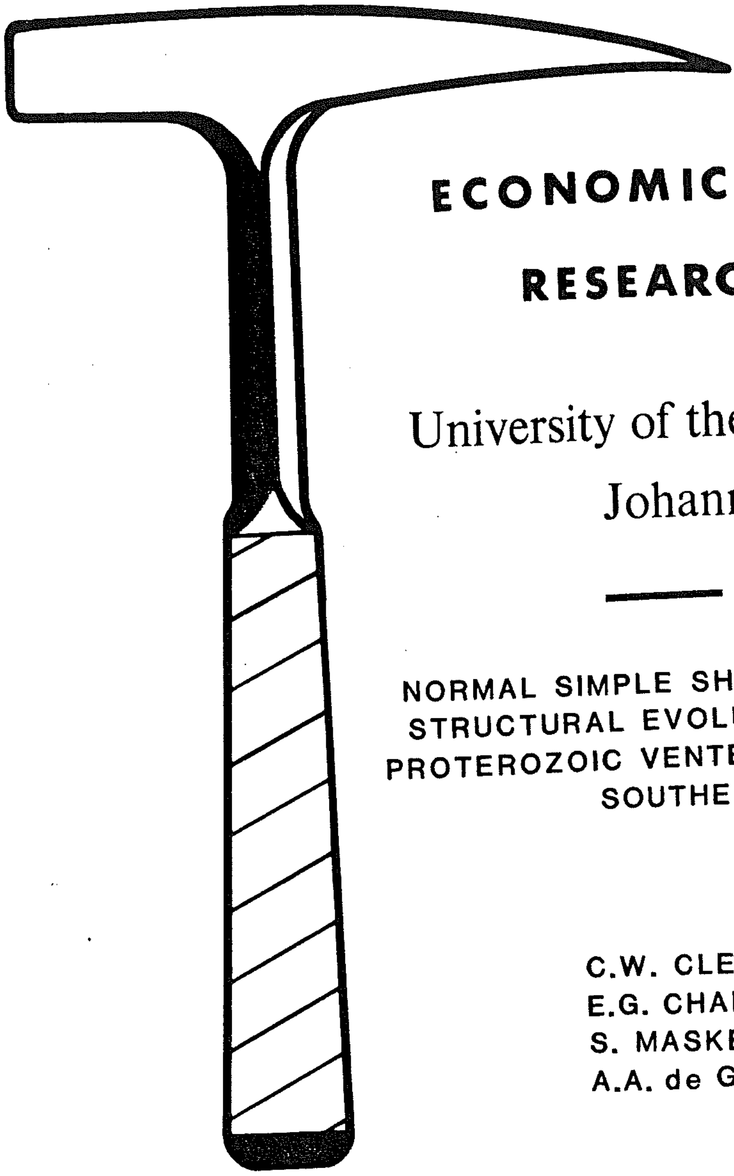

ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

NORMAL SIMPLE SHEAR MODEL FOR THE STRUCTURAL EVOLUTION OF THE EARLY PROTEROZOIC VENTERSDORP SUPERGROUP, SOUTHERN AFRICA

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ABSTRACT

Early Proterozoic extension controlled the structural development of the Ventersdorp Supergroup, and based on integrated geological and geophysical observations a normal down-to-the-west simple shear model is proposed. Although a low-angle detachment which penetrates the entire thickness of the lithosphere is speculative, interpretations are consistent with Wernicke's normal simple shear hypothesis and its suggested zones of differing lithospheric extension. Stress amplification and warping of the basal fault plane resulted in the development of a second breakaway zone which superimposed large fault-block ranges on the earlier normal fault system. One-sided denudation is interpreted to have been the reason the Platberg Group graben developed only over the western half of the extended terrane during the later periods of extension. The size, structural style, and depositional patterns of the Ventersdorp Supergroup are closely comparable to foreland rifts and these comparisons imply that large extensional terranes in the Precambrian and Phanerozoic are similar in character.

