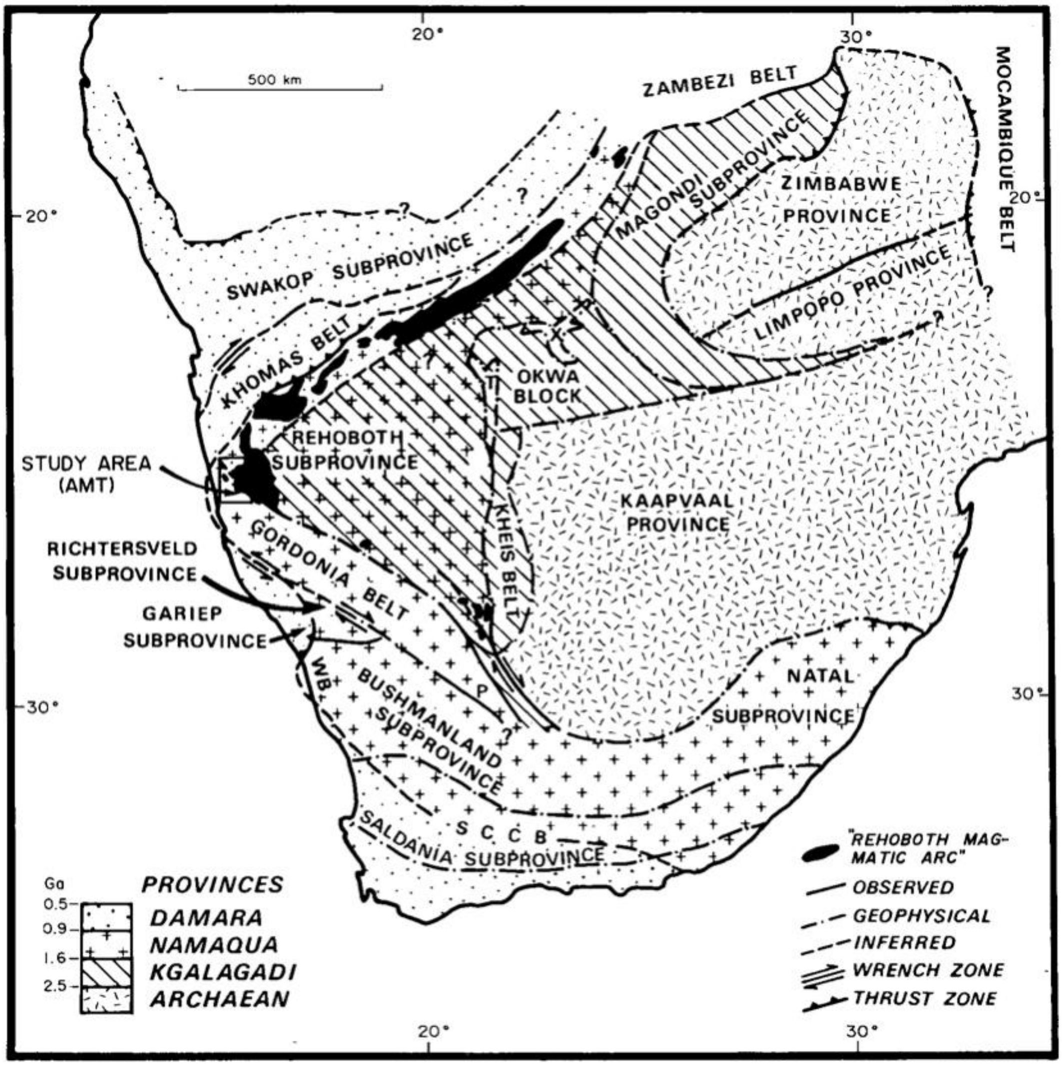

Fig. 2: Regional setting of the "Rehoboth Magmatic Arc" in the tectonic framework of southern Africa (after Hartnady *et al*., 1985). The situation of the Awasib Mountain terrain (AMT) is also illustrated relative to the Rehoboth and Gordonia subprovinces.

subprovinces is important with regard to two problems:

(i) the actual position of this boundary, and

(ii) the relationship between these subprovinces.

Work on this boundary has previously been restricted to the Excelsior-Lord Hill shear zone (e.g. Von Brunn, 1967; Blignault *et al*., 1974; Jackson, 1976; Tankard *et al*., 1982) and has not been extended to the north-west.

Metamorphic basement to the Sinclair Sequence has been grouped both with the Kheis Group (Von Brunn, 1967; Blignault *et al*., 1974) and the Namaqualand Metamorphic Complex (Jackson, 1975; Kröner, 1977), while SACS (1980) proposed separate groupings of these "floor rocks" into the Mooirivier Metamorphic Complex and Neuhof Formation.

