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A. REPORTS BY THE GEOLOGICAL SURVEY

PRELIMINARY REPORT ON THE GEOLOGY OF THE SOUTH-EASTERN PART OF DIAMOND AREA NO.2, SOUTH WEST AFRICA/NAMIBIA

by

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ABSTRACT

Preliminary results of detailed mapping in Area 2515 (Awasib) are presented. The area consists of a variety of igneous and sedimentary lithostratigraphic units most of which are considered to be equivalents of the Sinclair Sequence whereas the others are considered as basement to the former, possibly to be associated with the Namaqualand Metamorphic Complex. The terrain is situated just to the west of the type area of the Sinclair Sequence but separated from it by outcrops of basement rocks (Kumbis Complex), and it is not possible to trace stratigraphic units occurring there into the study area. However, several lithologic units, especially plutonic and sedimentary rocks, distinctly resemble certain units of the Sinclair Sequence, and have been correlated with these. On the other hand, some plutonic and volcanic assemblages display both a higher degree of deformation and metamorphism than would be expected from Sinclair rocks, and their inclusion in the Sinclair Sequence is in some doubt.

The supposedly oldest rocks, distinguished by pronounced deformational and metamorphic fabrics, are grouped in the Kairab Complex, subdivided into several lithologic units resembling those of the Namaqualand Complex, viz. the Garub-type sequence, Magnettafelberg serpentinite, biotite gneiss and late granitic intrusives.

The stratigraphic positions of the Aunis granodiorite and the Khorasib granite have not been elucidated; while the former may be part of the Naisib River Suite, the latter is younger and a possible correlate of the Tumuab Granite.

The Tsaurab and Haiber Flats formations are volcaniclastic successions resembling some units of the Sinclair Sequence. Whereas the Sinclair rocks are unsheared in the type area, the former are distinctly sheared and in places foliated. They have been intruded by a number of magmas ranging from basic and intermediate (Haisib Suite) to syenitic (Gorrasis syenite), granodioritic (Amsib granodiorite) to granitic (Awasib granite); the latter resembles the Nubib Granite of the Sinclair area and may be a correlate.

The Urusib Formation, some 2 000 m thick, consists of conglomerate, quartzite and shale. Considered formerly as a correlate of the Kunjas Formation, it is now tentatively correlated with the Guperas Formation.

The coarse-grained red Chowachasib granite seems to have intruded the Urusib succession; it is the youngest major intrusive rock in this area and possibly belongs to the Gamsberg Granite Suite.

Five successive phases of deformation have affected the rocks in this area, the two older ones only the basement successions, the three later ones also the supposed Sinclair correlates. The metamorphic fabric of the pre-Sinclair successions originated during phases D_1 and D_2 while undergoing amphibolite-grade metamorphism. D_3, of post-Urusib age, led to the formation of open folds and a prominent set of shear planes which during D_4 were kink-folded and crenulated. During a D_5 event, some pre-existing tectonic planes were bent on a large scale around an E- to ENE-trending axis. Metamorphism associated with the D_3 to D_5 phases has probably not exceeded the greenschist grade.

UITTREKSEL

Voorlopige resultate van 'n gedetailleerde kartering in Gebied 2515 (Awasib) word aangebied. Die area word deur verskeie magmatiese en sedimentêre litostratigrafiese eenhede beslaan waarvan die meeste as ekwivalente van die Opeenvolging Sinclair beskou word; die res word as vloergesteentes van hierdie aanvaar wat moontlik met die Metamorfe Kompleks Namakwaland geassosieer is.

Die gebied lê net wes van die tipe-area van die Opeenvolging Sinclair, maar is deur dagsome van vloergesteentes (Kompleks Kumbis) daarvan geskei sodat dit nie moontlik is om stratigrafiese eenhede wat daar voorkom in die studiegebied te volg nie. Sekere litologiese eenhede, veral plutoniese en sedimentêre gesteentes, is duidelik soortgelyk aan sekere Sinclair eenhede en is daarmee gekorreleer. Daarenteen vertoon sekere plutoniese en vulkaniese groepe 'n hoër graad van albei deformasie en metamorfose as dit wat van Sinclairgesteentes verwag sou word en daar bestaan twyfel oor hul moontlike korrelasie met die Sinclair eenhede.

Die vermoedelik oudste gesteentes, gekenmerk deur 'n duidelike deformasionele en metamorfe maaksel, word in die Komplekse Kairab ingesluit wat in 'n aantal litologiese eenhede, soortgelyk aan sekere Namakwalandgesteentes, onderverdeel is, t.w. die Garubtipe opeenvolging, die Magnettafelbergserpentiniet, biotietgneis en laat granitiese intrusies.

Die stratigrafiese posisies van die Aunisgranodioriet en die Khorasibgraniet is nog nie vasgestel nie; terwyl eersgenoemde aan die Naisib River Suite kon behoort is laasgenoemde jonger en 'n moontlike korrelaat van die Tumuabgraniet

Die formasies Tsaurab en Haiber Flats is vulkanoklastiese opeenvolgings wat soortgelyk aan sekere Sinclaireenhede is. Terwyl Sinclairgesteentes egter in hul tipe-area nie geskuifskeur is nie, is eersgenoemde duidelik geskuifskeur en op plekke gefolieer. Hulle is deur 'n aantal magmas ingedring met 'n samestelling wat van basies en intermediêr (Haisib Suite) tot siënities (Gorrasissiëniet), granodiorities (Amsibgranodioriet) en granities (Awasibgraniet) wissel.

Laasgenoemde is baie soortgelyk aan die Nubibgraniet in die Sinclairgebied en kon sy korrelaat wees.

Die Formasie Urusib, ongeveer 2 000 m dik, bestaan uit konglomeraat, kwartsiet en skalie. Vroeër as 'n ekwivalent van die Formasie Kunjas beskou, word dit nou voorlopig met die Formasie Guperas gekorreleer.

Die grofkorrelrige rooi Chowachasibgraniet het blykbaar in die Urusibgesteentes ingedring; dis die jongste van die vernaamste intrusiewe gesteentes in die gebied en behoort waarskynlik aan die Gamsberg Granitiese Suite.

Vyf opeenvolgende vervormingsfases het die gesteentes van die studiegebied geaffekteer; die twee oudstes net die vloergesteentes, die drie jongeres ook die Sinclairkorrelate. Die metamorfe maaksel van die vloergesteentes het gedurende fases D_1 en D_2 ontstaan terwyl hulle metamorfose van amfibolietgraad ondergaan het. D_3, van na-Urusib ouderdom, het tot vorming van oop plooie gely wat gedurende D_4 geknikplooi is en 'n kartelingsfoliasie ontvang het. Gedurende 'n D_5 gebeurtenis is verskeie voorafbestaande tektoniese vlakke op 'n groot skaal om 'n O tot ONO strekkende as gebuig metamorfose geassosieer met D_3 tot D_5 het waarskynlik nie die groenskisgraad oorskrei nie.

1. INTRODUCTION

The area under investigation is situated largely within the Namib Desert and is bounded by latitudes 25°00'S and 26°00'S, and longitudes 15°00'E and 16°00'E. The area is approximately 11 200 km^2 in extent but outcrop is virtually restricted to the central-eastern part and makes up only a small portion of the total area. The Namib sand sea has largely restricted work to the eastern half of the area, where the terrain is characterized by rugged inselbergs rising steeply above sand- and scree-covered plains.