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I. INTRODUCTION

During the early Proterozoic, the Ventersdorp Supergroup (2.6-2.3 Ga ?) accumulated in fault-bounded troughs in the Kaapvaal Craton of southern Africa and is estimated to have covered an area of 300 000 km^2 (Pretorius, 1976). Approximately 200 000 km^2 of the estimated original area is preserved over the central portion of the craton with about one fourth cropping out. The structural setting of the Ventersdorp Supergroup, along with the observed sedimentary patterns, has led several authors to suggest that the Ventersdorp Supergroup represents an early Proterozoic rift system (Bickle and Erikkson, 1982; Tankard *et al.*, 1982; Burke *et al.*, 1985). Recently, during an analysis of some early Proterozoic basins on the Kaapvaal Craton, Clendenin *et al.*, (1988) backstripped these basins to the 'Old Granite' basement and proposed that the tectonic history of the Ventersdorp Supergroup was more complex than previously assumed. In their interpretation the Ventersdorp Supergroup represented not only the graben stage, but it also made up part of the pre-graben stage of a fully-evolved, three-stage rift system (Fig. 1). Timing of graben development was identified using Mohr's (1982) suggested sequence of rifting events with graben development being a late stage phenomenon, and this was followed by phases of subaerial tectonic and subaqueous thermal subsidence which developed parts of the overlying Transvaal Sequence (Clendenin *et al.*, 1988). (Fig. 1).

These interpretations clarify crustal responses and support earlier, more general rift interpretations; but the structural style of extension has not been fully addressed. Burke *et al.* (1985) have suggested that the rift appears impactogenal in nature, but the authors have presented arguments elsewhere (Clendenin *et al.*, 1987) against Burke *et. al's* interpreted plate tectonic setting which they based only on an extensive literature review. It is significant to note that the Platberg Group graben structures are over 200 km wide and that the width of this extended terrane is four to six times the characteristic width of a continental rift which has been interpreted to be only 30 to 50 km (Brun and Choukroune, 1983; Ramberg and Morgan, 1984). The width is comparable to larger areas of continental stretching as defined by Brun and Choukroune (1983), and both Tankard *et. al.*, (1982) and Burke *et al.*, (1985) have alluded to comparisons of the Ventersdorp Supergroup with the modern Basin and Range Province. These comparisons imply backarc spreading or foreland rifting as defined by Jowett and Jarvis (1984) and not narrow continental rifting. Thermal subsidence patterns interpreted from the preserved carbonate lithofacies of the Transvaal Sequence show a skewed or asymmetric pattern; and although the initial phase of overstepping had a somewhat symmetric distribution to the basin centre overlying the Platberg Group grabens, later stages of overstepping are asymmetric and thickness distributions are skewed to the western margin of the extended Ventersdorp terrane which is vertically juxtaposed with the basin centre (Clendenin and Maske, 1986). Based on the width of the extended terrane and the skewed pattern of thermal subsidence, it is clearly evident that a particular extensional style influenced and developed the Ventersdorp Supergroup. The present authors have based their study approach on Harding and Lowell's (1979) statement that identification of structural style can be