With regard to the Sinclair Sequence (which includes the late-stage crust of the AMT), the regional setting is seen as part of a curvilinear association of Irumide-age rocks (the so-called "Rehoboth Magmatic Arc", Fig. 2) which extends from the Koras Group near Upington to the Goha Hills in northern Botswana (Watters, 1974 and subsequent workers). The geotectonic setting of this association has been variously interpreted as an ancient active continental margin (Watters, 1974; Hoal, 1987), an aulacogen (Kröner, 1977), an intracontinental rift similar to the East African rift (Mason, 1981; Borg, 1988) and a collision-related rift (Hoal, 1987).

Geophysical studies, on a regional scale, have provided useful information with regard to some of the major structures at the boundary of the Gordonia and Rehoboth subprovinces, e.g. Bouguer gravity anomalies (Kleywegt, 1967; SWA/Namibia Geological Map, 1980) and aeromagnetic lineaments (CDM Mineral Surveys, 1981). Gravity contours (with dark-shaded highs) indicate a continuation of the line of anomalies identified by De Beer and Meyer (1984) along the margin of the Kaapvaal Craton (Fig. 3). This feature is important with regard to the north-westward continuation of the *ca.* 1.3 Ga old active continental margin proposed by De Beer and Meyer (1984). Possible further extension

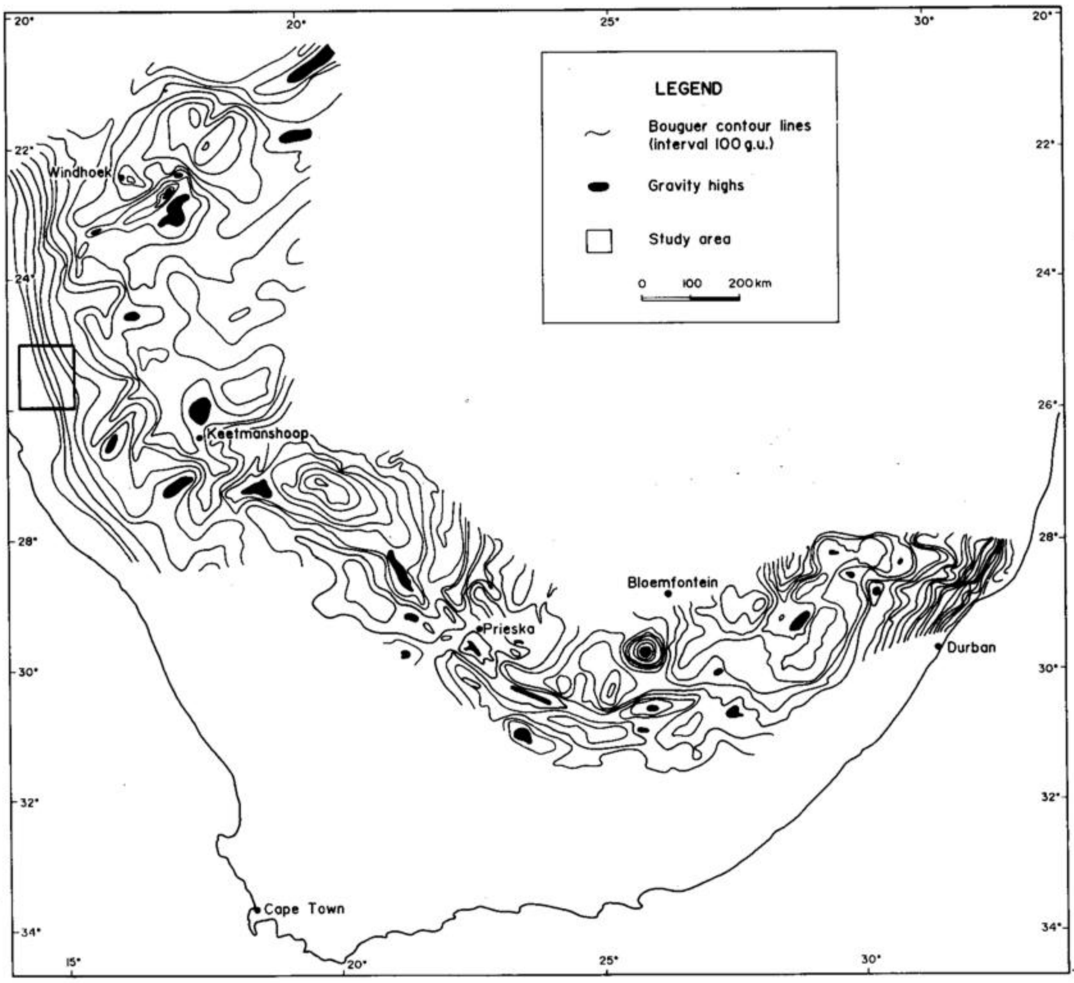

Fig. 3: **A simplified Bouguer anomaly map compiled from data for the northern boundary of the Namaqua-Natal Belt (after De Beer and Meyer, 1984) and southern Namibia (after Kleywegt,1967).**

of this ancient margin into South America (Hoal, 1989) provides an alternative interpretation to the extrapolation of this line along the younger lrumide belt (e.g. Borg, 1988). The paucity of gravity stations between the Sinclair and Rehoboth areas does not allow for a confident choice between these options.

