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THE OKAHANDJA LINEAMENT, A FUNDAMENTAL TECTONIC BOUNDARY IN THE DAMARA OROGEN OF SOUTH WEST AFRICA/NAMIBIA

by

R. McG. MILLER

ABSTRACT

The Okahandja Lineament forms the northern border of the 25–40 km wide Okahandja Lineament Zone in the north-east-trending arm of the Damara Orogen. The lineament has been compared to the median tectonic line separating paired metamorphic belts (Sawyer, 1978) which are here represented by the high temperature/medium pressure Central Zone north of the lineament and the low temperature/high pressure Southern Zone, the two being separated by the Okahandja Lineament Zone. Central and Southern Zones each contain their own distinctive granites and only the uppermost unit of the stratigraphic succession, the schistose Kuiseb Formation, is common to both zones. Southern and Okahandja Lineament Zones, though lithologically and aeromagnetically indistinguishable, are structurally distinct. The Okahandja Lineament is a huge monocline-like downfold of the whole Damara succession that exceeds 530 km in length. The lineament is clearly defined by remote sensing techniques but is difficult to pinpoint in the field for few of the rocks types in it show evidence of shearing. The Okahandja Lineament is believed to have been a fundamental line of weakness in the crust throughout the history of the Damara Orogen which (i) was the locus of late Nosib block faulting and acid volcanism, (ii) coincided with the margin of a deep early Khomas depository, (iii) separated regions in which the intensity and orientation of folds that formed during each of the three main phases of deformation differ, (iv) formed the margin of the Central Zone during uplift relative to the Southern Zone of possibly 24 km, (v) largely delineates the northern limit of the Donkerhuk Granite, and (vi) was the locus of strike-parallel post-Karoo faulting. The last Damaran movements on the lineament ceased prior to intrusion of the Donkerhuk Granite 523 ± 8 m.y. (Ma) ago. The Purros Lineament in north-western South West Africa/Namibia is similar in several respects to the Okahandja Lineament.

CONTENTS

I. INTRODUCTION

Geological mapping in parts of the Damara Orogen over the past 15 years has greatly improved our understanding of this fold belt but it has also become clear that the history of the orogen has been extremely complex. This paper describes a major linear feature within the orogen that is not obvious from single mapping projects but which appears to have been most important during evolution of the orogen. The stratigraphic subdivision, basic lithology and nomenclature of the Damara Sequence is given in Table I.

The north-easterly-trending, "eugeosynclinal" branch of the orogen, the Swakop Basin, can be divided into Northern (Transition Zone—Martin and Porada, 1977), Central and Southern Zones. Figure 1 shows the limits of the Swakop Basin delineated as accurately as possible from recent data. The Central Zone consists of medium- to high-grade metamorphic rocks with abundant intrusive granite and is characterised by a north-east-trending pattern of dome and basin structures and, along its southern margin, by a deep stratigraphic level of exposure. The Southern Zone is contrastingly characterised by low temperature/high pressure metamorphism (Sawyer, 1978) and by remarkably linear, tight to isoclinal folds (Hälbich, 1977; Porada and Wittig, 1975) and a high stratigraphic level of exposure (Martin, 1965). The Central and Southern Zones with their contrasting structural styles and stratigraphic levels of exposure are separated from each other by the Okahandja Lineament Zone which is between 25 and 40 km wide. The Okahandja Lineament forms the northern edge of the Okahandja Lineament Zone and the southern boundary of the Central Zone. With the exception of the Okahandja Lineament, the Southern Zone and Okahandja Lineament Zone are lithologically and aeromagnetically indistinguishable from each other and are often referred to together as the Khomas Trough (e.g.

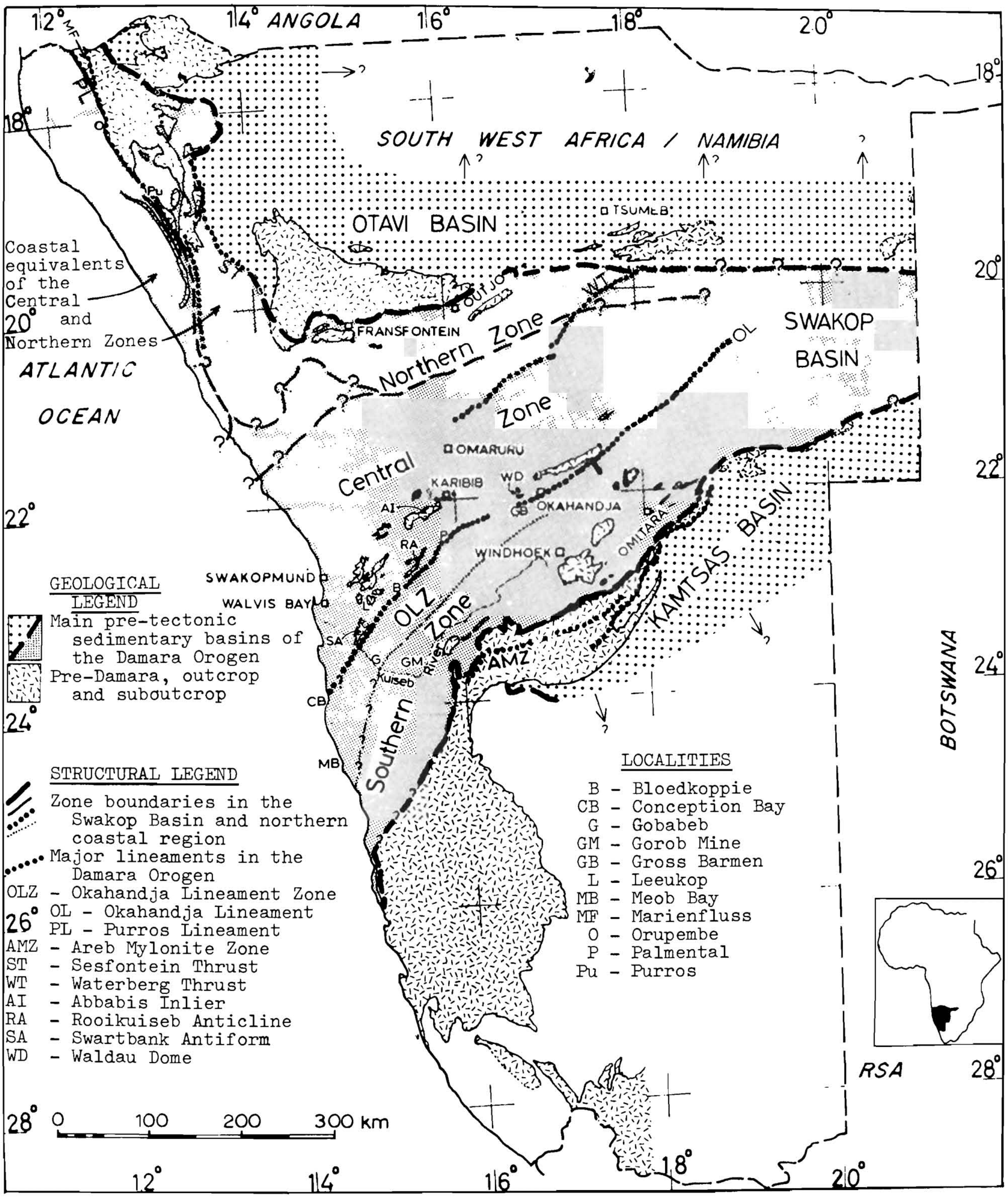

Figure 1

The main sedimentary basins of the Damara Orogen; Otavi, Swakop and Kamtsas Basins. The three zones of the Swakop Basin and their coastal equivalents are shown. The southern edge of the Swakop Basin overlaps the northern facies of the Kamtsas rocks; Otavi rocks occur along the southern edge of the Kamanjab Inlier (KI). Major tectonic lineaments of Damaran or probable Damaran age are: PL—Purros Lineament; ST—Sesfontein Thrust; WT—Waterberg Thrust; OL—Okahandja Lineament; AMZ—Areb Mylonite Zone; lineaments along the southern margin of the Swakop Basin only partially reflect the extensive thrusting in this region. Post-Damara cover has been omitted for clarity. Lineaments and some basement occurrences are repeated in Figures 4 and 5 to aid orientation.