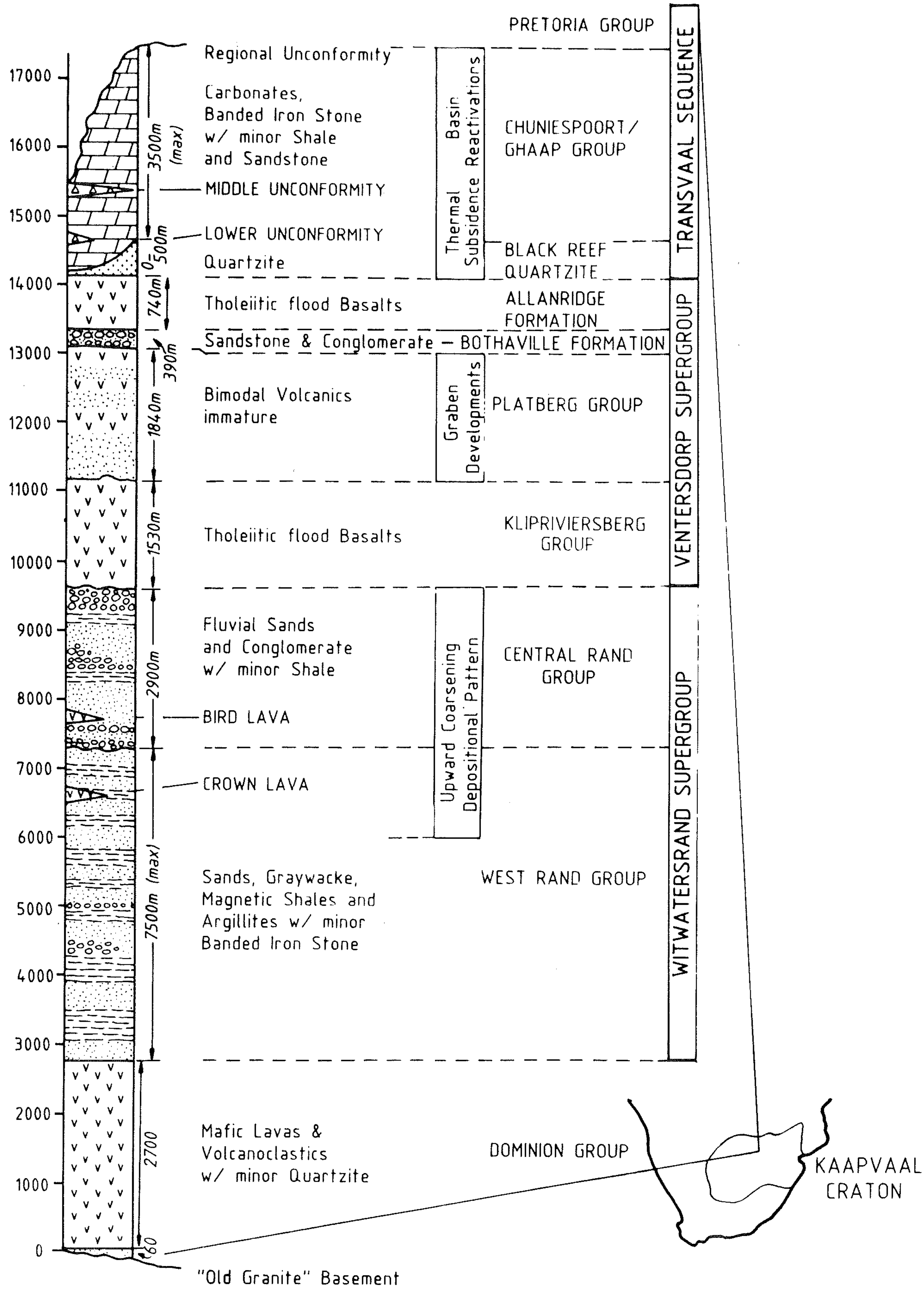


Figure 1 : General stratigraphic section of successor basin sequence on the Kaapvaal Craton (after Clendenin *et al.*, 1987).

made with few data if based on the gross regional patterns of the structures, and it is the purpose of this paper to demonstrate that normal down-to-the-west simple shear influenced basin development on the Kaapvaal Craton during the early Proterozoic.

II. GEOLOGICAL RELATIONSHIPS

Normal faulting was initiated during late Central Rand Group, Witwatersrand Supergroup time and the palaeorelief developed by this faulting varied from 1 to 30 m (Tankard *et al.*, 1982). Fault structures strike obliquely north-south to other Witwatersrand Supergroup structural features and the faulted blocks acted as sediment sources prior to the extrusion of Klipriviersberg Group lava (Tankard *et al.*, 1982) (Fig. 1). Thicknesses, geometries, and dispersal patterns of deposited fanglomerates suggest down-to-the-west faulting (Minter, 1978).

The Klipriviersberg Group consists of a repetitive sequence of alkali-rich, continental tholeiitic basalts in which lava flows of variable thickness filled irregularities on the underlying Witwatersrand Supergroup palaeosurface (Tankard *et al.*, 1982) (Fig. 1). However, locally at the base, high-Mg, mafic komatiitic basalt flows are present (McIver *et al.*, 1981). Overall, the general chemical homogeneity of the extrusives, along with the general lack of intercalated sedimentary horizons, suggest rapid extrusion was penecontemporaneous with faulting (Tyler, 1979) and faults acted as conduits for ascending magmas (Visser, 1957). The lower flows which filled the irregularities on the Witwatersrand palaeosurface do not have the aerial extent of some of the upper Klipriviersberg flows (K. Palmer, pers. comm., 1987) and this suggests a widening propagation of volcanism during Klipriviersberg time which could have been related to alternating periods of faulting.