Although several reconnaissance studies have been conducted since the early sixties, the present study is the first detailed geological investigation of this area in its entirety and will also include both geochemical and isotopic aspects. Initial mapping of the Awasib Mountain area was carried out by geologists from Consolidated Diamond Mines during 1963, but these maps remain unpublished. Martin (1965) was the first to correlate felsites and reddish granites in the Awasib Mountains with the Nagatis Formation and Tumuab Granite respectively. He further assigned a Kunjas age to sediments forming a "small synclinorium" within the Awasib Mountains (*ibid*., p. 94). Watters (1974), after completing a study of the Sinclair Sequence to the east of the abovementioned area, produced a generalised geological map of the Sinclair, Helmeringhausen and Awasib areas (*ibid*., Fig. 33) in which he depicted the latter terrane almost entirely as part of the Sinclair Sequence. The most recent study by Harrison (1979), also on a reconnaissance scale, largely corroborated the ideas of Watters (1974), and was a first attempt to elucidate the palaeoenvironment of the "Guperas Formation" (Kunjas Formation according to Martin, 1965) and the overall structural evolution of the area.

Fieldwork carried out during the winter months of 1981 and 1982 has covered almost 80 per cent of the outcrop (Fig. 1) and, together with the results of petrographic studies and literature search, it is now possible to present a preliminary outline of the stratigraphic succession and geological history of the area. It should, however, be noted that many of the inferences made in this report are of a tentative nature and await not only further fieldwork, but the support from both geochemical and isotopic studies. The latter approach, particularly, is likely to be instrumental in the determination of the relationship between the Sinclair Sequence and the Namaqualand Metamorphic Complex.

2. LITHOSTRATIGRAPHY AND LITHOLOGIC UNITS

2.1 Introduction

The possibility exists that several of the rock types and successions described from the area under investigation may later prove to be unequivocal correlates of lithologic and lithostratigraphic units of the Sinclair Sequence which have already been adopted by the South African Committee for Stratigraphy (SACS), e.g. Nubib Granite and Barby Formation. In order to emphasise both the tentative and "unofficial" nature of the names used in this report, it has been decided to use lower case for the accompanying terms "Granite" and "Formation", e.g. Awasib granite and Haiber Flats formation.

The paucity of locality names has posed a great problem in this regard, and it was therefore convenient to invoke the uniqueness of the Nama language. Translations of what are considered to be suitable English adjectives have been used wherever possible, e.g. Kairab (old), Khorasib (coarse), Tsaurab (soft), Haisib (grey) and Amsib (green), However, in order to preserve continuity with existing names, e.g. Awasib, Urusib and Chowachasib, it has been necessary to corrupt the Nama language by omitting click symbols and occasionally using incorrect endings.

A proposed correlation of the geological succession within the area of the present investigation with that of the established lithostratigraphy of the Sinclair Sequence (SACS, 1980) is given in Table 1.

2.2 Kairab Complex

Although there is still considerable uncertainty as regards the age of "basement" in the study area, there are several reasons for suspecting a correlation with the Namaqualand Metamorphic Complex (NMC) rather than the Kumbis Formation of Watters (1974) or the Mooirivier Complex or Neuhof Formation of SACS (1980):

(i) The geographical proximity of similar rock types belonging to the NMC as mapped by Jackson (1976) and McDaid (1976, 1978) is compatible with their extension northwards into the area of the present investigation,

(ii) The pre-Sinclair Kumbis Formation of Watters (1974), which has subsequently been included in the Mooirivier Complex by SACS (1980), has been correlated with the NMC by Jackson (1975).

(iii) Radiometric ages of the Sinclair Sequence "cover" rocks, ranging from 1 080 ± 70 m.y. for the Gamsberg Granite Suite (Hugo and Schalk 1972; U-Pb zircon) to 1 392 ± 33 m.y. for shoshonitic lavas and intrusives of the Barby Formation (Watters 1982, Rb-Sr), overlap with the age of 1 000 my widely accepted for the Namaqualand event, and might suggest a genetic relationship between "basement" and so-called "cover". It appears also that the Sinclair Sequence and the NMC represent greatly differing tectonic regimes, and this concept favours the grouping of all high grade metamorphic rocks in the area under the sack term "Namaqualand Metamorphic Complex".

Accepting, then, that medium to high grade "basement" rocks of the Kairab complex may be correlated with similar rock types in the NMC, it should be further possible to group these lithotypes on the basis of established lithologic units in the Aus area as mapped by Jackson (1976) and McDaid (1978). The following subdivision is an attempt to highlight the similarities between the two complexes.

2.2.1 Garub-type Sequence

In the study area this succession is of fairly limited extent and occurs mainly in the extreme south-eastern corner, immediately west of the beacon Diar 10 and possibly also in the central part. Rock types are essentially similar to those recorded further south by Jackson (1976) and McDaid (1978), and include amphibolite, metaquartzite, biotite schist, epidote schist, tremolite schist, chlorite schist, ortho- and paragneiss and minor calc-silicate rocks. Reconstruction of a palaeoenvironment for this sequence is not possible at this stage, but a few tentative statements can be made:

(i) The general paucity of calcareous and pelitic rocks indicates that the basin of carbonate sedimentation envisaged by Jackson (1976, p. 68) has lensed out to the north.

(ii) In the south-east the regular contact between finely banded plagioclase amphibolite and overlying tremolite schist suggests a sedimentary or volcanic origin of the former, whereas the blastoporphyritic appearance of the amphibolite west of Diar 10 indicates a volcanic origin.

(iii) West of Diar 10 garnet-biotite schist and overlying magnetite metaquartzite may be correlated with shallow water semi-pelitic facies and associated iron formation mapped by Jackson (1976) and McDaid (1978).

2.2.2 Magnettafelberg-type Serpentinite

The only outcrop of this rock type is in the south-eastern corner of the study area where several light green serpentinite bodies are concordant with the regional foliation in the host tremolite schist. The serpentinite is also foliated in the regional sense and contains numerous irregular and crosscutting veins of white magnesite which have intruded along later fractures and shears. Associated talc schist and largely unfoliated talc-anthophyllite fels (competent dyke or sill?) may be genetically related to the serpentinite. A small digging on the south-western side has exposed an outcrop of asbestiform tremolite.

Although scree cover has blurred the age relationship between the serpentinite and the host rock, the lithological characteristics of the former are very similar to those of the Magnettafelberg serpentinite mapped by Jackson (1976). Such a correlation would support the concept of intrusion of several ultramafic bodies early on in the tectonic history of the area, followed by serpentinisation due to later metamorphism.

2.2.3 NMC-type Biotite Gneiss

This unit crops out throughout the area and appears to be a complex one, including several gneisses of different origin. The composition is generally granitic to granodioritic, but texture varies greatly from that of fine-grained mylonite gneisses to that of relatively coarse-grained augen gneisses. Layered biotite gneiss at two localities on the western side of the Haiber Flats is cut by both concordant and discordant pegmatite veins and dykes, here taken to represent neosome pro-