Aeromagnetic lineaments in the Sinclair and adjacent NMC have been interpreted from aeromagnetic contours (Hoal, 1987) and show strong north-westerly and, to a lesser degree, north-easterly trends (Fig. 4). These trends appear to be related to faults (frequently transcurrent) which allow for significant offsets or branching of the major Excelsior-Lord Rill shear belt and its possible north-westward continuation towards Rauchab as a complex fault zone. This "Excelsior-Rauchab Lineament" (EHL; Hoal, 1987) also has associated with it several serpentinite and metagabbroid (including diorite) bodies in a relationship similar to that of the better known Tantalite Valley Shear Zone (e.g. Tankard *et al*., 1982).

In the regional context, the AMT consists of both early-stage crust of possible NMC affinity and late-stage crust which forms, together with the Konipberg Formation, the most westerly occurrence of the Sinclair Sequence.

Lithostratigraphy

While individual units in early-stage crust of the AMT have been studied in some detail, the stratigraphic succession remains uncertain and will only be dealt with briefly in conjunction with the associated metamorphic and structural history in the following section. A more comprehensive breakdown of individual units forms part of the legend to the 1: 100 000 scale Open File geological map of the AMT. This paper is primarily concerned with the late-stage crust in the AMT and its relationship to the type area of the Sinclair Sequence as established by SACS (1980) and revised by Hoal (1985).

Table 1 compares the stratigraphic succession in the type area of the Sinclair Sequence with the succession observed in the AMT. This comparative table is based on field observations and not radiometric data, the latter having produced conflicting results (see Hoal, 1989). An example of this dilemma is provided by the petro-