The Platberg Group lies to the west of the preserved Witwatersrand structural basin and represents a shift in both faulting and depocentres to the west during major graben development (Fig. 1). A phase of extensional block faulting became active in late Klipriviersberg time and was responsible for the development of the Platberg Group grabens. Field relationships suggest that attenuation increased with the development of horst blocks and strike-slip faults (Buck, 1980; Stanistreet *et al.*, 1986). Graben development resulted in a pronounced Platberg Group unconformity with the underlying Klipriviersberg Group along a general north-south line near the western margin of the preserved Witwatersrand structural basin, and this is in sharp contrast with the general nonconformable contact between the Klipriviersberg and Central Rand Groups to the east. Fault displacement varies across the region and throw on faults show differences from hundreds of metres along the eastern margin of the graben to as much as 5 km along the western margin (Visser *et al.*, 1976; Buck, 1980). The differences in throw along these marginal faults have resulted in an overall skewed, if not asymmetric, graben configuration. Lithologies within the Platberg Group are made up of an interfingering sequence of bimodal volcanics, immature clastics, and playa lake sediments (Buck, 1980); and these suggest that an interior or closed drainage system occurred within the developing graben system. Geometries of fanaglomerate are a reflection of penecontemporaneous faulting (Winter, 1976) and dispersion patterns again indicate a down-to-the-west pattern of faulting. By the end of Platberg time, faulting and graben development were virtually complete (Buck, 1980).

The Bothaville Formation is unconformable with the underlying Platberg Group and is dominated by cyclic clastic sedimentation with lithologies varying from conglomerate to impure sand and shales to conglomerate (Buck, 1980) (Fig. 1). Winter (1965) has suggested that this phase of sedimentation was the intitial phase of deposition of the Transvaal Sequence. This phase has subsequently been interpreted by Clendenin *et al.* (1988) as a post-graben tectonic subsidence stage which is equivalent to the subaerial phase of thermal subsidence as proposed by Houseman and England (1986). The Bothaville Formation was not deposited over parts of the eastern graben margin and this suggests that parts of the margin might have undergone differential uplift and were positive physiographic features. The Allenridge Formation flood basalts buried both the Bothaville Formation and these marginal features prior to periods of basin-forming thermal subsidence (Clendenin *et al.*, 1988). Burke *et al.* (1985) proposed that the Allenridge Formation represented renewed rifting; but with the rift unconformity lying between the Bothaville Formation and the Platberg Supergroup, the authors believe this is only a period of volcanism in the early stages of thermal subsidence. With a steeper geothermal gradient during the early Proterozoic, thermal re-equilibration between mechanical and thermal subsidence stages should be expected to be more protracted; and Royden *et al.* (1980) have suggested that if thermal history is more protracted mafic magmatism could characterize the early parts of thermal subsidence of a basin.

The Chuniespoort/Ghaap Group, Transvaal Sequence, carbonates were deposited in a shallow epeiric sea which developed during periods of subsequent thermal subsidence (Clendenin and Maske, 1986; Clendenin *et al.*, 1988) (Fig. 1). Carbonate lithofacies distributions show that thermal subsidence was episodic and consisted of a number of transgressions. The first two transgressions were restricted somewhat to the regional limits of the Ventersdorp Supergroup or just to the west of these limits (Fig. 2). The first transgression was restricted to the southwestern half of the Platberg Group graben and an area just to the west of the graben (Fig. 2). The second transgression overstepped the northern margin and greatly expanded the basin to the north-northwest within the structural limits of the extended terrane. East-west basin expansion during this second period was asymmetric, with the basin expanding to the east while again being somewhat restricted to the area just west of the graben margin (Fig. 2). However, eastward expansion was retarded to the east of Johannesburg, close to the limits of the underlying Klipriviersberg Group (Fig. 2). The third transgression overstepped this eastern margin and greatly expanded the basin over the eastern portion of the Kaapvaal Craton while again being restricted to the west (Fig. 2). Field relationships show that differences in thicknesses of particular carbonate units developed by these transgressions vary as much as 150 m over the region west to east. The juxtaposition of the Chuniespoort/ Ghaap Group depositional axes with the underlying Platberg Group graben implies that the thickest sedimentary packages overlie the thinnest crust and the thickest carbonate sequences lie close to the western margin of the graben (Fig. 2).