TYPE-AREA OF SINCLAIR SEQUENCE			AREA OF PRESENT INVESTIGATION		
Formation	Sedimentary and Volcanic Rocks	Intrusive Rocks	Intrusive Rocks	Sedimentary and Volcanic Rocks	Formation
AUBURES	Red quartzite, arkose				
	Conglomerate, minor shale				
			Basic dykes	Dolerite, microdiorite	
			Porphyritic felsic dykes	Microgranite, micro-granodiorite	
GUPERAS	Red, fine-grained porphyritic granite	Sonntag and Gamsberg Granites	Chowaehasib granite	Red, medium-grained syenogranite	
	Quarz porphyry lavas	Quartz porphyry intrusive	Microgranite porphyry		URUSIB
		Quartz porphyry dykes			
		Basic stocks and plugs	Basic stocks and plugs		
		Basic dykes	Basic dykes		
	Quartz porphyry lava, agglomerate, minor basic lava				
	Sandstone, siltstone conglomerate, minor orthoquartzite, shale			Lithic arenite, sub-greywacke, subarkose, siltstone, conglomerate, minor quartz arenite, shale	
	Red, fine- to medium-grained porphyritic granite	Nubib and Rooikam Granites	Awasib granite and Amsib granodiorite	Red to grey, fine- to medium-grained porphyritic granite/granodiorite	
	Syenite, diorite, monzonite	Spes Bona Syenite	Gorrasis syenite	Syenite	
	Gabbro, norite, anorthosite, picrite	Basic intrusives	Haisib suite	Granodiorite, monzonite, diorite, dolerite, gabbro, gabbronorite, troctolite	
	Feldspar porphyry trachyandesite	Dykes and plugs	Dykes and plugs	Feldspar porphyry trachyandesite	
BARBY	Sandstone, conglomerate, grit, tuffaceous sandstone				HAIBER FLATS
	Basic and intermediate lava and agglomerate, minor acid lava: interbedded quartzite, conglomerate and bands of felsic lava. Acid lava, ignimbrite, tuff			Basic and intermediate lava and agglomerate, minor acid lava and interbedded sediment. Porphyritic rhyolite, rhyodacite, lapilli tuff, minor basic lava.	
KUNJAS	Arkose, shale, grit, quartzite, conglomerate			Arkose, siltstone, grit, quarzite, conglomerate, lithic arenite, tuffite	TSAURAB
	Granite, granite porphyry	Tumuab, Haremub and Kotzerus Granites, Okarus Granite porphyry	Khorasib granite	Granite, granodiorite, granite porphyry	
NAGATIS	Acid lavas and ignimbrites, conglomerate, grit, arkose, shale, minor basic lava				
NAISIB RIVER SUITE, NEUHOF FORMATION, MOOIRIVIER COMPLEX, NAMAQUALAND METAMORPHIC COMPLEX			AUNIS GRANODIORITE and KAIRAB COMPLEX		

Table 1: Proposed correlation of lithostratigraphic units within the area of the present investigation with those of the Sinclair Sequence (as established by SACS, 1980).

duced through anatexis. The presence of scattered mafic xenoliths suggests an intrusive origin for several of the metamorphic rocks belonging to this unit. These xenoliths may be streaked out in the plane of the foliation.

Widespread shearing in the area has complicated the identification of older gneissic rocks due to the locally intense deformation of what may be lithotypes of a much younger age. Several suspected "basement" terrains may yet turn out to be mylonite zones in "cover" rocks. The occurrence of older rocks in such shear zones cannot, however, be excluded, since it is commonly difficult to recognize any progressive deformation from, say, protomylonitic granites through granite mylonite to mylonite gneiss or schist.

2.2.4 Late NMC-type Granitic Intrusives

The possibility of several foliated granitic and granodioritic rock types, which have been mapped as Khorasib granite and Aunis granodiorite respectively, belonging to an older suite of granitoids must be entertained. The inselberg nature of many of the outcrops often makes it necessary to identify a body on the basis of field and petrographic appearance alone, and the general paucity of contact relationships must lend a certain subjectivity to such groupings. However, it is interesting to note that ages obtained for late granitoids in the Namaqua Province are remarkably similar to some typical Sinclair granite ages, all falling within the range 1 000 - 1 300 my. (Table 2).

2.3 Aunis Granodiorite

Occurring mainly in the central-eastern part of the area near Aunis waterhole, this rock unit is distinguished from the granodioritic portions of the Khorasib granite by its generally foliated appearance and its content in mafic xenoliths. In thin section there is a marked similarity to the undeformed Amsib granite, blue-green hornblende and dark brown biotite being features of both. The Aunis granodiorite is apparently gradational with more tonalitic varieties and possibly also with a quartz-hornblende diorite (a possible correlate of the Tierkloof Diorite, Jackson 1976).

Less deformed tonalites in the extreme SE of the area have been intruded by medium-grained red Khorasib granite and therefore probably also belong to the Aunis unit. Further north protomylonitic textures are not uncommon and parallel the NW-trending regional foliation. The Aunis granodiorite is possibly a correlate of the Houmoed Granodiorite which, together with the Tierkloof Diorite and Klein Tiras Granite, is regarded by Jackson (1976) as belonging to the Naisib River Suite.

2.4 Khorasib Granite

This granite underlies a large area south of 25°20'S and shows considerable variability in both mineralogical composition and texture. It varies from a pink alkali granite to a grey-green tonalite, but is most commonly a mesocratic syeno- or monzogranite. In general, it would appear as if the more mafic phases are earlier and ,have been intruded by the lighter-coloured granitic phases. Several of the outcrops are devoid of contact relationships and again the unsatisfactory criterion of physical appearance must be used at these localities in order to place the rocks in the overall lithostratigraphy.

Where mafic xenoliths (schist and amphibolite) are common, the granite takes on a darker and more hybrid appearance. In parts this hybrid character has been accentuated by shear-induced mixing of intrusive rock and xenoliths. Incipient foliation and/or lineation is common throughout the granite; porphyritic varieties were apparently less resistant to deformation. Garnetiferous granite-aplite and fine-grained dykes are widespread and seem to be related to the Khorasib granite. Stress, which has produced a weak to moderate foliation in the massive granite, has been more effective in the sheet-like dykes, often transforming them into fine-grained mylonites.

In the extreme SE, the Khorasib granite has intruded

LITHOLOGIC UNIT	PROVINCE	AGE (m.y.)	REFERENCE AND METHOD
Pyramide Granite Gneiss	Namaqua	1082 - 1114	Kröner (1975), U-Pb zircon
Glockenberg Granite	Namaqua	1022 - 1086 1178 - 1194	Burger (1978), U-Pb zircon
Houmoed Granodiorite of Naisib River Suite	Namaqua/Sinclair	1078	Burger, in Jackson (1976), U-Pb zircon
Nubib Granite*)	Sinclair	1302 ± 20 1350 ± 40	Burger and Coertze (1975), U-Pb zircon Hugo and Schalk (1972) U-Pb zircon
Gamsberg Granite Suite	Sinclair	1080 ± 70	
		1092 ± 40	Mailing (in prep.), Rb-Sr
		1110 - 1210	Burger and Coertze (1973), (1976), U-Pb zircon, Rb-Sr

*) A Rb-Sr age of 1104 1: 88 m.y. obtained by Mailing (in prep.) for the "Nubib Granite" is believed to result either from misidentification of an intrusive rock belonging to the Gamsberg Granite Suite, or to indicate a period of isotopic re-equilibration.

Table 2: Radiometric ages of some granitic intrusive rocks in both the Sinclair and Namaqua Provinces.

both Garub-type rocks of the Kairab complex and Aunis granodiorite, whereas further north clasts of this granite are found in conglomerate of the Tsaurab formation. In the latter area there is also evidence for intrusion of the granite by diorite plugs belonging to the Haisib suite. Possible correlates of the Khorasib granite are the Kotzerus and Tumuab Granites of Von Brunn (1967), but not the Haremub Granite of Watters (1974). The latter is here considered to be a younger intrusive, since it has clearly intruded Kunjas Formation shales on Klein Haremub 1 and cannot therefore occupy the stratigraphic position assigned to it by Watters (1974, p. 19).