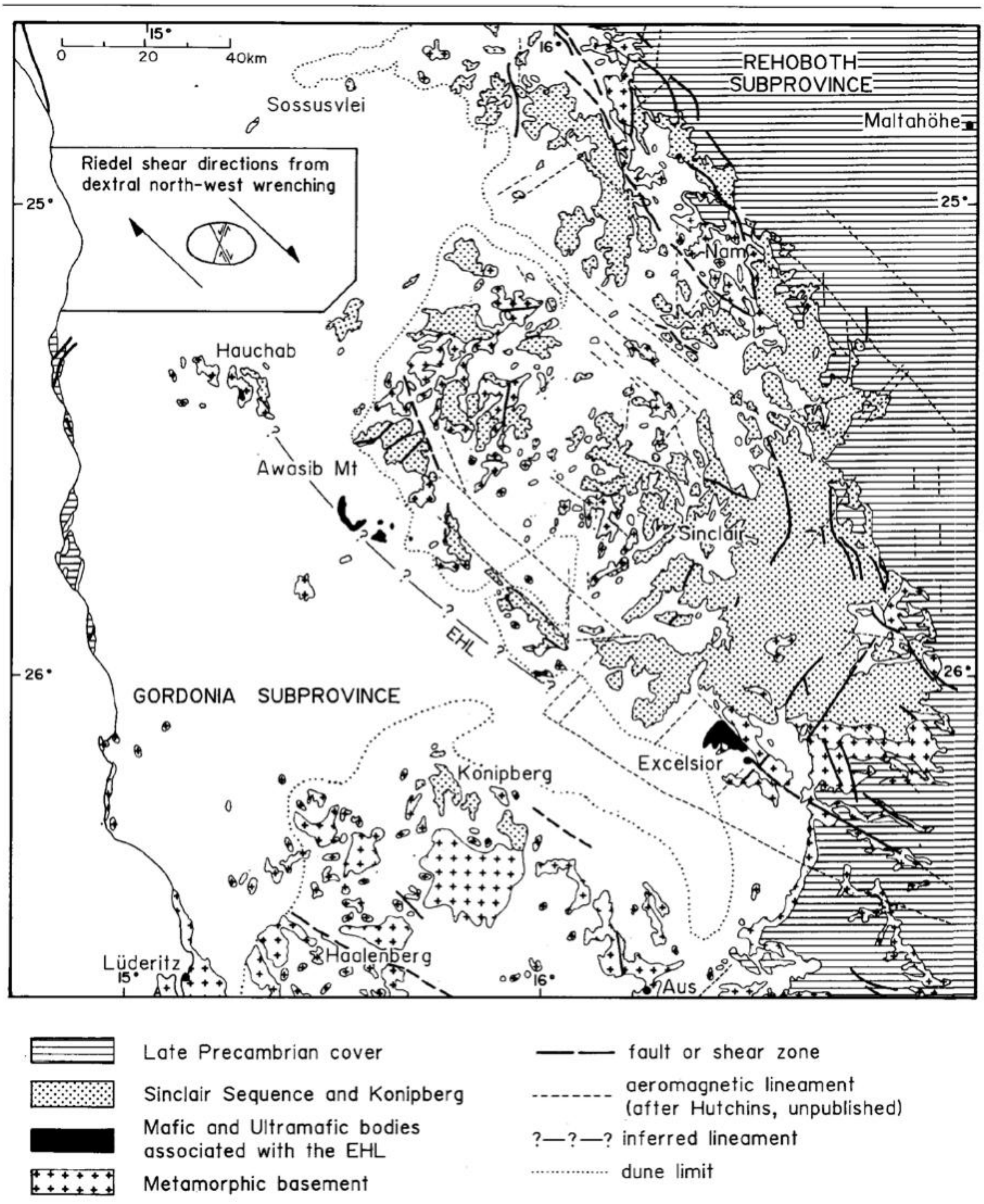

Fig. 4: A simplified geological map of portion of the Rehoboth and Gordonia subprovinces indicating major structural trends inferred from aeromagnetic data (EHL: Excelsior - Hauchab Lineament).

graphic and geochemical similarities between the Raiber Flats and Barby Formations, yet Rb-Sr data indicate a difference of *ca.* 100 Ma in their ages of extrusion (Hoal, op. cit.).

Mafic to intermediate intrusions of the "Barby Formation" and "Spes Bona Syenite" (SACS, 1980) now form part of the "Saffier Intrusive Suite" (new name) and, where recognised in the AMT, these intrusions have been mapped as such. The mutual relationship between the Haisib Intrusive Suite, Bushman Hill Quartz Diorite and Saffier Intrusive Suite is not well established but these units are depicted as broadly contemporaneous. Table 1 also indicates the post-Sinclair status of the Aubures (previously "Auborus"; Watters, 1974) Formation on the following grounds:

(i) The Aubures Formation is hosted in fault-bounded troughs which cut across the regional trend of typical Sinclair-age basins.

(ii) The Aubures Formation is younger than the latest granite magmatism in the Sinclair Sequence, which represents the closing off of the last volcano-sedimentary episode (Table 2).

(iii) Correlation of the Aubures Formation with the Doornpoort Formation in the Rehoboth area is significant in view of the post-Gamsberg Granite age of the latter. Hoffmann (this issue p. 60) considers the Doornpoort Formation to be of early Damaran age.

(iv) A palaeomagnetic age of *ca.* 1000 Ma led Kröner (1977) to suggest that the Aubures Formation was younger than the Sinclair Sequence.

Most of these problems of correlation reflect the deposition of volcano-sedimentary successions of the Sinclair Sequence in isolated basins which have developed both synchronously and diachronously. Coupled to the episodic nature of the magmatism, contemporaneous faulting and vertical movement, it is hardly surprising

TABLE 1: Lithostratigraphy of late-stage crust in the Awasib Mountain terrain (AMT) compared with the lithostratigraphy of the Sinclair Sequence (modified from SACS, 1980).

TYPE AREA OF THE SINCLAIR SEQUENCE			AREA OF PRESENT INVESTIGATION		
Formation	**Lithology**	**Intrusion**	**Formation**	**Lithology**	**Intrusion**
AUBURES	Red quartzite, arkose, conglomerate, minor shale.				
				Mafic and felsic (dolerite, gabbro, quartz porphyry).	Dykes, sills and plugs.
	Red, fine- to medium-grained granite.	SONNTAG and GAMSBERG GRANITES		Red, medium-grained monzo- to alkali-feldspar granite.	CHOWACHASIB GRANITE
GUPERAS	Quartz porphyry lavas. Quartz porphyry lava, agglomerate, minor basic lava. Sandstone, siltstone, conglomerate, minor orthoquartzite, shale.	Quartz porphyry intrusive. Quartz porphyry dykes. Basic stocks and plugs. Basic dykes.	GUPERAS	Mafic and felsic.	Dykes, sills and plugs.
	Red, fine- to medium-grained, porphyritic granite.	NUBIB and ROOIKAM GRANITES		Red, very fine- to medium-grained granite porphyry.	AWASIB GRANITE
				Quartz diorite, tonalite and diorite	BUSHMAN HILL QUARTZ DIORITE
				Monzonite, quartz monzonite, quartz syenite, granodiorite, monzogranite	HAISIB INTRUSIVE SUITE
	Gabbro, norite, picrite, anorthosite, monzonite, diorite, syenite	SAFFIER INTRUSIVE SUITE		Gabbro, norite, picrite, anorthosite, troctolite, monzonite, diorite, syenite	SAFFIER INTRUSIVE SUITE
BARBY	Sandstone, conglomerate, grit, tuffaceous sandstone. Basic and intermediate lava and agglomerate, minor acid lava; interbedded quartzite, conglomerate and bands of felsic lava. Acid lava, ignimbrite, tuff.		HAIBER FLATS	Acid welded ash-flow tuff, volcaniclastics, lava. Basic to intermediate lava, ash-flow and airfall tuff. Interbedded sandstone and conglomerate.	
			BARBY	Basic to intermediate lava, volcaniclastic sediment, airfall.	
KUNJAS	Arkose, shale, grit, quartzite, conglomerate.		URUSIB	Arkose, grit, sandstone, conglomerate, quartz arenite, shale.	
	Granite, granite porphyry.	TUMUAB and KOTZERUS GRANITES, OKARUS GRANITE PORPHYRY			
NAGATIS	Acid lavas and ignimbrites, conglomerate, grit, arkose, shale, minor basic lava.				