TABLE I

Stratigraphy of the Damara Sequence and Associated Granites in the Southern Half of the North-east-trending Branch of the Damara Orogen

Southern Central Zone				Khomas Trough			
GROUP	SUBGROUP	Formation (maximum thickness (m))	Lithology	GROUP	SUBGROUP	Formation (maximum thickness (m))	Lithology
		Ida Dome Granite	Late- to post-tectonic alaskite			Donkerhuk Granite	Post-tectonic granite
		Red granites	Syn- to post-tectonic red granites				
		Salem Granitic Suite	Syn- to post-tectonic diorite, granodiorite, granite				
SWAKOP	KHOMAS	Kuiseb	Mica schist	SWAKOP	KHOMAS	Kuiseb (10 000?)	Mica schist; amphibolite (Matchless Member)
		Karibib (500)	Dolomite, limestone.			Auas (700)	Quartzite, schist, dolomite, amphibolite
		Tinkas	Schist, Calc-silicate				
		Chuos (600)	Mixtite, schist, iron formation			Chuos (600)	Mixtite, schist, amphibolite, iron-formation
	UGAB	Rössing (180)	Dolomite, schist, quartzite		KUDIS	(1 600?)	Dolomite, mica schist, graphite schist, quartzite
NOSIB		Khan	Feldspathic pyribole quartzite	NOSIB		Duruchaus	Phyllite
		Etusis (3 000)	Quartzite; rhyolite			Kamtsas (4 000)	Quartzite

Martin and Porada, 1977). Structurally, however, these two zones are quite distinct. The Okahandja Lineament, in contrast, has sharp lithologic, aerial photographic and aeromagnetic expressions. Although the Okahandja Lineament and Okahandja Lineament Zone are distinct structural entities the stratigraphic succession is continuous across them from Central Zone to Southern Zone. The juxtaposition of these major units of the suprastructure and infrastructure in this region was recognised by Gevers (1963).

There is both direct and indirect evidence indicating that vertical movements of elongate sections of the Swakop Basin took place at various times along marginal and intrabasinal lineaments. The distribution of volcanic rocks in the Damara Sequence and two records of associated faults (Frets, 1969; Miller, 1974, in press) indicate deep-penetrating fracture systems and major block faults in the pre-Damara crust. The Okahandja Lineament had a major influence throughout both depositional and tectonic history of the orogen and was probably controlled by large-scale crustal faults. Linear features in the northern coastal branch of the orogen suggest similar deep structural controls.

II. THE LOCATION AND PRESENT EXPRESSION OF THE OKAHANDJA LINEAMENT

The Okahandja Lineament is situated in the steep, slightly overturned north-western flank of the Khomas Trough. This feature also coincides with the south-eastern limb of some of the anticlines or domes on the south-eastern margin of the Central Zone (i.e. Rooikuiseb Anticline). The lineament can be traced on aeromagnetic contour patterns for 530 km from beneath the Namib dunes south of the Kuiseb River to 19°E where aeromagnetic coverage stops.

Because of the continuity of the stratigraphic succession across the lineament (particularly the Kuiseb Formation), it is a feature that is not readily detectable in the field nor on normal aerial photographs but it is very clear on LANDSAT imagery between Okahandja and the Kuiseb River. Its orientation parallel to the trend of major structures in both the Central and Southern Zones makes it all the more difficult to locate. It is not an obvious fault as shown by Söhnge (1964), nor is it a major shear zone as implied by Gevers (1963). Some shearing and even cataclasis produced well-developed penetrative fabrics in the more competent rock types in the lineament during the main stages of deformation at high temperatures, e.g. sheared vertical, layer-parallel granite veins in a 300 metre wide zone in the schist on the northern portions of the farms Gross Barmen 7 (Blaine, 1977) and Rüdenau Nord 6, sheared Nosib quartzite and rhyolite along the south-eastern edge of the Rooikuiseb Anticline (Miller, 1974), and mylonitic granite and calc-silicate bands in the Kuiseb Formation in the Namib Desert Park (Sawyer, 1978). This shearing is simply due to folding of competent rocks and is not associated with faulting or disruption of stratigraphy. Narrow vertical zones of slaty cleavage in the schist at Gross Barman (Gevers, 1963; Gevers *et al.*, 1963) and several very thin, vertical, discontinuous, post-foliation, layer-parallel breccia bands and mylonites in the Kuiseb Formation in the Namib Desert Park (Sawyer, 1978) are ascribed to late-stage brittle deformation. The latter have displacements of only a few metres. South-west of Rooikuiseb the schist in the Lineament Zone is characteristically much finer-grained than elsewhere and has developed a very good vertical fissility (Sawyer, 1978).

The Central Zone consists of a series of elongate, steep-limbed dome structures cored by basement and separated by the Kuiseb schist. At the Okahandja Lineament the stratigraphy folds down sharply and dips steeply into the lineament. To the south only the uppermost stratigraphic unit, the Kuiseb schist, is present. The Okahandja Lineament is thus a major very linear, monocline-like downfold of the whole Damara succession from the Central Zone into the Khomas Trough.

III. AEROMAGNETIC EXPRESSION OF THE OKAHANDJA LINEAMENT

Figure 2 shows five maximum-contrast sections from aeromagnetic contour maps across the Okahandja Lineament. West of 17°30′E the lineament stands out as a sharp line marking an abrupt change from the disturbed magnetics of the Central Zone to the quiet magnetics of the Khomas Trough. Sections a, b and c demonstrate this clearly. Disturbed patterns across anticlinal areas in the Central Zone (sections b, c and d) are due to the large variety of rock types exposed, namely pre-Damara metasediments, gneisses and granites, Nosib Group quartzites, Swakop Group marbles, quartzites and schists, and various Damaran granites. Large areas of the Central Zone that are underlain by either Kuiseb schist or Salem granite have a magnetic intensity and contour pattern similar to the Khomas Trough and consequently the lineament, although still detectable on the contour pattern, is not so well-defined where these units extend up to the lineament, e.g. south-east of Leeukop in the Namib Desert Park. In contrast the south-eastern edge of the Lineament Zone is not detectable on the aeromagnetic contour pattern (e.g. section a where the Lineament Zone is about 30 km wide).

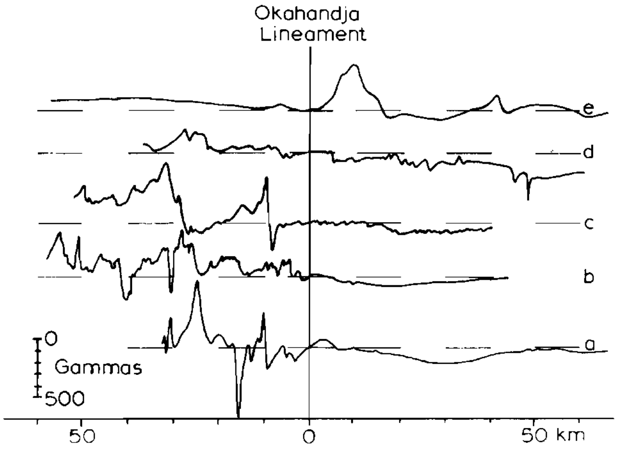

Figure 2
Maximum contrast sections drawn from aeromagnetic contour maps across the Okahandja Lineament. Location of sections shown on Figure 4; a—Sandwich Harbour; b—Rooikuiseb Anticline; c—Waldau Dome; d—Hochfeld area; e—north of Steinhausen.

East of 17°30′E the Khomas Trough magnetics are disturbed and similar to those of the Central Zone (sections d and e). This is related to a sudden change in the structural style of the Southern Zone. At about 17°30′E the linear fabric of the Southern Zone is replaced by a series of dome and basin structures in which quartzite, marble, schist and amphibolite of the lower stratigraphic levels of the Damara Sequence crop out. Some of the domes are cored by pre-Damara gneissic rocks (Hegenberger, 1978). There has clearly been large-scale uplift of the eastern end of the Southern Zone to expose deep stratigraphic levels and it is probable that the pattern of section e is produced by similarly varied rock types in sub-outcrop below the Kalahari cover which is about 100 metres thick in this area. The smoother profile of this section is probably due to the Kalahari cover and to the wider spacing of flight lines in the aeromagnetic survey of that area. All profiles in Fig. 2 show the average magnetic intensity of the Southern Zone to be lower than in the adjoining portion of the Central Zone.