III. GEOPHYSICAL RELATIONSHIPS

With much of the geology known from surface outcrop, mine development, or boreholes, seismic surveys have only recently been introduced by the mining industry to assist in the determination of hidden exploration targets. Many of

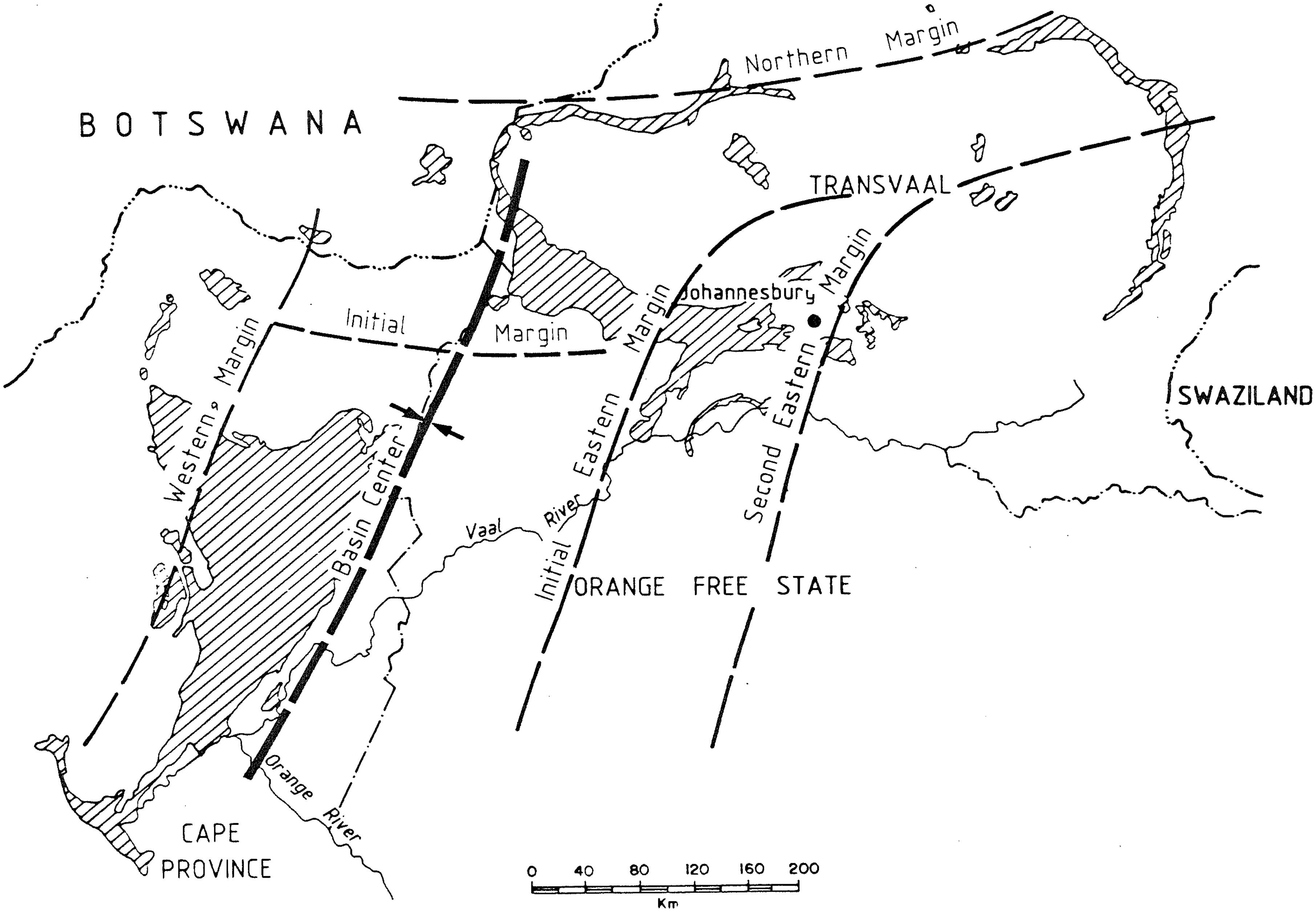


Figure 2 : Compartments of the Chuniespoort/Ghaap Group as indicated by thermal subsidence patterns from borehole core information. Preserved outcrop of the Chuniespoort/Ghaap Group shown by striped pattern.