TABLE 2: Comparison of evolutionary schemes for the Sinclair Sequence and late-stage crust in the Awasib Mountain terrain (AMT).

Cycle	Proposed Evolution of the Sinclair Sequence (Watters, 1974)	Cycle	Observed Evolution of the Sinclair Sequence (SACS, 1980; this study)	Cycle	Proposed Evolution of late-stage crust in the AMT(this study)
3rd cycle	Auborus Formation *sandstone, conglomerate*		Post-Sinclair (early Damara?)		
	Rooiberg granite (now Sonntag Granite) Guperas Formation *rhyolitic intrusives and extrusives basic lava and intrusives*	3rd cycle	Sonntag/Gamsberg Granite and dyke swarms Guperas Formation *rhyolitic extrusives basic lava*	3rd cycle	Chowachasib Granite and dyke swarms
2nd cycle	Guperas Formation *sandstone, conglomerate*		*sandstone, conglomerate*		
	Nubib/Rooikam/Tumuab Granite Spes Bona syenite Barby Formation *basic lava and intrusives, rhyolitic extrusives*	2nd cycle	Nubib/Rooikam/Haremub Granite Saffier Intrusive Suite *gabbro, norite, monzonite,diorite, syenite* Barby Formation *basic lava and rhyolitic extrusives*	2nd cycle	Awasib Granite Saffier Intrusive Suite, Haisib Intrusive Suite, Bushman Hill Quartz Diorite. Barby Formation and Haiber Flats Formation
1st cycle	Kunjas Formation *arkose, grit shale*		Kunjas Formation *arkose, grit shale*		Urusib Formation
	Haremub/Kotzerus Granite Nagatis Formation *rhyolitic extrusives and minor basic lava, arkose, grit, shale* (?Unexposed basic intrusives and extrusives)	1st cycle	Tumuab/Kotzerus Granite Nagatis Formation *rhyolitic extrusives and minor basic lava arkose, grit, shale*	1st cycle	

that the resultant stratigraphy is difficult to unravel.

Watters (1974, 1976) viewed the Sinclair Sequence as having evolved in three cycles, each cycle being initiated by the emplacement of basic magma and terminated by sedimentation. Table 2 presents a reinterpretation of this cyclical evolution, which is more compatible with field evidence, i.e. artificial boundaries are not created within formations, and places the evolution of the late-stage AMT predominantly within the second cycle of activity. In this revised model, each cycle is initiated by sedimentation, followed by volcano-sedimentary activity, and terminated by plutonism. Each cycle represents an episode of both extension and vertical tectonics, with accompanying sedimentation and pulses of magmatism. The final stage of plutonism in the third cycle terminates the development of the Sinclair Sequence and excludes the Aubures Formation.

Structure and metamorphism

Table 3 compares the geologic history of the AMT with that of the neighbouring NMC ("Central Zone") and possible Sinclair-type supracrustals within the latter province. The type area of the Sinclair Sequence is excluded from this table due to its relatively undeformed and unmetamorphosed nature. The controversial Nam Shear Zone appears to have affected Sinclair-type lithologies (Watters, 1974), but Schalk (pers. comm., 1985) regards this zone as part of the older Neuhof Formation which has suffered only minor reactivation in Sinclair times.

Within the early-stage crust of the AMT, the Kairab Complex shows many similarities to the "pretectonic"

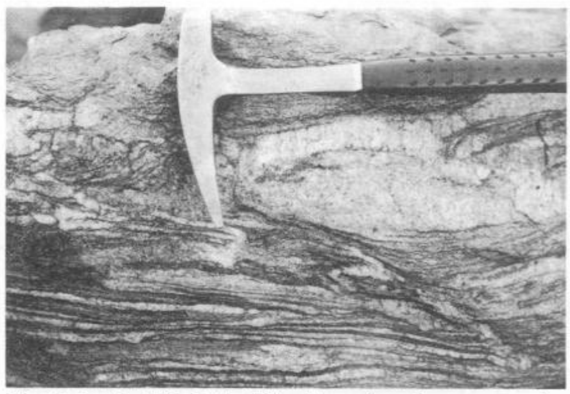

Fig. 5: Isoclinal F_1 folds defined by migmatite neosomes in garnet-biotite gneiss of the Kairab Complex. Flattening and boudinage of the early layering (s_0) have resulted in the development of transposed layering (s_1).