IV. THE OKAHANDJA LINEAMENT AS A BOUNDARY BETWEEN THE LITHOLOGIES OF THE CENTRAL AND SOUTHERN ZONES

Rocks of the pre-Damara Abbabis Complex, the Nosib quartzites, the Rössing marbles, the various red granites and alaskites and most of the Karibib marbles and Salem Granitic Suite rocks do not occur south of the Okahandja Lineament. An exception to the above statement are the Nosib quartzites of the Lievenberg Dome which is situated in the Lineament Zone south-west of Okahandja (Fig. 4) in an area known only from reconnaissance mapping. Differentiates of the Salem suite protrude slightly into the northern edge of the lineament south of Leeukop and near the Bloedkoppie; they occur well inside the Lineament Zone near the Kuiseb River and in the Meob Bay–Conception Bay area but none are known south of the Lineament Zone.

Near the southern margin of the Central Zone the Karibib marbles undergo a south-eastward facies change to the fine-grained graphitic schists and calc-silicate bands of the Tinkas Member (Jacob, 1974; Sawyer, 1978). However, thin layers of Karibib marble still occur interbedded with these schists in the southernmost occurrences of the Tinkas Member which occupy the lineament between Palmental and the Kuiseb River.

The only unit extending right across the lineament into the Lineament Zone and across it into the Southern Zone is the Kuiseb Formation which does so just east of Palmental and in the Waldau Dome area.

The unit that characterises the Lineament Zone is the Donkerhuk Granite* which is quite distinct from the granites of the Central Zone in that it is a grey medium-grained muscovite-biotite granite containing scattered garnet and having a large number of pegmatites associated with it. The main granite occurs as a slightly arcuate band of plutons, stocks, plugs, dykes and sills (Faupel, 1974; Nieberding, 1976; Sawyer, 1978) which extends from just south-west of Okahandja to Meob Bay. It occurs up to 20 km inside the Southern Zone north of the Kuiseb River near Gorob Mine. From this area the band of intrusions cuts obliquely across the Lineament Zone towards the north-east and reaches the lineament in several places east of Palmental where most of the Tinkas Member is displaced and granite occurs in contact with Nosib rocks. West of the Waldau Dome a large body of granite disrupts the lineament and intrudes the Central Zone up to 6 km north of where the lineament should be. Dykes of the granite occur for another 10 km farther north (this break in the Okahandja Lineament is clearly visible on LANDSAT imagery). This is the only locality where the Donkerhuk Granite is known to extend for any distance into the Central Zone.

V. STRUCTURAL ELEMENTS OF THE LINEAMENT AND ADJOINING AREAS AND THEIR RELATION TO METAMORPHISM AND GRANITE INTRUSION

The structural elements are given in Table II. Numbering of deformation phases (D), folds (F) and fabrics (S) follows Sawyer (1978) and is applied regionally to the southern part of the Central Zone, the Lineament Zone and the Southern Zone. Additional deformation phases of local importance only are recorded by Smith (1965), Nash (1971), Kasch (1976) and Blaine (1977).

A. Central Zone

The Central Zone is characterised by two intense schistosities that are subparallel to bedding and to each other in fold limbs where they are consequently often difficult to distinguish. Designated S_1 and S_3 by Sawyer (1978), these are the S_1 and S_2 schistosities of Smith (1965), Jacob (1974) and Blaine (1977). The original nature of F_1 folds is uncertain because of the intensity of D_3 deformation but they were probably large-scale recumbent structures (Jacob, 1974; Sawyer, 1978) with axial planes dipping gently to the

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*This granite is named after the farm Donkerhuk 91 in the Karibib District and the SACS Working Group on the pre-Cape stratigraphy of SWA/Namibia has recommended the above spelling.

TABLE II

Numbering of Deformation Phases (D), S Fabrics and Metamorphic Events (M) in the Southern Central Zone, the Okahandja Lineament Zone and the Southern Zone as Used in this Study, and the Relationship of Events and Structures Recorded in Local Studies to this Numbering

Jacob (1974)	Sawyer (1978)			Blaine (1977)		Porada and Wittig (1975); Hälbich (1977)		Sawyer (in prep.)	Kasch (1978b)	This paper		
CZ	CZ	OLZ	SZ	CZ	OLZ	Okahandja area = OLZ	SZ	OLZ	SZ	CZ	OLZ	SZ
D_1 S_1	D_1 S_1	D_1 S_1	D_1 S_1	D_1 S_1			D_1 S_1	D_1	D_1 S_1	D_1 S_1	D_1 S_1	D_1 S_1
				M_1					$(D_2$ $S_2)$*			
									M_1			
M										G_1		
	D_2 S_2 M_1	D_2 S_f M_1	D_2 S_2 M_1				D_2 S_2	S_f M_1	D_3 S_3	D_2 S_2 M_1	D_2 S? M_1	D_2 S_2 M_1
										G_1		
D_2 S_2	D_3 S_3	D_3 S_3	D_3 S_3	D_2 S_2	D_4 S_1	D_1 S_1†	D_3 S_3	D_3 S_3	D_4 S_4	D_3 S_3	D_3 S_3	D_3 S_3
$(D_3$ $S_3)$*				$(D_3$ $S_3)$*	M_1							
$(D_4$ $S_4)$*				$(D_4$ $S_4)$*						G_2		
	M_2	M_2	M_2			M	M	M_2	M_2	M_2	S_f M_2	M_2
	(D_4)*	D_4a S_4a								(D_4)*	D_4	
		D_4b S_4b								G_4	$S//S_3$	
	(D_5)*	D_5	$(D_4$ $S_4)$*							(D_5)*	D_5	$(D_5$ $S_5)$*
D M_T	(D_6)*	D_6 S_6 M_T	$(D_5$ $S_5)$*M_T	D_5 S_5 M_2	D_5 S_2 M_2			D_4 S_4 M_T		(D_6)*	D_6 S_6 G_3 M	$(D_6$ $S_6)$* G_3 M_T

* These deformation phases appear to be confined to portions of one zone only

† Equated with S_1 of the Southern Zone by Porada and Wittig (1975) and Hälbich (1977)

M_T = thermal metamorphism caused by the Donkerhuk Granite.

G_1 and G_2 = Red granite and/or Salem granite; G_3 = Donkerhuk Granite; G_4 = alaskite and possibly Salem granite west or north-west (Blaine, 1977; Sawyer, 1978). Major dislocations (thrusts?) appear to be associated with these folds in places (Sawyer, 1979).

D_2 deformation produced megascopic to mesoscopic recumbent folds with north-westerly-dipping axial planes along which a poor S_2 is developed (Sawyer, 1978, 1979). On a regional scale development of F_2 structures is variable; Blaine (1977) records no equivalent of these structures in the Waldau Dome (Blaine's D_2 structures are equated with Sawyer's D_3 because of similarity in intensity, style and relationship to the Okahandja Lineament), whereas along the Omaruru River F_2 folds and S_2 are strongly developed at deep structural and stratigraphic levels but can be entirely absent at higher levels (J. A. Klein, pers. comm.).

The present structural style of the Central Zone is largely the expression of the D_3 deformation which produced north-west-trending upright, steep-limbed elongate domes that were strongly modified in the area east of Walvis Bay by late-D_3 diapiric rise of a less dense, partially molten granitic basement into a denser cover sequence of marble and metapelite (Sawyer, 1978). The intensity of the associated S_3 fabric (S_2 of Smith and Jacob) is variable. East of Swakopmund it is vertical or dips steeply south-east (Smith, 1965; Jacob, 1974). Close to the Lineament F_3 structures are overturned to the south-east, axial planes having a variable inclination to the north-west as in the Rooikuiseb Anticline (Smith, 1965; Jacob, 1974). In most of the area east of Walvis Bay S_3 is inclined fairly steeply to the north-west (Sawyer, 1978). Equivalent structures in the Waldau Dome are southward vergent, overturned to recumbent folds (Blaine, 1977). All along the linear southern edge of the Central Zone the stratigraphy is folded down sharply in a gigantic F_3 monocline-like structure to produce the Okahandja Lineament.

Three subsequent phases of deformation, D_4–D_6, in the area east of Walvis Bay produced relatively small-scale folds, some of which have S fabrics. Jacob's (1974) F_3 structures are confined to the lineament but his north-west and north-east-trending F_4 structures which have axial planar crenulation cleavages have very similar orientations to and probably correspond with Sawyer's (1978) Central Zone F_4 and F_5 structures respectively. It is uncertain to which of these latter deformation phases minor north–south (Smith, 1965) and east–west folds (Nash, 1971) belong. Similarly, Blaine's (1977) Central Zone F_3 structures cannot be related to any of Sawyer's F_4–F_6 structures. D_5 in the Waldau Dome is related to intrusion of the Donkerhuk Granite (Blaine, 1977) and is thus equivalent to Sawyer's (1978) D_6 of the Lineament Zone.