2.5 Tsaurab Formation

This largely sedimentary succession consists of clastic rocks overlying the Kairab complex and Khorasib granite unconformably. The formation is best developed south of 25°50'S, where steeply dipping cross-bedded lithic arenite and petromict conglomerate overlying Khorasib granite reach a thickness approaching 2000 m, with the contact zone consisting of a polymict breccia. The upper part of the succession becomes increasingly volcanic as the overlying rhyolites and ignimbrites of the Haiber Flats formation are approached. The contact zone is obscured by a swarm of NW-trending acid dykes, but the presence of epiclastic-pyroclastic (so-called "tuffite") material persists up to the lower-most aphyric basic flow. This serves as an arbitrary boundary between the two formations in this area.

North of 25°50'S there is a fairly continuous outcrop of clastic rocks overlying the Kairab complex and Khorasib granite unconformably, with the development of a coarse basal conglomerate containing clasts of metadiorite, gneissic granodiorite and granite. Towards the top of the succession there is a local development of dark siltstone beds which have not been recorded further south.

In general, the bedding dips steeply (60° to vertical) to the NE and later fracture cleavage and shear planes are parallel to this trend. As one proceeds northwards, however, the trend of this bedding-parallel foliation changes from NW to N. Many of the primary sedimentary structures have been obliterated by shearing, and this has adversely affected the interpretation of the palaeoenvironment of the succession. Nevertheless, such features as imbrication within pebbly lithic arenites, upward fining, and alternation of plane-bedded and cross-bedded strata are all indications of a fluvial environment. In addition, the coarse-grained nature and compositional immaturity of most of the sediments suggest a rapid uplift of the source, the latter comprising both granite and felsic volcanics. The occurrence of a significant amount of volcaniclastic material towards the top of the succession infers contemporaneous volcanism and sedimentation, with the provenance area (as indicated by cross-bedding) situated to the west.

Many of the features of the Tsaurab formation are also characteristic of the younger Urusib formation. It is possible that these formations may represent separate rift environments, each related to an independent event of granite intrusion and volcanism. The Tsaurab formation would appear to be the stratigraphic equivalent of the Kunjas Formation.

2.6 Haiber Flats Formation

This predominantly volcanic succession of basic, intermediate and acid rocks covers considerable tracts of the area. Sediments are rare and form only minor intercalations of stratified tuffite and rare quartzite. The contact with the underlying Tsaurab formation is essentially gradational and has been arbitrarily placed at the lowermost volcanic flow. In the south this flow is an aphyric metabasic which is overlain by porphyritic rhyodacite/dacite, rhyolite, lapilli tuff, agglomerate and felsic porphyry. This succession was previously believed to belong to the Nagatis Formation (Von Brunn 1967, p. 75).

The pile of acid volcanics, previously mapped as Guperas Formation (Watters 1974, Harrison 1979), extends to the north-west, where it builds a significant portion of the northern part of Awasib Mountain (1 752 m). Here relatively unaltered and undeformed flows, resembling the basaltic andesite described by Watters (1974, p. 34), overlie the acid volcanics. In general, however, it would appear that the degree of both deformation and metamorphism is variable and could possibly be related to a combination of shearing and intrusion by various bodies. Many of the rocks are best described as blastoporphyritic greenschists, and the prefix "meta" should be used in most cases. This is particularly true of those outcrops south of Chowachasib Mountain and at Bushman Hill.

The regional foliation is commonly parallel to "bedding" in the extrusives, with a strong development adjacent to the Haiber Flats. It has been suggested by Harrison (1979, p. 16) that shearing has both epidotised and amphibolitised basic rocks in this area. The metamorphic grade of the Haiber Flats formation poses a problem in that the occurrence of amphibolites is not expected in this "cover" sequence. However, the intercalation of easily recognizable lapilli tuff with orthoamphibolite on the south-eastern tip of Bushman Hill would seem to support the inclusion of such high grade mafic rocks in the Haiber Flats formation.

Intermediate rocks of the Haisib suite, together with bodies of Gorrasis syenite, have intruded the Haiber Flats formation both at Bushman Hill and on the south-eastern side of Awasib Mountain. Intrusion by the Amsib granodiorite in the central part of the area has led to a variety of contaminated rocks much like the Nubib Granite - Barby Formation hybrid rocks described by Watters (1974, p. 59). Younger intrusions such as the Awasib and Chowachasib granites do not appear to have undergone similar contamination where they have intruded basic rocks of the Haiber Flats formation. The likely correlate, then, of this largely volcanic succession would appear to be the Barby Formation. The absence of sediments, apart from minor intercalations of tuffite and quartzite, is probably due to a combination of erosion and lensing out towards the west.

2.7 Haisib Suite

This suite of intrusive rocks includes a variety of lithotypes ranging from granodiorite to troctolite which often show a close spatial association with basic volcanics of the Haiber Flats formation and possibly also with the Gorrasis syenite. This association may indicate a genetic relationship between the abovementioned lithologic units, and the possibility that they constitute a comagmatic suite should be considered. Watters (1982) has grouped similar rocks in the Barby Formation on the basis of both chemical and isotopic similarities.

The relative ages of intermediate and basic intrusive rocks within the Haisib suite are not yet certain, but it would appear as if the former are generally younger. This is illustrated by the high content of basic xenoliths in both granodioritic and quartz monzonitic intrusives on the eastern and southern sides of Awasib Mountain. Where the more basic intrusives of the suite have intruded dark lithotypes of the Haiber Flats formation, their distinction from the latter is difficult in outcrop due to the uniformly dark weathering colour.

Cumulate textures are not uncommon in the rocks of this suite, and the gabbronorite-troctolite body in the south-west of the area is likely to be a layered intrusion. The regional foliation is parallel to the cumulate layering which has an almost vertical dip. The general similarity to the Konip mafic complex (McDaid, 1976, 1978) is noteworthy, but the latter has a much stronger metamorphic imprint.

The Haisib suite has been intruded by the Awasib granite north of Haiber Hill, by the Chowachasib granite on the southern side of Chowachasib Mountain, and by numerous felsic and basic dykes throughout the area.

2.8 Gorrasis Syenite

Syenite bodies are relatively uncommon, occurring only in the southern part of Awasib Mountain, the south-eastern part of Bushman Hill and at Piekniek koppe. Although still unmapped, the presence of a large body of grey syenite has been noted on the farm Gorrasis and it was therefore decided to use this outcrop as the type locality. The coarse-grained hornblende-biotite syenites at both the Awasib Mountain and Piekniekkoppe localities bear a fair resemblance to the Gorrasis-type, whereas the syenite at Bushman Hill is pinkish, medium-grained and is petrographically a pyroxene-biotite syenite cumulate.

Contact relationships are best illustrated by the latter syenite, which has intruded the metabasic flows of the Haiber Flats formation and possibly also quartz diorite of the Haisib suite, but was itself intruded by NE-trending dolerite dykes. South of Awasib Mountain and at Piekniekkoppe, the syenite has been intruded by NW-trending porphyritic microgranite dykes and granite-aplite, both of which may be related to the Awasib granite. A weak foliation parallel to the regional NW-trend was observed at Piekniekkoppe.

The Gorrasis syenite does, in many parts, bear a strong likeness to the Spes Bona Syenite, but there is still uncertainty with regard to its relationship to the Haisib suite. If the latter does represent the commonly associated zone of monzonitic and dioritic intrusions described by Watters (1974, p. 54), then the above correlation would seem to be correct.

2.9 Amsib Granodiorite

Outcrop of this medium-grained hornblende-biotite granodiorite or tonalite is restricted to the central part of the area where it has typically intruded basic rocks of the Haiber Flats formation and the Haisib suite. The resulting contamination of the granodiorite through assimilation of basic material has been fairly thorough in several outcrops. Since shear-induced mixing has only taken place to a limited degree, it seems likely that portions of both the Haiber Flats formation and the Haisib suite were relatively plastic during intrusion by the granodiorite.