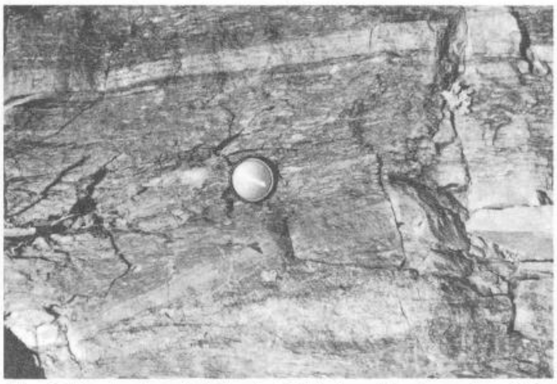

Fig. 6: Regional s_1 foliation in biotite-hornblende gneiss of the Kairab Complex which has been refoliated in a narrow zone (s_2) between the lens cap and patchy neosome.

Garub Sequence described by Jackson (1976). The oldest regional fabric (s_1) is present in grey gneisses as a gneissic or migmatitic layering which is inferred to be parallel to the lithologic layering (s_0). The foliation s_1 is the result of transposition or overprinting of so during the D_1 deformational event (Fig. 5). Tight, often overturned folds (F_2) are typical of D_2, but their orientation does not appear to have any regional consistency., A penetrative mineral lineation is usually present and designated l_2. Distinction between s_1 and s_2 foliations is difficult on a regional scale, since refoliation is only locally observed (Fig. 6). The deformational episodes D_1 and D_2 both appear to be characterised by high grade metamorphism (upper amphibolite facies) and associated metatexis.

The regional fabric (s_3) typical of syn- to late-tectonic granitoids in the AMT "basement" is widespread but shows variable development (Fig. 7). Metasedimentary (and possibly amphibolitic) xenoliths may also show earlier fabrics (s_1/s_2) despite flattening in the plane of s_3. A mineral lineation (b) is occasionally developed. The extent of this D_3 phase of deformation is difficult to ascertain, but associated dextral shears may be the earliest manifestation of transcurrent movements which culminated in the creation of pull-apart basins in late-stage (or "Sinclair-age") crust. Later movement (D_5?) has occurred along these faults and resulted in shear zones at several basin margins in the AMT.

Fig. 7: Migmatised biotite gneiss of the Kairab Complex which has been intruded by a dyke of Khorasib Granite Gneiss. Earlier s_1 and s_2 fabrics in the migmatite are clearly cross-cut by the s_3 foliation within the granite gneiss.

The recognition of several phases of deformation in late-stage crust of the AMT constitutes a significant departure from the generally accepted idea of minimal tilting and gentle folding in the Sinclair Sequence (e.g. Watters, 1974; Kröner, 1977; Mason, 1981). Harrison (1979) identified two post- "Guperas Formation" deformational phases as well as a late phase of normal and reverse faulting in the AMT. This deformational sequence was revised and expanded by Hoal (1985) and is now considered to comprise four recognisable phases of deformation as well as a late phase of faulting.

The D_3 event recognised by McDaid (1978) in the Sinclair-age Konipberg Formation appears to be restricted to the syn- to late-tectonic "basement" granitoids in the AMT. The first recognisable phase of deformation in latestage crust of the AMT affected all units except the

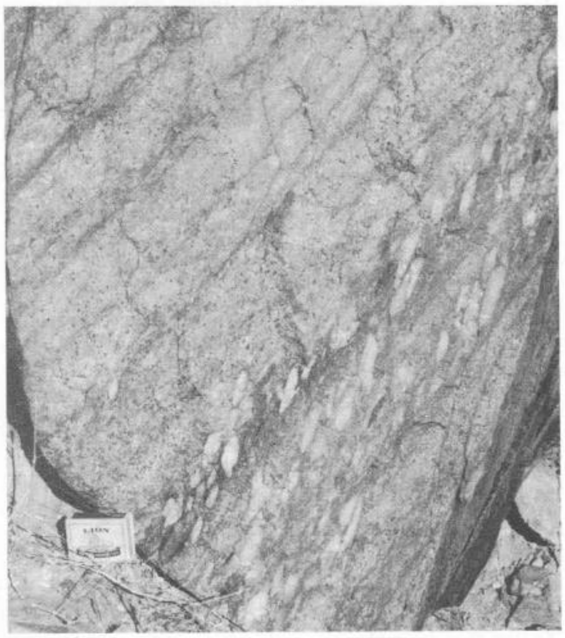

Fig. 8: Eastern limb of upright fold in lithic arenite of the Urusib Formation. Axial planar cleavage is defined by pebble flattening and illustrates a high angle to the more moderately dipping bedding planes, here defined by heavy mineral concentrations. Core of Urusib synclinorium.

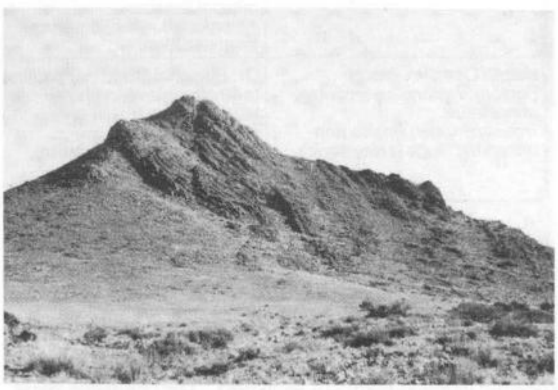

Fig. 9: Steeply-dipping to overturned western limb of Urusib synclinorium.