M_1 metamorphism is approximately D_2 in age and M_2 late- to post-D_3 (Sawyer, 1978). Extensive intrusion of granite occurred between the D_1 and D_2 events, between D_2 and D_3 and subsequent to D_3 (Sawyer, 1978; Blaxland *et al.*, 1979). An M_2 geothermal gradient of between 40 and 60 °C/km has been calculated for the Central Zone (Haack, 1976; Sawyer, 1978).

B. Okahandja Lineament Zone

The principal fabric is a vertical to steep north-westerly-dipping S_3 schistosity which parallels the trend of the lineament, imparts a strong fissility to the rocks of the zone and is axial planar to tight to isoclinal upright folds. East of Walvis Bay S_3 strongly crenulates an early S_1 biotite lamination which is oblique to bedding. In some of the more micaceous schists a penetrative foliation that is defined by biotite and dips gently to the north-west was referred to as S_f by Sawyer (1978). This was not observed as an axial planar fabric to any folds and its relationship to S_3 is often obscure. Locally, however, Sawyer (1978) did find it cut and curving slightly into sharply-defined hair-line S_3 planes which often also mark the boundaries to thin layers or lenses of slightly differing composition in which the intensity of S_f varies considerably (Fig. 3). He suggested that S_f was metamorphic in origin and D_2 in age.

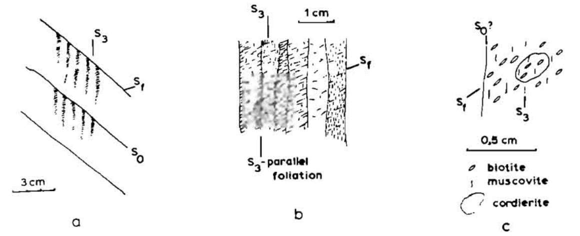

Figure 3

Various S_3/S_f relationships in the Okahandja Lineament Zone: (a) vertical pressure solution S_3 cleavage in graded beds at Gross Barmen, micas strongly reorientated parallel to north-westerly-dipping S_f; (b) narrow vertical bands of differing composition which contain a weakly developed S_3 foliation and are bounded by sharply defined hair-line planes that are parallel to S_3, S_f varies in intensity from band to band—area east of Walvis Bay and Gross Barmen area; (c) post-tectonic cordierite enclosing S_3 and S_f—Gross Barmen.

Post-D_3 structures appear to be associated with the intrusion of the Donkerhuk Granite. Early F_4 folds are tight steep north-westerly-dipping structures which fold S_3 and have a crenulation cleavage in their hinges. Later F_4 folds post-date the earliest Donkerhuk pegmatites and are tight north–south-trending structures with a steep easterly or westerly-dipping fracture cleavage in the hinges. Thin breccia and mylonite bands between 5 cm and one metre wide and up to 2,5 km long have been assigned to a tentative D_5 phase of deformation (Sawyer, 1978). These displace early Donkerhuk pegmatites by about 20 metres but are cut by later pegmatites. D_6 structures are open folds, kink bands and crenulation cleavages produced by intrusion of the main mass of the Donkerhuk Granite.

At Gross Barmen, west of Okahandja (Fig. 4) an intense north–east-trending vertical schistosity (pressure solution banding in the more pelitic rocks) is axial planar to open to tight upright folds defined by bedding (Hälbich, 1977; Porada and Wittig, 1975; Blaine, 1977; Sawyer, in prep.). This fabric is referred to as S_1 by Hälbich (1977), Porada and Wittig (1975) and Blaine (1977). However, Sawyer (in prep.) has recognised earlier gently-inclined isoclinal folds in this area and since the vertical fabric has all the characteristics of the S_3 cleavage in the area east of Walvis Bay it is equated with it. Hälbich (1977) calculated a 52 per cent shortening in this region during this phase of deformation (D_3).

Over much of the Gross Barmen area biotite has been reorientated to define a gently northward-dipping foliation which in places is clearly post-S_3 (Fig. 3) but in others is cut by S_3 or a younger S_3-parallel fabric (Fig. 3). This is identical to S_f east of Walvis Bay and has been designated as such by Sawyer (in prep.). It is helictically enclosed by cordierite and andalusite porphyroblasts of the Donkerhuk thermal aureole. The earliest Donkerhuk Granite veins intrude along the northern edge of the lineament on the farms Gross Barmen 7 and Rüdenau Nord 6. These were intensely sheared and are extremely well-foliated but are shown in thin section to have recrystallised completely and show no signs of strain. Intrusion of the main mass of Donkerhuk Granite produced vertical north–east-trending D_6 kink bands with an associated axial planar cleavage (D_5 of Blain, 1977). The S_3 fabric, F_6 folds and associated mineral growth are particularly well illustrated by Gevers (1963).

The magnetic expression of the Okahandja Lineament is the southern edge of the Central Zone. The photographic expression is a little broader and extends to the southern limit of the dark Tinkas Member schists. However, Sawyer (1978) has found that structural elements define the lineament as a zone 30 km wide where it is crossed by the Kuiseb River. Blaine (1977) notes that his S_1 schistosity of the Lineament Zone (S_3 in this paper) occurs over a zone

25 km wide immediately south of the Waldau Dome. This zone of open upright folds is between 15 and 20 km wide south of the Donkerhuk Granite east of 16°E (Porada and Wittig, 1975). The whole outcrop area between Conception Bay and Meob Bay is part of and contains all the lithological characteristics of the Lineament Zone (Miller *et al.*, 1976) which must be approximately 40 km wide here. Thus in terms of both structure and lithology the lineament is a zone between 40 and 25 km wide which broadens gradually to the south-west.

As in the Central Zone, M_1 was syn-D_2 and M_2 immediately post-D_3 (Sawyer, 1978). Intrusions of Salem granite both predate and post-date D_3 (Gobabeb area). The earliest Donkerhuk pegmatites in the area east of Walvis Bay are folded by late D_4 folds and displaced by D_5 breccia bands. Intrusion of the main mass of the Donkerhuk Granite and the accompanying thermal metamorphism were D_6 events. Sawyer (1978) has calculated an M_2 geothermal gradient of about 40 °C/km for this zone.

C. Southern Zone

Two intense south-eastward vergent sets of overturned folds with accompanying S fabrics characterise the Southern Zone. F_1 folds have been recognised in the southern (Hälbich, 1977; Porada and Wittig, 1975; Sawyer, 1978) and northern (Porada and Wittig, 1975) portions of the zone but these two regions are separated by a belt containing a bedding-parallel foliation ($S_1//S_2$) in which fold closures are absent (Porada and Wittig, 1975). S_1 is oblique to bedding in the northern portion of the zone (Porada and Wittig, 1975; Sawyer, 1978) but becomes bedding-parallel farther south (Porada and Wittig, 1975). S_2 becomes more intense southwards and S_1 becomes difficult to recognise (Hälbich, 1977; Porada and Wittig, 1975; Sawyer, 1978). East of Windhoek S_1 is the most intense fabric (Kasch, 1976, 1978b). Sawyer (1978) has calculated a shortening of between 50 and 80 per cent during D_2 in the Southern Zone.

D_3 deformation of the Southern Zone produced minor north-trending asymmetric folds with axial planes that dip steeply westwards (Hälbich, 1977; Porada and Wittig, 1975; Sawyer, 1978). Local F_4 and F_5 structures in the west are ascribed to intrusion of the Donkerhuk Granite.

In the Omitara area (Fig. 4) at the southern edge of the Southern Zone, Kasch (1976, 1978a) recognises four phases of folding (Table II). Two of these (D_1 and D_3 of Kasch) correspond in intensity and style to D_1 and D_2 of the Southern Zone but are separated from each other by a local and relatively minor phase of deformation (D_2 of Kasch, 1978b). F_4 structures in the Omitara area correspond in intensity, style and orientation to F_3 structures in the rest of the zone.