The generally undeformed nature of this granodiorite must serve to distinguish it from the Aunis granodiorite, which also contains blue-green hornblende and dark brown biotite. The Amsib granodiorite is unconformably overlain by cross-bedded lithic arenite of the Urusib formation in the central part of the area, and has furthermore been intruded by both basic and felsic dykes.

If the Haiber Flats formation is indeed the correlate of the Barby Formation, then it seems likely that the Amsib granodiorite can be correlated with what may be called “hybrid” Nubib Granite.

2.10 Awasib Granite

The major outcrop of this granite is in the central-western part of the area, where it builds the bulk of Awasib Mountain (1752 m). Here the granite is - essentially a red microgranite porphyry with occasional fluidal banding and the development of a granophyric texture. Further to the SE there is an outcrop of coarser-grained granite porphyry. At both localities, the granite has intruded acid and basic volcanics of the Haiber Flats formation, but the hybridisation seen in the Amsib granodiorite is not apparent here. Intrusion of quartz monzonite belonging to the Haisib suite has similarly resulted in negligible contamination of the granite. The exact relationship between the Awasib granite and Amsib granodiorite is not yet clear, but at this stage the possibility of both belonging to the Nubib Granite “suite” must be entertained.

Intrusion of the Awasib granite by coarse-grained Chowachasib granite has occurred in both the central and northern part of the Awasib Mountain. A similar relationship apparently exists between the Nubib Granite and Gamsberg Granite Suite in the Nubib Mountains (K. Schalk, pers. comm. 1982).

2.11 Urusib Formation

2.11.1 Distribution and Lithology

This entirely sedimentary succession, with a minimum thickness of 2 000 m, covers a large area north of the Urusib waterhole and may be subdivided into four different units:

Unit 4: laminated grey shale (about 300 m?)
Unit 3: pebbly lithic arenite, arkosic wacke, lithic wacke (exceeds 1 000 m)
Unit 2: siltstone, subgreywacke, laminated quartz wacke (50 to 100 m)
Unit 1: petromict conglomerate, lithic arenite, subarkose (about 600 m)

Units 1 and 3 are very similar in appearance, both being characterised by trough and planar cross-bedding which indicate a source area to the west and north-west (Harrison 1979, p. 31). There does, however, seem to be a facies change in the outcrop of Urusib sediments to the south-west of Chowachasib Mountain:

Unit 3: arkosic litharenite
Unit 2: laminated lithic wacke
Unit 1: quartz arenite (occasionally pebbly)

Some carbonate was found associated with lithic wacke, of Unit 2 but appeared to form veins rather than the 2 metre thick sedimentary horizon recorded by Harrison (*ibid*., p. 26) within "central-eastern Awasib".

Harrison (*ibid*., p. 23) proposed a 5-unit subdivision of what he regarded to be a Guperas Formation sedimentary succession. However, the lithological similarity between his "Units 3 and 4" makes distinction in the field practically impossible and a simpler 4-unit subdivision is herewith proposed. The retention of Unit 3, which is also very similar to Unit 1, is necessary due to the intervening siltstone-wacke of Unit 2.

2.11.2 Provenance and Palaeoenvironment

The granitic source proposed for these sediments by Harrison (1979, p. 32) need not necessarily be restricted to the "Nubib Granite" (Awasib granite and Amsib granodiorite, this report), but should be extended to include the Khorasib granite and granite gneisses of the Kairab complex. The most likely source for the abundant volcanic fragments in Unit 3 is the Haiber Flats formation, particularly the large outcrop in the northern part of Awasib Mountain. In each case, rapid uplift of the source is implied by the coarse-grained nature and compositional immaturity of much of the sediment in this succession.

Imbrication within conglomerates, upward fining, ripple marks, and the presence of both horizontal bedding and cross-bedding are all indications of a fluvial environment, more specifically a pebbly braided stream as noted by Harrison (*ibid*., p. 52). The latter worker has further interpreted the principal depositional facies as representing longitudinal bar and channel scour and fill sequences. Mud clasts occurring within much coarser-grained sediment are probably channel fill remnants. The succession would appear, then, to have been fairly rapidly laid down by periodic floods during which a high energy flow regime operated.

The suggestion that Unit 2 is lacustrine in origin (*ibid*., p. 54) is based on features such as parallel laminations, ripple marks and wavy bedding within the siltstone, and on the presence of the carbonate-chert association which Harrison regarded to be of playa lake origin. However, the occurrence of quartz and lithic wacke in much of this unit seems to indicate that clastic material must have formed a significant proportion of the fluvial load discharged into the lake.

Some structures regarded as ripples might actually be deformed sedimentary laminae which obtained a wavy appearance when portions of the siltstone-wacke were isolated and bent during dewatering.

The limited extent of the laminated grey shale in Unit 4 and its general similarity to parts of Unit 2 suggest that it may likewise be a lacustrine deposit. It is therefore likely that two cycles of sedimentation existed, each being initiated by uplift of the source area leading to the rapid fluvial deposition of coarse clastic material, and terminated by stable crustal conditions resulting in the predominance of lacustrine conditions. Harrison (*ibid*., p. 58) requires an additional "rejuvenation within source area" in order to explain his "Unit 4" gravels. This effectively excludes a period of tranquility after the deposition of earlier gravels succeeding the formation of a playa lake. From a consideration of both field criteria (the lithological similarity between "Units 3 and 4") and palaeoenvironment, it is clearly convenient to group "Units 3 and 4" and thereby recognize two cycles of sedimentation.

Harrison (*ibid*., p. 28) has recorded an eastward-fining of petromict conglomerate and pebbly lithic sandstone within "central-eastern Awasib", and a northward-fining of similar sediments within "north-eastern Awasib". Together with a proposed increase in maturity of the overlying gravels and pebbly sediments of "Unit 4", one may postulate a change from an alluvial fan, or braided streamflow fan, environment towards one of increasing maturity such as a meandering stream. It is also possible that the more mature sediment higher up in the succession may represent the more distal portions of a younger fan. It is interesting to note that many examples of the preservation of ancient alluvial fan deposits, with associated lake deposits, within fault-bounded basins have been recorded in the literature (Blatt *et al.*, 1980, p. 631). This is further illustrated by the general similarity of much of the Urusib formation to the older Tsaurab formation.

2.11.3 Age and Correlation

In the central part of the area, the Urusib formation unconformably overlies strongly foliated Aunis granodiorite, metabasic lithotypes of the Haiber Flats formation, and undeformed Amsib granodiorite. In the north this formation is underlain by diorite of the Haisib suite.

On the western tip of Chowachasib Mountain, sediments of the Urusib formation have been intruded by Chowachasib granite and later microgranite dykes. Xenoliths of feldspathic greywacke and quartz arenite are not uncommon within the granite on the SW flank of the mountain, and tilting of the bedding is observed to increase towards the granite. Basic dykes and sills have intruded the sediments at several localities and their general appearance and mineralogical composition would seem to indicate a correlation with the basic dykes recorded by Watters (1974, p. 73) as Guperas in age. Intrusion of the sediments in the central-eastern part of the area by a profusion of dykes, sills and plugs (or bodies) of porphyritic microgranite, or so-called "quartz porphyry", has similarly been attributed to late Guperas activity by Harrison (1979, p. 24). However, similar dykes have clearly intruded the post "Guperas" Chowachasib granite, and so these acid intrusions have not been correlated with the Guperas Formation in this report.

The Urusib formation is broadly correlated with the. Guperas Formation, but more specifically with the sedimentary succession of the Naudaus beacon area as observed by Watters (1974, p. 14).