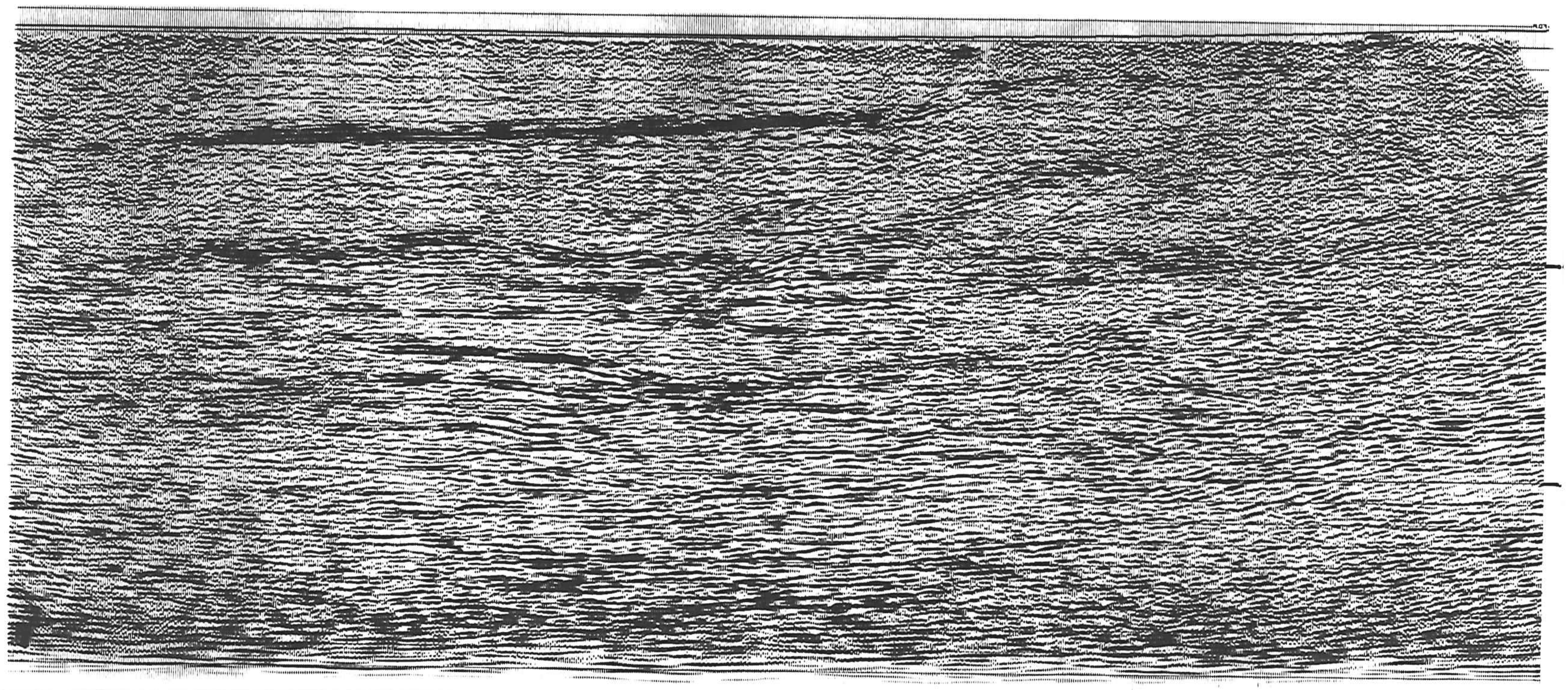
the surveys are, however, presently confidential. Magnetic and gravimetric surveys have been utilized extensively in gold field scale exploration, but many geophysical anomalies have yet to be detected because the focus has not been on a cratonic-wide scale.

Regional seismic lines do not presently exist and very few descriptions of mining company seismic sections have been published. However, Weder (1987) has recently described a number of section lines just to the south of Johannesburg in an area known as the Central Rand. In these sections he has identified low-angle imbricate thrusts that verge to the northeast and which flatten into a sole thrust within a major shale unit in the upper West Rand Group, Witwatersrand Supergroup, just below its contact with the Central Rand Group (Fig. 3a,b). Individual thrusts may show independent block movement (Fig. 3b), but all structures flatten into the sole thrust (Weder, 1988, pers. comm.) (Fig. 3b). These structures show multiple movements because the Klipriviersberg Group developed under an extensional stress (Clendenin *et.al.*, 1987) and the contact shows both normal and reverse offsets of these structures (Weder, 1988, pers. comm.) (Fig. 3b).

With the limitation on seismic profiles, observations were concentrated on regional aeromagnetic and Bouguer gravity expressions (Fig. 4a,b). Although data sets show a number of superimposed features, i.e. the Bushveld Complex and the Vredefort Dome, other prominent features can be identified from the geophysical data. A preliminary analysis using a similar data base has been presented by Corner *et al.* (1986), but their analysis primarily involved the northern and central portions of the preserved Witwatersrand structural basin.