An early phase of regional metamorphism (M_1) (Sawyer, 1978; Kasch, 1978a) is considered D_2 (Sawyer, 1978) or pre-D_2 (Kasch, 1978a) in age, whereas M_2 is immediately post-D_3 (Kasch, 1978a; Sawyer, 1978). Hälbich (1977), Hoffer (1975) and Porada and Wittig (1975) recognise only one phase of regional metamorphism which reached peak temperatures post-tectonically, i.e. post-D_3. The Donkerhuk intrusion and thermal overprint is post-M_2. An M_2 geothermal gradient of about 20 °C/km has been calculated for this zone (Sawyer, 1978; Blaxland *et al.*, 1979).

D. Correlation of Deformation Phases in the Central, Lineament and Southern Zones

Assuming that neither of the regional metamorphic events M_1 and M_2, were diachronous, it is possible to suggest a correlation of deformation phases in the three structural zones. On the basis of textural evidence Sawyer (1978) considers M_1 to be coeval with D_2 throughout and has proposed that D_1 and D_2 were the same events in all three zones. D_3 was clearly the same event in the Central and Lineament Zones. M_2 is immediately post-D_3 and it is thus probable that D_3 was a single event throughout all zones despite the vastly different magnitude and style of D_3 structures in the Central and Southern Zones. The D_4–D_6 events in the Central Zone have no equivalent in the Lineament or Southern Zones (except Blaine's D_5 structures) where all post-D_3 structures are related to intrusion of the Donkerhuk Granite. On the basis of this correlation it would appear that Kasch (1976, 1978a) has recognised a local deformation event in the Omitara area at the southern margin of the Southern Zone which is post-D_1–pre-D_2 in age.

VI. THE HISTORY OF THE OKAHANDJA LINEAMENT

Several features suggest that the Okahandja Lineament has had a long history.

A. Provinence of Nosib Quartzites in the Central Zone

The earliest evidence suggesting the possibility of a major fault parallel to and in the vicinity of the present-day lineament is controversial. Porada and Wittig (1977) and Martin and Porada (1977) suggest, on the evidence of cross-bedding measurements from Etusis Formation quartzites along the margins of the Abbabis Inlier, that a major portion of the rocks were derived from the south-east and propose a horst and graben type environment with a topographic high in the region now occupied by the Khomas Trough. The data is not conclusive for a large number of readings indicate supply of sediment from the south-west as well, i.e. parallel to the trend of the Swakop Basin. Furthermore, Sawyer (1976) records supply directions from the south-west and west for Etusis quartzites in the Swartbank Antiform and nothing at all from the south-east. The evidence for a provinence area to the south-east is thus scanty and needs to be substantiated by many more readings for the area between the Abbabis Inlier and the lineament—if the effects of folding can be satisfactorily removed.

B. Acid Volcanic Rocks in the Nosib Group of the Central Zone

Stronger evidence for block faulting of Nosib age in the vicinity of the present location of the lineament is provided by the presence and distribution of acid volcanics in the Nosib Group of the Central Zone (Fig. 4). They form a thick unit along the south-eastern edge of the Rooikuiseb Anticline (Miller, 1974) and have been strongly sheared by movements on the lineament. A special search has been made for similar volcanics in the Nosib exposures farther west and north without success. Porada and Wittig (1977) report pre-Swakop quartz porphyry dykes cutting the Etusis quartzites on the south-eastern margin of the Abbabis Inlier. This appears to be an isolated occurrence.

Two thin volcanic layers have been located in the Nosib succession 35 km south-east of Karibib. A large portion of the Nosib succession described by Blaine (1977) in the Waldau Dome is homogeneous and massive, consists mainly of quartz and microcline microperthite and has a texture and appearance very similar to the highly recrystallised acid volcanics of the Naauwpoort Formation farther north (Miller, 1972, 1974, in press). These rocks have the composition of alkali granite and although described by Blaine (1977) as biotite-microcline gneiss are considered by us to be acid volcanics.

Figure 4 clearly shows that the Nosib volcanics of the Central Zone occur only very close to lineament. Like the acid volcanics of the Naauwpoort Formation (Frets, 1969; Miller, 1974, in press) those of the Central Zone were probably related to deep penetrating block faults which must have been located close to or along the Okahandja Lineament to produce their observed distribution.

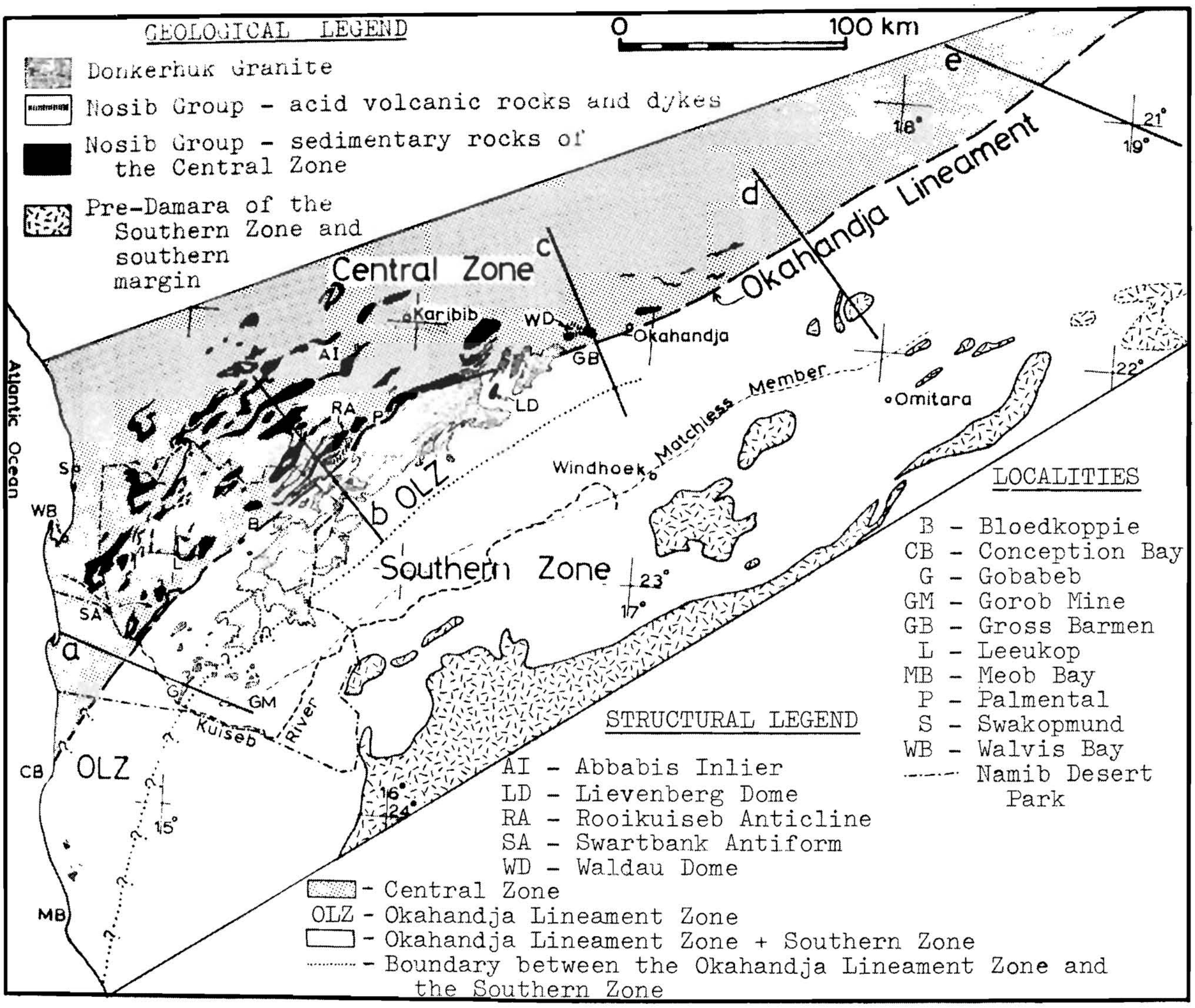

Figure 4

Distribution of Nosib Group sedimentary and acid volcanic rocks in the Central Zone. Note the location of most of the volcanic rocks close to the Okahandja Lineament. The locations of aeromagnetic sections a—e of Figure 2 are shown.