2.12 Chowachasib Granite

Generally unfoliated medium- to coarse-grained biotite syenogranite is widespread in the northern and central parts of the area, where it builds the greater portions of Chowachasib Mountain (2063 m), Bushman Hill (1 690 m) and Guinasib Mountain (1 327 m), and a significant part of Awasib Mountain (1 752 m). The texture of the granite is variable and may strongly resemble that of the Khorasib granite, but unfortunately the two types have not been observed in contact. Although protomylonitic textures can be seen in discrete NW-trending shear zones, the widespread occurrence of both fractures and joints is an indication of a generally more brittle deformation.

On the south-western side of Chowachasib Mountain there is evidence, in the form of xenoliths and tilted bedding, for intrusion by this granite into both sediments of the Urusib formation and diorite of the Haisib suite. Chowachasib granite has also tilted sediments of Urusib age on the SW flank of Guinasib Mountain, and has intruded metabasic lavas of the Haiber Flats formation on the SE tip of Bushman Hill. In the central part of Awasib Mountain this granite has intruded both Haiber Flats formation lithotypes and Awasib granite.

The Chowachasib granite has itself been intruded by both basic and microgranitoid dykes which have apparently utilised a conjugate NE- and ESE-trending fracture system. The basic dykes are generally porphyritic dolerite, but also include diorite and rare porphyritic phonolite or nepheline microsyenite. The porphyritic microgranite, microgranodiorite and granophyre dykes are clearly younger than the Chowachasib granite, although they may be related to it, and cannot therefore be of Guperas age (Watters, 1974, p. 97) if this granite is a correlate of the Gamsberg Granite Suite.

3. STRUCTURE

In addition to an early pre-Sinclair phase of deformation, Harrison (1979, p. 14) has identified two post-"Guperas" deformational events as well as a late phase of normal and reverse faulting. In this report, the recognition of five phases of deformation (Table 3), three of which appear to have affected Sinclair correlates, would seem to require a revision of the popular idea that the Sinclair Sequence represents relatively undeformed "cover".

The earliest phase of deformation is designated D_1 and is defined by gneissic layering s_1 and a penetrative mineral lineation l_1, The associated mineral parageneses are high grade constituting a succession of biotite schist, amphibolite, augen gneiss, mylonite and migmatite. Folding of the foliation s_1 has produced tight and often irregular f_2 folds with a mineral lineation l_2, but no recorded axial planar cleavage. The two phases D_1 and D_2 have resulted in the typical "basement fabric" (amphibolite facies) and are pre-Sinclair in age.

Large open f_3 folds, with associated NNW-trending S_3 shears and mineral lineation l_3, constitute evidence for the first post-Urusib phase of deformation (D_3). The f_3 syncline in the vicinity of Urusib waterhole has a steeply dipping to overturned western limb and a moderately to steeply dipping eastern limb suggesting an asymmetric box fold morphology. Coaxial warps of the limbs have fold axial traces parallel to the shear planes which have developed so markedly in the core of the syncline.

Harrison (1979, p. 15) has suggested that shearing took place along earlier formed axial planar cleavage of the f_3 folds ("F_2" in his report). It is interesting to note that the trend of the shearing both here, within the "Haiber Flats Shear Zone" (*ibid*., p. 16), and further south, has an orientation (1450 to 1650 and steeply dipping) which bisects the angle formed by a conjugate set of fractures that have been utilised by later NE- and ESE-trending dyke swarms. It is proposed that these fractures represent a conjugate set developed as a result of primary dextral simple shear along a zone of conti-

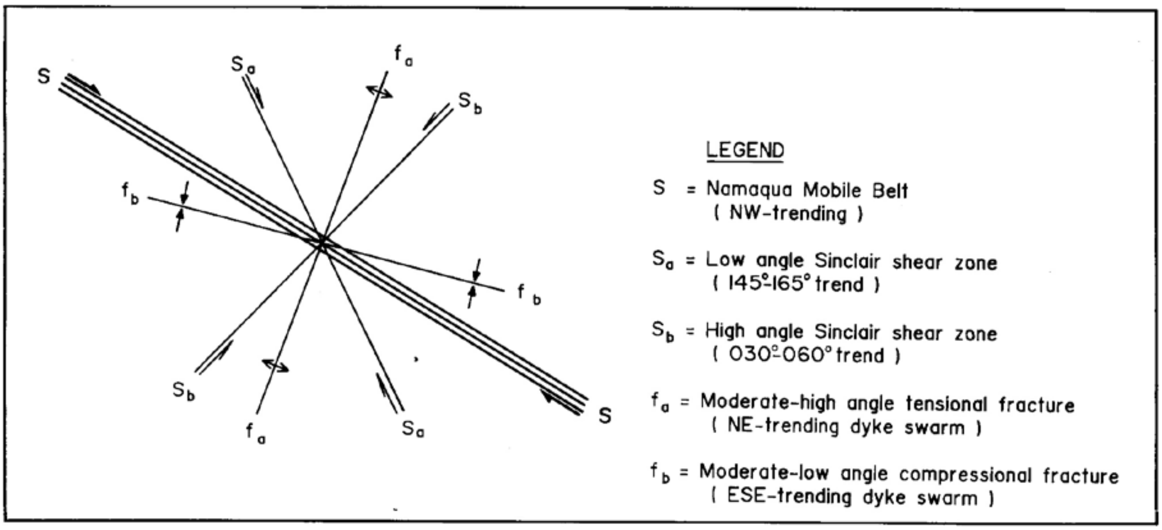

Fig. 2: Relationship of secondary shears and fractures in the Sinclair Sequence to primary shearing in the Namaqualand Metamorphic Complex (adapted from Katz 1981, Fig. 2).

nental dimensions (after Katz, 1981). It is not yet certain whether this major shear is represented within the area under investigation, or if shearing is only present in the form of conjugate Riedel shears, themselves secondary structures developed as a result of the primary shear zone (Fig. 2).

The results of shearing are in evidence throughout the area in the form of discrete mylonite zones and foliation marginal to these zones. The mineral lineation l_3 is commonly a stretching lineation where it is defined by elongated rock and mineral fragments. Several of the coarser-grained intrusives have acquired a gneissic foliation in, or near to, zones of shearing, although the "syntectonic or post-tectonic pegmatites" which are attributed to shearing by Harrison (1979, p. 16) can, in fact, be shown to be migmatitic in origin and therefore pretectonic in age. Basic rocks of the Haiber Flats formation and Haisib suite have apparently been converted to greenschists and epidiorites through shearing, but the presence of orthoamphibolites is difficult to relate to the effects of shearing alone, and these rocks may therefore represent inliers or rafts of pre-Sinclair age. In general, many rocks have a protomylonitic or cataclastic texture, and the ubiquitous presence of sheet silicates (muscovite, sericite, chlorite) and evidence of mineral strain are characteristic features.

South of Haiber Hill, the s_3 shear planes are bedding-parallel and generally dip steeply to the east or north-east. During the D_4 episode of deformation, these planes have been folded into NW- and NE-trending conjugate kink bands and crenulations (f_4) , with a well-developed axial planar cleavage S_4 and crenulation lineation l_4 in the more micaceous rocks.

The last major episode of deformation (D_5) resulted in the large scale arcuation about an E- to ENE-trending axis of three main features:

(i) The axial plane of the f_3 syncline in the central-eastern part of the area which is concave to the south-west;

(ii) "Bedding'-parallel cleavage of the westernmost Haisib suite mafic intrusion which is concave to the east;

(iii) The s_3 foliation in the southern part of the Haiber Flats formation which swings from a northwesterly trend in the south to a northerly trend towards the north.