Chowachasib Granite Suite. This event (D_4) is represented by open north-west to north-north-west trending folds (F_4) which have been intersected by an axial planar cleavage (s_4; Fig. 8) and display a mineral lineation (l_4). These folds are both upright and more rarely overturned, while coaxial warps of the limbs were observed in the synclinorium north of Urusib waterhole (Fig. 9). Associated with this phase of deformation are widespread fracture cleavage and block tilting, possibly as a result of sliding on listric or detachment faults.

The following deformational event (D_3) probably followed shortly after D_4 and is characterised by widespread shearing along s_4 planes of weakness. The conjugate shear couple represented by the north-west trending Haiber Flats Shear Zone (HFSZ; first named by Harrison, 1979) and a smaller north to north-east trending shear zone to the south-east of Haiber Hill may represent Riedel shears in response to overall dextral wrench-

TABLE 3: Comparison between geological histories of the Awasib Mountain terrain (AMT) and the adjacent Central Zone of the Namaqualand Metamorphic Complex (NMC).

AMT (THIS STUDY)		CENTRAL ZONE OF THE NMC (TANKARD *ET AL.*, 1982)	
LITHOLOGIC UNIT	STRUCTURAL & METAMORPHIC FEATURES	LITHOLOGIC UNIT	STRUCTURAL & METAMORPHIC FEATURES
	Faults causing dyke offsets and brittle deformation (Aubures age?)		
	D_7: Open folds and warps		
Mafic and felsic dykes.	Utilisation of conjugate fractures.		
	D_6: Crenulation folds, kinkbands, crenulation lineation, conjugate fractures (NW-SE & NE-SW). Retrograde metamorphism.		
	D_5: Dextral and sinistral shearing (NW-SE, NE-SW, E-W), shear-related folds, stretching lineation, localised thrusting. Greenschist metamorphism.		D_6: Dextral shearing (NW-SE) Excelsior, Tantalite Valley, Nam (D4/D5) - McDaid (1978)
Chowachasib Granite?			D_5: Open folding, trends NW-SE and E-W. Retrograde metamorphism.
	D_4: Open folds (NW-SE), fracture cleavage, block tilting, faulting.		D_4: Open folding, trends NW-SE, N-S, NE-SW.
Mafic to felsic intrusions (Haisib and Saffier Intrusive Suites, Bushman Hill Quartz Diorite, Awasib Granite). Volcano-sedimentary successions (Urusib, Haiber Flats and Barby Formations).		Granitoid batholiths (Glockenberg Granite) Volcano-sedimentary successions (Konipberg Formation)	D_3: Fabric in cover, tight E-W folding (McDaid, 1978).
		Granitoid batholiths (Tumuab and Kotzerus) Volcano-sedimentary successions (Nagatis Formation) Naisib River Igneous Suite	D_3*: Regional fabric N-S to NW-SE, isoclinal to open folding, local refoliation. Amphibolite metamorphism. * not identified by McDaid (1978).
Khorasib Granite, Aunis Tonalite Gneiss Kairab Complex gabbro, diorite. Khorasib Granite Gneiss (?)	D_3: Regional fabric (s_3) in granitoid gneisses which contain schist xenoliths bearing earlier fabric (s_1/s_2), mineral lineation.	Jakkalskop charnockite, alaskitic batholiths (Aus, Kubub, Anib), granitoid batholiths (Kunguib, Tschauchaib), gabbroids (Konip).	
	D_2: Close asymmetric folds in layered gneiss and schists, local refoliation of s_1 by s_2, mineral lineation. Amphibolite metamorphism, migmatisation.		D_2: Regional fabric, isoclinal to tight folding, local refoliation. Amphibolite metamorphism, metatexis.
Kairab Complex (basal portion).Volcano-sedimentary succession. Intrusive augen gneiss and ultramafic plugs (pretectonic).	D_1: Regional fabric (s_1) parallel to lithologic layering (s_0). Isoclinal folds (F_1) in grey gneiss. Amphibolite metamorphism, migmatisation.	Garub Sequence volcano-sedimentary succession with significant carbonate. Tsirub augen gneiss (pre-/post-D_1). Magnettafelberg serpentinite (pretectonic).	D_1: Regional fabric, isoclinal to tight folding. Amphibolite metamorphism, metatexis.

ing (Hoal, 1989). Hence the sense of movement in the shear zone south-east of Haiber Hill is sinistral (Fig. 10), while sense of movement in the HFSZ is inferred to be dextral (Fig. 4). Associated with this widespread shearing event are a number of tight, often reclined, folds (F_5), local thrusts, and a well defined stretching lineation (l_5). The latter indicates both strike-slip and dip-slip movement. The presence of prograde biotite in basaltic andesites of the Haiber Flats Formation reflects medium to upper greenschist facies metamorphism.