C. The Early Khomas Sedimentary Basin South of the Central Zone

Along the southern edge of the Central Zone, the Tinkas Member, the lateral pelitic equivalent of the Karibib Formation, provides the first clear evidence of a deep post-Nosib depository in the region of the Khomas Trough. This unit consists largely of an alternating, well-layered sequence of dark fine-grained graphitic schist and calc-silicate rock that was deposited by turbidity currents (Sawyer, 1976, 1978; H. R. Porada, pers. comm.). Thickness changes, rare cross-beds (Sawyer, 1976, 1978) and direction of decreasing thickness of interbedded Karibib marbles, point to source areas to the west and north where the Karibib Formation carbonates are thick. A rapid southward increase in thickness of the Tinkas Member from 500 metres to 3 000 metres (Sawyer, 1978) coincides with the position of the Okahandja Lineament and probably marks the boundary between a gradually deepening Central Zone and a rapidly deepening Khomas Trough.

In the Gross Barmen–Okahandja area the Tinkas Member appears to be absent and only typical Kuiseb schists are present but in these rocks graded bedding is a common feature. Similarity of the depositional environments in the area east of Walvis Bay and in the Gross-Barmen area suggests that the rapid southward deepening of the early Khomas basin was a feature of the whole southern edge of the Central Zone and was associated with reactivation of the Okahandja Lineament.

D. Syntectonic Evolution of the Okahandja Lineament

Large-scale vertical movements during the Damara tectogenesis can be inferred from structures characteristic of the Okahandja Lineament or its vicinity.

The influence the Okahandja Lineament had on the development of F_1 and F_2 structures is unknown because of the strong D_3 expression of the lineament. That it may have been active during D_1 is suggested by the difference in vergence directions of the F_1 folds in the Central and Southern Zones, i.e. east and south-east respectively. The difference in vergence directions of F_2 folds is similar and also suggests a major boundary of D_2 age between the Central and Southern Zones.

The sharp monoclinal downfolding of the stratigraphy along the southern edge of the Central Zone into the Okahandja Lineament together with the localisation of overturned to recumbent F_3 folds along the southern edge of the Central Zone points to uplift of the Central Zone relative to the Southern Zone. This probably involved large-scale, gravity-induced slumping of the Damara cover sequence along the southern edge of the Central Zone onto the Southern Zone along the lines suggested by Hälbich (1977). Temperature and pressure immediately after D_3 are given by M_2 mineral reactions. These indicate a northward rise in temperature across the Southern Zone and a maximum of about 660 °C in the western part of the Central Zone (Hoffer and Puhan, 1975; Sawyer, 1978). There does not appear to be a significant temperature jump across the lineament. Important pressure differences are indicated by thermodynamic calculation of M_2 reaction equilibria; about 4 kb is recorded for the Central and Lineament Zones and about 7 kb for the Southern Zone (Sawyer, 1978).

The last major phase of movement in the Lineament Zone was a reversal of D_3 movements and resulted in an uplift of the Southern Zone relative to the Lineament and Central Zones of about 10 km prior to or during intrusion of the Donkerhuk Granite. Thermodynamic data for mineral equilibria in the Southern Zone indicate a difference of about 2,8 kb in the pressure for M_2 and that for the later Donkerhuk thermal overprint (Sawyer, 1978). The Lineament Zone which, at the time of intrusion of the granite, had "welded" itself onto the southern edge of the Central Zone, shows that there was no concomitant uplift of the Central Zone (Sawyer, 1978). The above pressure differences imply a 10 km relative uplift of the Southern Zone yet there is no foliation in the Lineament Zone which is clearly related to this phase of movement. However, it is possible that the contradictory S_3/S_f relationships provide an answer to this problem (see Discussion).

Structures associated with the relative uplift of the Southern Zone and intrusion of the Donkerhuk Granite show the style of deformation in the Lineament Zone changing from ductile to brittle. The early F_4 folds east of Walvis Bay have an axial planar crenulation cleavage whereas later F_4 structures that fold the earliest Donkerhuk pegmatites (which preceded the granite itself) have a fanned fracture cleavage. Highly sheared concordant granite veins at the northern edge of the Lineament Zone on Gross Barmen 7 (Blaine, 1977) and the adjoining farm Rüdenau Nord 6, probably belong to the same phase of deformation. Later pegmatites occurring nearby are quite undeformed.

Brittle deformation (D_5) produced narrow, discontinuous, layer-parallel breccias and mylonites and resulted in slight fracturing and displacement of early Donkerhuk pegmatites. Intrusion of the main body of the Donkerhuk Granite post-dates all these movements and produced a new set of structures (F_6) in the surrounding schist. No shear zones have been reported in the Donkerhuk Granite where it cuts the lineament west of Waldau Dome.

The Gawib Granite (Jacob, 1974; Bunting, 1977) which cuts the Okahandja Lineament about 20 km south-west of the Bloedkoppie (Fig. 4) is also entirely post-tectonic for it displaces all structures in the surrounding Damaran rocks and itself lacks fabrics which can be related to movements on the lineament.

Major lithological boundaries in the lineament have also been the site of strike-parallel, post-Karoo faulting, e.g. the contact between Nosib and Tinkas rocks along the southern edge of the Rooikuiseb Anticline.

VII. THE AGE AND GEOCHRONOLOGICAL EXPRESSION OF THE OKAHANDJA LINEAMENT

Some members of the Salem Granitic Suite in the area east of Walvis Bay have been sheared by movements along the lineament, others post-date these movements (Sawyer, 1978; Blaxland *et al.*, 1979). The Donkerhuk Granite which is syn D_6, cuts the Okahandja Lineament and was intruded after uplift of the Southern Zone relative to the Central Zone of about 10 km (Sawyer, 1978). It has an age of 523 ± 8 m.y. (Ma) (Blaxland *et al.*, 1979). Final movements on the Okahandja Lineament are, therefore, older than 523 ± 8 m.y. Post-tectonic Salem granite from the farm Goas 79, 30 km south of Karibib, has an age of 515 ± 20 m.y. (Blaxland *et al.*, 1979). None of the pre-D_3 members of the Salem suite occurring near the Lineament Zone have been dated yet so the upper age limit of D_3 movements on the Okahandja Lineament is not known.

Although peak temperatures of the M_2 metamorphism were reached prior to 523 ± 8 m.y., thermal activity in the Central Zone continued for about another 60 m.y. The youngest ages recorded are 468 ± 8 m.y. for the Rössing alaskite (Kröner and Hawkesworth, 1977), 479 ± 10 m.y. and 461 ± 19 m.y. for the youngest members of the Salem suite along the Omaruru River and 474 ± 26 m.y. for leucogranite in the same area (Haack *et al.*, in prep.). These alaskites and granites intruded during the last Damaran thermal event which was also responsible for the setting of mineral ages. K/Ar ages of biotite, from localities across the orogen, cluster about an average of 485 m.y. (Haack and Hoffer, 1976). They show no change across the Okahandja Lineament and therefore clearly indicate that Central and Southern Zones had cooled to the same temperature (~300 °C) about 485 m.y. ago.

Thereafter the rate of cooling of the granite-rich Central Zone appears to have been slower, possibly due to radiogenic heat generated by the granites (Haack, 1976). This is clearly shown by fission track ages of garnet, epidote, vesuvianite and apatite (Haack, 1976). The garnet, epidote and vesuvianite have fission track annealing temperatures of about 260 ± 20 °C for a cooling rate of 1 °C/m.y. (Haack, 1976). Their ages are all younger than 400 m.y. in the Central Zone and greater than 400 m.y. in the Lineament and Southern Zones. The limit of the <400 m.y. ages is the southern limit of the Central Zone, i.e. the Okahandja Lineament (Fig. 5). One exception is the area west of Okahandja where the Donkerhuk Granite cuts the lineament and one result from this region gives an age of >400 m.y. which is characteristic for the Donkerhuk Granite area as a whole.

Apatite has a fission track annealing temperature of about 80 °C for a cooling rate of 1 °C/m.y. (Haack, 1976). The apatite ages of the Donkerhuk Granite area are similar to those for the Central Zone and show no difference across the Okahandja Lineament. They rise sharply on the southern edge of the granite. These results show a distinct difference in the low-temperature cooling history between the granites of the Central Zone (probably having a higher overall component of radiogenic heat which caused annealing fission tracks in minerals over a long period of time) and the Donkerhuk Granite (having a low component of radiogenic heat).