Harrison (1979, p. 20) included, as further evidence for this phase of deformation, both the variability of plunge within the Urusib syncline and the rotation of associated lineations. However, the doubly-plunging attitude of the syncline was probably inferred from the distribution of various strata and is more likely to be associated with the formation of the syncline during D_3. Furthermore, the change in orientation of l_3 is more likely to be a result of the combination of both D_4 and D_5, rather than D_5 alone. Foliation and minor shearing in the Chowachasib granite appear to be the result of renewed movement along existing shear planes in the country rock, since there is no visible manifestation of either D_4 or D_5 phases. However, the latter have left a marked imprint only on incompetent or layered rocks and the granite might still, therefore, predate these phases.

Late faults, normal where the sense of movement could be determined, vary in trend from NW to NE (commonly north) and may be associated with larger scale faults which have been suggested as the cause of N- to NW-trending horst and graben structures in the Sinclair area (Watters, 1974, p. 17). In general, however, the recognition of such faults is difficult due to the paucity of stratigraphic markers, widespread shearing and the inselberg nature of the landscape. Where these zones of discontinuity are recognizable, they are usually associated with typical fault breccia and quartz veining.

4. METAMORPHISM

Within rocks of the Kairab complex, which have been correlated with the Namaqualand Metamorphic Complex, the fabrics are generally associated with mineral parageneses indicating medium to high grade conditions of regional metamorphism during D_1 and D_2 (Table 3). Amphibolite facies grade is suggested by the occurrence of brown hornblende, labradorite, and clinopyroxene in orthoamphibolites; by the assemblage garnet + sillimanite + K-feldspar in pelitic gneisses; and by the occurrence of dark brown to red biotite and andesine-labradorite in various amphibolites, gneisses and schists. A further indication of this grade is the stability of both anthophyllite and tremolite-actinolite in calc-silicate rocks of the Garub-type sequence. From similar considerations, Jackson (1976, p. 254) has assigned a pressure limit of 4.5-6 kb and a geothermal gradient of 30-50° C/km to amphibolite facies rocks around Aus. Such a high gradient would provide sufficient heat for the formation of migmatites which have been recorded in the present area of investigation.

Metamorphism which accompanied deformation phases D_3-D_5 was of a lower intensity and has typically altered rocks to the greenschist facies. The D_3 phase of deformation was largely an episode of mylonitisation which has produced cataclastic, protomylonitic and mylonitic textures in a variety of sedimentary, volcanic and intrusive rocks. The mineral assemblage albite + epidote + chlorite + sericite + quartz ± actinolite ± biotite ± calcite is widespread in both metabasic and metasedimentary rocks. The presence of green hornblende, as opposed to actinolite, in some of the metabasic rocks indicates the slightly higher grade typical of the albite-epidote-amphibolite facies. The metamorphic grade here is significantly higher than that recorded further east in similar lithotypes (Watters, 1974), where it has been suggested (A. Wilson, pers. comm., 1982) that the prehnite-pumpellyite to lower greenschist facies grade of metabasic rocks could have been produced by burial metamorphism alone.

Widespread sericitisation has made it difficult to determine the proportion of matrix in metasediments, as well as to distinguish between such sediments and devitrified and sericitised volcanics which do not have a porphyritic texture. This problem has been compounded by the similar alteration of intercalated tuffites. In general, however, the original igneous texture of metabasic rocks is usually recognizable where pyroxene has not been completely altered to actinolite, or olivine to serpentine. The formation of coronas around olivine in metagabbros has been attributed by Chinner (1978, p. 354) to instability as a result of cooling and/or increasing pressure:

anorthite + olivine = diopside + hypersthene + spinel

The relatively undeformed and unmetamorphosed

ROCK UNIT	MODE OF FORMATION	STRUCTURAL FEATURES	DEFORMATIONAL PHASE	METAMORPHIC GRADE
Basic dykes	Intrusive	NW- to NE-trending faults		
Felsic dykes	Intrusive			
		NE- to ESE-trending fractures		
Chowachasib granite	Intrusive	Continued movement on NW- and NE-trending shears?		
		f_5 open E- to ENE-trending warps	D_5	Low
		f_4 conjugate kinks and crenulations, NW- to NE-trending axial planar S_4, l_4 crenulation	D_4	Low
		f_3 large open NW- to NNW-trending folds, axial planar S_3 shearing (conjugate NE trending shearing?), l3 mineral	D_3	Low-medium
Urusib formation	Sedimentary Lesser intrusive			
Awasib granite	Intrusive			
Amsib granodiorite	Intrusive			
Gorrasis syenite	Intrusive			
Haisib suite	Intrusive			
Haiber Flats formation	Volcano-Sedimentary			
Tsaurab formation	Sedimentary			
Khorasib granite	Intrusive			
Aunis granodiorite	Intrusive			
Kairab complex	Volcano-sedimentary Intrusive	f_2 tight, irregular folds, l_2 mineral	D_2	Medium-high
		s_1 regional, l_1 mineral	D_1	Medium-high

Table 3: Proposed geological history for the area under investigation

nature of some Sinclair rocks can only be explained by their position at some distance away from any noteworthy shear zone and must, therefore, serve as a strong indication that shearing was the major mode of deformation of "cover" rocks. The logical extension of this, then, is that part of the rocks occurring within the Nam Shear Belt, (Watters, 1974) albeit of higher metamorphic grade, may be of Sinclair age but situated within a much older zone of crustal weakness.

5. DISCUSSION AND CONCLUSIONS

From a consideration of both the regional mapping and petrographic work done thus far, it is possible to make the following tentative conclusions:

(i) within the area of investigation there are rock types which may be correlated with both the Namaqualand Metamorphic Complex and the Sinclair Sequence (Fig. 1, Table 1);

(ii) The braided stream palaeoenvironment suggested by Harrison (1979) for the "Guperas" sediments has been confirmed, and it seems likely that this sedimentary succession also includes an alluvial fan deposit and various strata accumulated in a lake. Two cycles of sedimentation can be distinguished which were initiated by uplift of the provenance area consisting of both granites and lavas. It is likely that the Urusib formation was deposited in a fault-bounded basin or rift;

(iii) The general similarity between sediments of the Urusib formation and those of the Tsaurab formation implies a similar palaeoenvironment for the latter. Volcanics of the Haiber Flats formation are closely associated with sediments in the upper portion of the Tsaurab formation, so that together these two formations constitute a thick volcano-sedimentary succession. In this regard, it is interesting to note that the lithological assemblage "bimodal volcanics-quartzite-arkose" is considered by Condie (1982, p. 341) to be a reflection of lithosphere-activated continental rifting;

(iv) The recognition of at least five phases of deformation, two of which are pre- "cover", and of the variation in the grade of metamorphism from amphibolite facies in the Kairab complex to greenschist facies or transitional in Sinclair-type correlates, together indicate an area of greater deformation and metamorphism on the western margin of the Sinclair domain.

(v) Both shear planes, with associated retrograde metamorphism in the Kairab complex, and fractures are considered to be secondary structures developed as a result of primary dextral simple shear along the Namaqua Mobile Belt (Fig. 2). This idea has been adapted from the more global considerations of Katz (1981).

(vi) Porphyritic microgranite ("quartz porphyry") dykes, regarded to be of Guperas age by Watters (1974, p. 97), are shown to have intruded the post-Guperas Chowachasib granite. As in the case of a later basic dyke swarm, these dykes have utilised a pre-existing set of conjugate fractures which are related to the shearing pattern (Fig. 2).