A late phase of deformation (D_6) is suggested by crenulation folding and kinking (F_6) of ss shear planes and the common occurrence of a crenulation lineation (l_6). Conjugate fractures associated with D_6 rather than D_5 (cf. Hoal, 1985) define a pattern which corresponds to the orientation of late- to post -tectonic basic and acid dyke swarms. Retrograde metamorphism in the form of widespread alteration is probably associated with this episode of deformation. A subsequent phase of folding and warping (F_7) about an east-north-east trending axis has resulted in the bending of both shear planes and the s_3 fold axial plane of the Urusib synclinorium.

Late-stage faults show a variable orientation, but are commonly parallel or transverse to basin margins, i.e. north-west or north-east trending. North trending faults may be younger and possibly of post-Sinclair (Aubures or Nama) age. The brittle nature of these faults is indicated by commonly associated breccia, while quartz veining is a characteristic feature. In the absence of stratigraphic marker horizons, older faults can usually be distinguished from their younger counterparts by the transcurrent rather than vertical sense of movement.

The degree of deformation and associated metamorphism within the Sinclair Sequence increases further to the west and south of the Awasib Mountains. This is indicated by the intense shearing of the Urusib Formation at Hauchab and the medium to high grade deformation and metamorphism within the Konipberg Formation (correlated with the Barby Formation by McDaid, 1978). The influence of the Pan-African Damaran Orogeny on the NMC has been severe along the coast of Namibia (Kröner and Jackson, 1974) and has resulted in low angle thrusts to the east. Possible effects of the Pan-African orogeny on the AMT must, therefore, be taken into account.

The degree to which Pan-African metamorphism is evident in the AMT may be assessed by interpolation between illite crystallinity isolines and extrapolation of the biotite isograd established for Pan-African outcrops by Ahrendt *et al*. (1977). Fig. 11 illustrates that the AMT lies close to the Hb_{rel}>130 isoline which suggests that the grade of metamorphism attributable to the Pan-African orogeny did not exceed "very low grade" (i.e. $Hb_{rel} \approx 130$, which is equivalent to temperatures lower than 300-360°C). Extrapolation of the biotite isograd is less easily achieved but was assumed to be sub-parallel to the Hbrel isolines. According to this interpretation, biotite grade metamorphism during the Pan-African should be confined to the AMT outliers (Hauchab and

Fig. 10: Isoclinal s-fold defined by "quartz porphyry" dyke in sheared meta-andesite of the Haiber Flats Formation. Inferred sense of movement is sinistral.

Fig. 10: Isoclinal s-fold defined by "quartz porphyry" dyke in sheared meta-andesite of the Haiber Flats Formation. Inferred sense of movement is sinistral.

Uri Hauchab) and not recorded further east within the AMT proper or the Konipberg Formation. The presence of metamorphic biotite within the HFF basaltic andesites and Urusib Formation sediments suggests that the late-stage AMT crust has undergone an episode of metamorphism unrelated to the Pan-African event.

Conclusions

(i) The middle to late Proterozoic Awasib Mountain terrain (AMT) comprises early- and late-stage crustal components that are correlated with the Namaqualand Metamorphic Complex (NMC) and Sinclair Sequence, respectively.

(ii) The mixed gneiss and amphibolite terrain of the Kairab Complex constitutes a major part of the early-stage crust of the AMT. Within this complex, a relatively well preserved volcano-sedimentary succession bears lithological resemblances to the Garub Sequence in the Central Zone of the NMC.

(iii) The post-Kairab Complex Aunis and Khorasib granite (*sensu lato*) gneisses in the early-stage crust of the AMT appear to have counterparts amongst the numerous granitoid batholiths in the NMC (Table 3).

(iv) The early-stage crust has undergone polyphase deformation (at least three episodes), the earliest phase being characterised by amphibolite grade metamorphism and migmatisation.

(v) Within the late-stage crust of the AMT, trough-hosted volcano-sedimentary successions (Urusib, Haiber Flats and Barby Formations) and high-level intrusive rocks (Saffier and Haisib Intrusive Suites, Bushman Hill Quartz Diorite, and Awasib and Chowachasib Granites) most closely resemble lithologies in the middle part, or second cycle, of the Sinclair Sequence (Tables 1 and 2).

(vi) Late-stage AMT rocks are strongly deformed (four episodes of deformation) and metamorphosed (greenschist facies) in comparison to lithologies of the Sinclair Sequence. If these differences are related to pre-Pan-African tectonomagmatic activity in the adjacent Central Zone of the NMC, then the highly deformed and metamorphosed Konipberg Formation may demarcate a palaeomargin to the south-west of the AMT.

(vii) Late bimodal dyke swarms in the AMT are correlated with similar dyke swarms in the Sinclair Sequence and are hence inferred to pre-date deposition of the Aubures Formation. The latter, formerly considered to be an integral part of the Sinclair Sequence, was probably deposited during early Pan-African rifting.

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