VIII. DISCUSSION

Blaine (1977) could not recognise any of his Central Zone structures in the Lineament Zone and suggested that the rocks occupying the latter position were younger syntectonic deposits derived from uplift and erosion of the Central Zone during early deformation. This would imply a major unconformity in the Kuiseb Formation separating older more-deformed rocks from a younger less-deformed unit. He found no such unconformity and none has been revealed by detailed mapping elsewhere along the lineament (Smith, 1965; Jacob, 1974; Sawyer, 1978, in prep.). Furthermore, recognition of earlier structures in the lineament in the Gross Barmen area (Sawyer, in prep.) makes Blaine's suggestion most unlikely for present exposure levels.

The recognition of the strong vertical fabric of the Okahandja Lineament Zone as S_3 means that the correlation of this fabric by Hälbich (1977) and Porada and Wittig (1975) with S_1 of the Southern Zone is incorrect.

If deformation phases in the Central, Lineament and Southern Zones are related to one another by means of the M_1 and M_2 metamorphic events, assuming that these were regional and non-diachronous, M_1 being syn-D_2 and M_2 immediately post-D_3, then certain differences between Central and Southern Zones emerge.

The general response of the cover sequence to D_1 and D_2 deformation in the Central and Southern Zones was broadly similar in that overturned to recumbent folds formed. However, even at this early stage major differ-

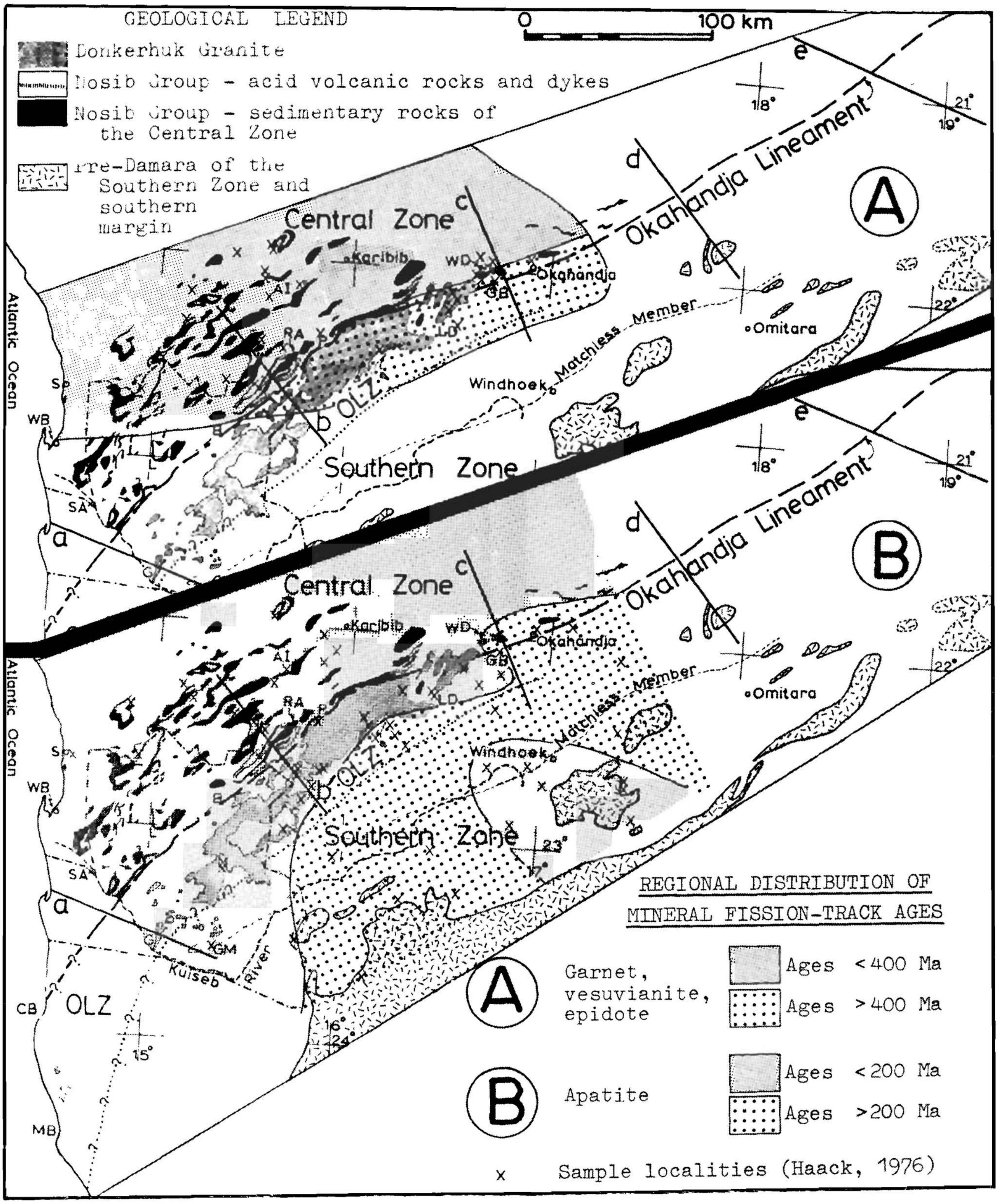

Figure 5

Distribution of mineral fission track ages across the Central, Lineament and Southern Zones of the Swakop Basin after Haack, 1976. A—Garnet, epidote and vesuvianite ages younger than 400 m.y. all occur north of the Okahandja Lineament. B—The boundary between the younger and older apatite ages largely follows the southern edge of the Donkerhuk Granite. In the Gross Barmen–Okahandja area where only Donkerhuk pegmatites are present the boundary occurs just north of the Okahandja Lineament. An area of low apatite ages around Windhoek may result from local late-Damaran thermal activity that is represented by cross-cutting post-tectonic pegmatite dykes south of Windhoek (K. Schalk, pers. comm.).

ences existed between these two regions in that Central Zone F_1 structures are overturned to the east and Southern Zone F_1 structures to the south-east. In addition F_1 structures in the Central Zone appear to have been isoclinal with S_1 parallel to bedding, whereas S_1 is oblique to bedding in the northern part of the Southern Zone and only becomes bedding-parallel farther south. The different stress orientations required to produce the contrasting vergence directions of F_1 structures in the Central and Southern Zones and the different bedding/S_1 relationships suggest the presence of a major discontinuity of D_1 age between these two regions. Similarly, the poorly developed S_2 in the Central Zone and its changing intensity across the Southern Zone also suggest basic differences of D_2 age between these two regions. These differences still have to be explained and more work needs to be done in the Lineament Zone to try and trace D_1 and D_2 structures across it in an attempt to reconstruct the initial link between the Central and Southern Zones. One of the key areas in this regard is the northern edge of the Southern Zone where S_1 and S_2 fabrics pass into the Lineament Zone.

A further major difference between the Central and Southern Zones is the fact that intense deformation ceased at different times in each. D_2 in the Southern Zone was the last intense phase of deformation and resulted in shortening of between 50 and 80 per cent (Sawyer, 1978). The tight large-scale north-east-trending F_3 structures of the Central and Lineament Zones are in marked contrast to the minor north-trending F_3 folds of the Southern Zone. In the Central and Lineament Zones intense deformation extended to D_3 resulting in a 50 to 80 per cent shortening in the latter (Hälbich, 1977; Sawyer, 1978). The regional S_3 fabric of the Central Zone is clearly indicative of significant D_3 shortening in this region.

It is unlikely that the contrasting responses of the different regions to D_3 deformation can be ascribed entirely to juxtaposition of different structural levels and to the high temperatures, partial melting and extensive granite intrusion in the Central Zone. Further work is needed to explain, in terms of geodynamics if possible, the apparent difference in the D_3 stress fields of the Southern and Central Zones, and the lack of an obvious response in the Southern Zone to D_3 north-west–south-east shortening in the Central and Lineament Zones. The possible coeval nature of deformation phases across the Okahandja Lineament Zone needs to be authenticated or disproved by attempting to date rock-forming events which can be related to the different phases of deformation, e.g. granite intrusion in the southern part of the Central Zone and formation of mica selvedges on thrust planes that can be related to D_1 and D_2 deformation phases along the southern edge of the Southern Zone.