A further consideration is the correlation that has been made by McDaid (1978, p. 134) between the deformed Konipberg sequence within the Namaqualand Province and the Barby Formation of the Sinclair Sequence. From descriptions of the Konipberg sequence in the literature (McDaid, 1976, 1978), this predominantly volcano-sedimentary succession would seem to bear a strong resemblance to the Tsaurab and Haiber Flats formations in the present area of study. Further correlations may exist on a basis of both lithological similarity and age between the Glockenberg granite and the Nubib Granite or Gamsberg Granite Suite, as well as between the Konip mafic complex and post-Barby mafic intrusives, especially the large gabbronorite body in the west of the study area. The intrusion of both conglomerates belonging to the Konipberg sequence and amphibolite of the Konip mafic complex by the Glockenberg granite is compatible with the above correlations.

Whatever the relationship between these rock types, it seems clear that Sinclair Sequence correlates may occur within the confines of the Namaqua Province, and the implied genetic relationship between them has at least two possible explanations:

(a) The juxtaposition of tensional and compressional environments, as suggested by Botha *et al.* (1979) for the evolution of the Koras lava and Namaqualand granite, may also broadly apply to the Sinclair-Namaqua relationship. It seems possible that the occurrence of Sinclair Sequence lithotypes within the compressional regime in the Namaqualand Metamorphic Complex could account for the presence of deformed "cover".

(b) The emplacement of granite diapirs into the upper crust of western North America is proposed by Gastil (1979) as a deformation mechanism capable of simultaneously producing extensional structures at the surface, steeply foliated rocks in a zone of compression at intermediate depth, and gneisses at greater depths.

The second possible explanation points to a partly vertical expression of the pressure regimes envisaged in the first, but is able to account for a greater variety of tectonic environments distributed through both space and time. This varied distribution of both tensional and compressional tectonics would appear to be a feature of the Sinclair-Namaqua relationship, and would further account for the similarity in recorded ages between "cover" and "basement" granites (Table 2). The "1 000 m.y." Namaqua event is significantly younger than the 1 392 ± 33 m.y. age (Watters, 1982) of the relatively undeformed Barby Formation basic volcanics which supposedly overlie the Namaqualand Metamorphic Complex. However, an age of re-equilibration of 1 151

± 32 m.y. for the same volcanics and comagmatic intrusives is related by Watters (1982) to the final stages of metamorphism and deformation associated with the formation of the Namaqua Mobile Belt.

The likelihood, then, is that deformation of a compressional nature continued below a "plane of decoupling" (Gastil, 1979, p. 543) after the deposition and extrusion of supracrustal rocks. The presence of deformed supracrustals such as the Barby Formation correlates of McDaid (1978) is possibly a result of the zone of decoupling being ruptured by diapirs, thus leading to metamorphism and deformation of rocks previously in a tensional regime only. According to Gastil (1979), the level of decoupling is determined by the rate of denudation as opposed to the rate of volcanic deposition. So, if volcanic deposition did exceed denudation to the west and south-west of the Sinclair area, the result would have been a rise in the level of decoupling and concomitant deformation of the overlying rocks.

What is significant about the space-time distribution of compressional and extensional tectonics in the North American Cordillera is Gastil's contention (*ibid*., p. 544) that the pattern cannot be explained by either plate collision or incipient intraplate rifting. It is agreed that the deformational effects resulting from plate collision would be largely compressional and would decrease in intensity away from the plane of collision. However, the process of intraplate rifting is here seen to be a likely consequence of the intrusion of a large volume of diapirs into the upper crust, whatever the origin of such emplacement might be. In this regard it is interesting to note that Kröner (1977) has not only proposed that the Sinclair Sequence accumulated in an aulacogen, but has further related its formation to tectonic activity in the intracratonic Namaqua Mobile Belt.

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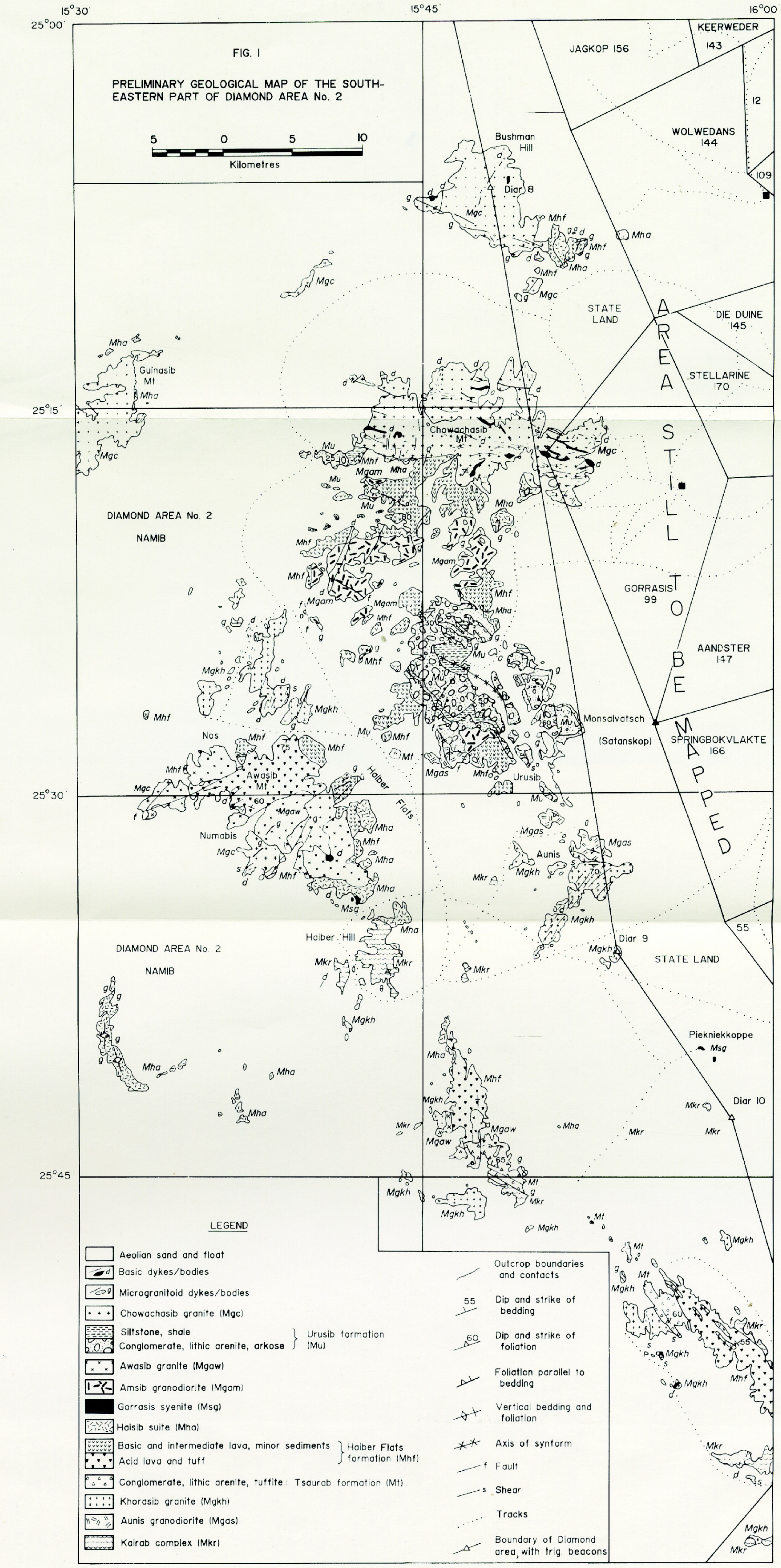

FIG. 1

PRELIMINARY GEOLOGICAL MAP OF THE SOUTH-EASTERN PART OF DIAMOND AREA No. 2