The S_f fabric which Sawyer (1978) has suggested may be of D_2 age presents problems in that there is evidence for it having both pre- and post-S_3 ages, i.e. it cuts and is cut by S_3. S_f is orientated at a high angle to S_3 and is only slightly bent into it in places (Sawyer, 1978, in prep.). S_3 is a very well-defined fabric which in places clearly developed by metamorphic differentiation (Fig. 3a). If S_f were pre-S_3 then it should have been strongly crenulated and would probably be strongly folded into and largely parallel to S_3. That this is not the case is indicative of S_f being post-S_3 (supported by textural relationships—Fig. 3a) and it is probably a metamorphic fabric as suggested by Sawyer (1978) that was produced during M_2 metamorphism. The sharp hair-line boundaries that "S_3" planes form in places between centimetre-wide microlithons of slightly differing composition in which the intensity of S_f varies considerably, and the slight bending of S_f into such planes (Fig. 3b), point to post-S_f movements (i.e. post-M_2) on S_3 planes or new S_3-parallel planes. This probably occurred during the 10 km rebound of the Southern Zone just prior to or during intrusion of the Donkerhuk Granite when deformation was changing from ductile to brittle as regional temperatures gradually fell. This could also explain the expression of S_3 both as a metamorphic banding cleavage, recrystallised in places where S_f is developed (S_3 pre-S_f—Fig. 3a), and as a sharply defined penetrative cleavage ("S_3" post-S_f—Fig. 3b).

Late-stage deformation also shows a difference between Central and Southern Zones. Three rather minor post-D_3 phases of deformation have been recognised in the Central Zone (Sawyer, 1978) whereas post-D_3 structures in the Southern Zone are all associated with intrusion of the Donkerhuk Granite.

Most of the movement in the Lineament Zone took place at moderately high temperature and pressures. Blaine (1977) has pointed out that the F_3 recumbent folds (his F_2) in the Waldau Dome which formed by ductile shear under confining pressures of 4–5 kb at about 650 °C and incorporated the underlying pre-Damara Abbabis Complex to a greater extent than F_1 structures, are inconsistent with similar gravity-induced structures by "thin-skin" deformation at high crustal levels. Similar pressures and temperatures for M_2 metamorphism (post-F_3) have been obtained by Sawyer (1978) 200 km farther to the south-east. The Okahandja Lineament is thus a deep-level structure which suffered high-grade metamorphism after large-scale vertical movement had taken place along it. Prograde reactions in the pelitic rocks in the lineament will have resulted in a high fluid pressure and extensive recrystallisation. Strained grains are rare and the only evidence of earlier cataclasis are narrow zones in the Gross Barmen area in which a fine slaty cleavage is developed (Gevers, 1963; Gevers *et al.*, 1963), thin granulated bands parallel to foliation in calc-silicate layers (Sawyer, 1978), foliated Salem and Aussinanis granite in the Lineament Zone (Sawyer, 1978) sheared granite veins south of the Waldau Dome (Blaine, 1977) and sheared quartzofeldspathic rocks of the south-eastern edge of the Rooikuiseb Anticline. This recrystallisation during M_2, together with the probability that much of the movement along the lineament was by ductible shear, could account for the absence of a broad and well-defined mylonite zone. Later structures show the response of the rocks to further deformation becoming gradually more brittle but only during the final stage of regional deformation in the zone did failure occur and only on a relatively small scale, resulting in the formation of the D_5 breccia-mylonite bands.

An estimation of the amount of D_3 uplift of the Central Zone relative to the Southern Zone is hampered by the vastly different structural styles of the two zones and by the lack of regional marker horizons in the Kuiseb Formation, but a figure can be obtained from a comparison of stratigraphic levels juxtaposed across the lineament zone assuming that: (i) stratigraphic units on the southern edge of the Central Zone extended into the Southern Zone, (ii) the upper part of the Kuiseb Formation in the Southern Zone is the lateral equivalent of the same stratigraphic level in the Central Zone. Sawyer (1978) found evidence for a post-D_3 rebound of the Southern Zone of about 10 km; the remaining Kuiseb schist in this region is estimated to be about·10 km thick (Martin, 1965) which compares well with the figure of 9,8 km measured at the northern edge of the Central Zone (Miller, 1972, in press). The Tinkas Member is 3 000 metres thick in its southernmost outcrops (Sawyer, 1978) and the Nosib Group exceeds 1 000 metres in thickness in places in the southern portion of the Central Zone. Juxtaposed stratigraphic levels suggest uplift of the Central Zone of about 24 km during D_3 deformation.

The Okahandja Lineament is thus a major syntectonic structural boundary within the Damara Orogen which has been traced over a distance of 530 km. It is suggested that it marks the site of a deep penetrating and fundamental zone of weakness in the crust of Nosib age or even older, and that it exerted a major influence throughout the sedimentary and tectonic history of the orogen.

The north-north-west-trending Purros Lineament in the Kaokoveld (Fig. 1), extending from just east of the mouth of the Mudorib River, through Purros, past Orupembe to the Kunene River, has many features which are similar to the Okahandja Lineament. It is the line marking (i) the beginning of a rapid change from deep stratigraphic levels of exposure in the east (Epupa Complex, Nosib Group, Ugab Subgroup) to high stratigraphic levels of exposure in the west (Kuiseb Formation), (ii) the eastern limit of interbedded volcanic rocks in the lower Swakop Group , (iii) the highest thickness gradients in the stratigraphic sequence (Guj, 1970, p. 72), (iv) a belt of intense shearing producing mylonitic and cataclastic gneisses (Guj, 1970, p. 72), (v) the site along which relative uplift of this domain took place to expose these deep tectonic levels, and (vi) the trace of large post-Karoo faults. The Purros Lineament also forms the boundary between an eastern granite-free zone of low temperature/high pressure metamorphism and a western zone of high temperature/medium pressure metamorphism. In the eastern zone a westward increase in temperature towards the lineament is indicated by the increasing anorthite content of oligoclase (Guj, 1970, p. 117); high pressures are indicated by the occurrence of kyanite 12 km north-east of Purros (Geological map of South West Africa, 1963), in Kuiseb schist in the Hoarusib River 25 km south-east of Okumutati and in the western flank of the Marienfluss valley about 10 km east of the lineament. The western zone is extensively intruded by granite, and schists of the Kuiseb Formation have largely been transformed to coarse-grained porphyroblastic gneiss; sillimanite is the stable alumunosilicate (Guj, 1970). Brucite is reported from some of the marbles (Guj, 1970, p. 123).

The synorogenic dynamic history of the Purros Lineament is not well known but appears to be entirely different from that of the Okahandja Lineament.

IX. SUMMARY

The Okahandja Lineament Zone is 25 to 40 km wide and separates the north-east-trending Central and Southern Zones of the Swakop Basin in the Damara Orogen. The northern edge of this zone, the Okahandja Lineament, is the longest linear feature in South West Africa/Namibia and is sharply defined on LANDSAT imagery and aeromagnetic contour maps. No large-scale brittle shear occurs and the present expression of the lineament is a major monocline-like downfold of the whole Damara succession along the southern edge of the Central Zone. The last movements in the Lineament Zone ceased prior to 523 ± 8 m.y.

The Okahandja Lineament is believed to have been a fundamental line of weakness in and parallel to the length of the north-easterly-trending arm of the Damara Orogen which (i) was the locus of early Nosib block faulting, (ii) served as an access channel for Nosib acid volcanics, (iii) coincided with the margin of a deep early Khomas depository, (iv) formed the margin of the Central Zone during its uplift relative to the Southern Zone of possibly 24 km, (v) largely delineates the northern limit of the Donkerhuk Granite and its associated pegmatites, and (vi) was the locus of strike-parallel post-Karoo faulting. The Okahandja Lineament Zone was the boundary between Central and Southern Zones during all phases of deformation and during a 10 km rebound of the Southern Zone. It separates two highly contrasting zones within the Damara Orogen. The Central Zone, north of the lineament, was subjected to high temperature/medium pressure metamorphism under a high geothermal gradient. It is characterised by numerous elongate, often diapirically modified antiforms, many of which expose the full Damara succession, by irregularly shaped synforms, and by a wide spectrum of syn- to post-tectonic granites. The Southern Zone, located south of the Lineament Zone, is occupied largely by one stratigraphic unit, the Kuiseb Formation. It underwent low to moderate temperature/high pressure metamorphism under a low geothermal gradient. Characterised by a very linear but asymmetric structural style, it contains only one main granite which is post-tectonic and occurs at its northern edge. The Purros Lineament in north-western South West Africa/Namibia is similar in several aspects to the Okahandja Lineament.

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R. McG. Miller,
Geological Survey,
P.O. Box 2168,
9100 Windhoek.

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