The authors draw particular attention to a previously undescribed magnetic feature which occurs as a subdued trench-like zone which extends northwards from the southern limit of the map, between longitude 25° and 26° E (Fig. 4a). The western boundary of the trench-like zone is prominent while the eastern boundary is somewhat gradational with a regionally subdued area to the east. The western boundary strikes about N5°E and is continuous until it terminates against a northern linear magnetic feature which coincides with the Thabazimbi-Murchison Line striking N85°E across the northern quarter of the map (Fig. 4a). When compared with the higher-amplitude features of the surrounding region, the pronounced linear boundaries of subdued magnetic expression indicate that the magnetic basement is deeper within the zone than outside of it (Fig. 4a) and it is presumably down-faulted along zones which define the western and northern boundaries. The pronounced margins which grade eastward into a larger subdued magnetic expression suggests asymmetric configurations exist and implies the magnetic basement is deeper adjacent to the boundaries (Fig. 4a).

The Bouguer gravity field map also shows superimposed features, but if these are ignored, the most prominent feature on the map is a positive north-south anomaly which dominates the western third of the map (Fig. 4b). This positive anomaly is interpreted to represent thinned mantle lithosphere which resulted from asthenospheric upwelling. At first glance the anomaly appears to correspond with the aeromagnetic pattern, but relationships are offset (Fig. 4b). The larger, somewhat linear, Bouguer anomaly lies to the west of the magnetic break, while a second smaller anomaly corresponds to the trench-like zone (Fig. 4b). The offset relationship between the more pronounced anomaly and the subdued magnetic expression indicates that mantle lithospheric thinning was not juxtaposed vertically with crustal lithospheric



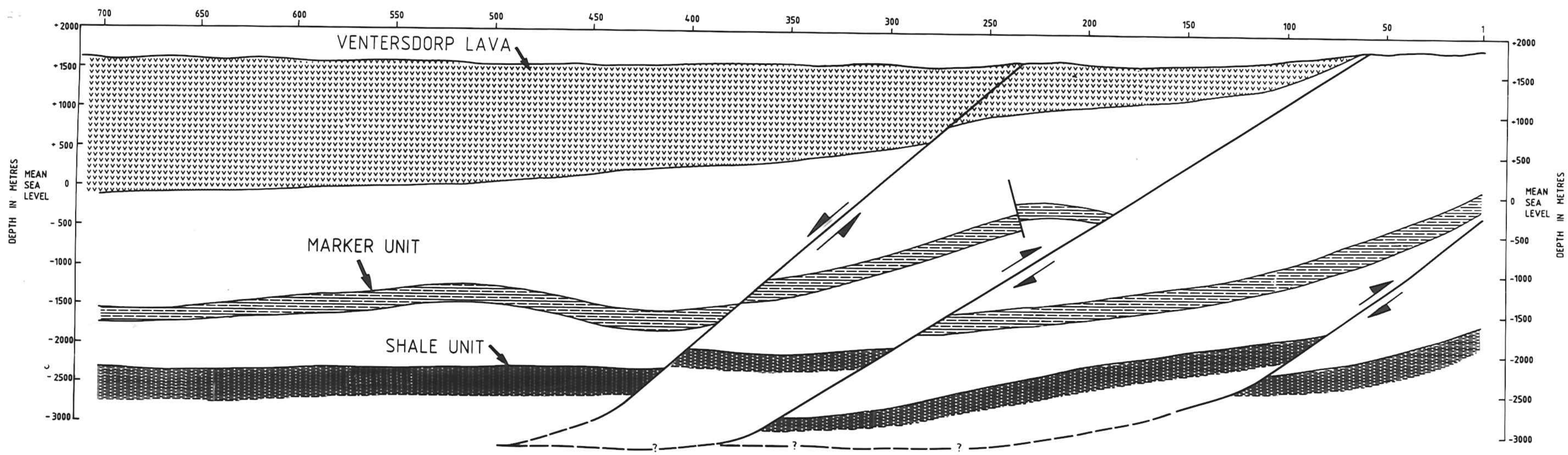


Figure 3a : Seismic profile across the Central Rand, south of Johannesburg.

Figure 3b : Interpretation of seismic profile showing low-angle imbricate thrust faults (modified after Weder, 1987).

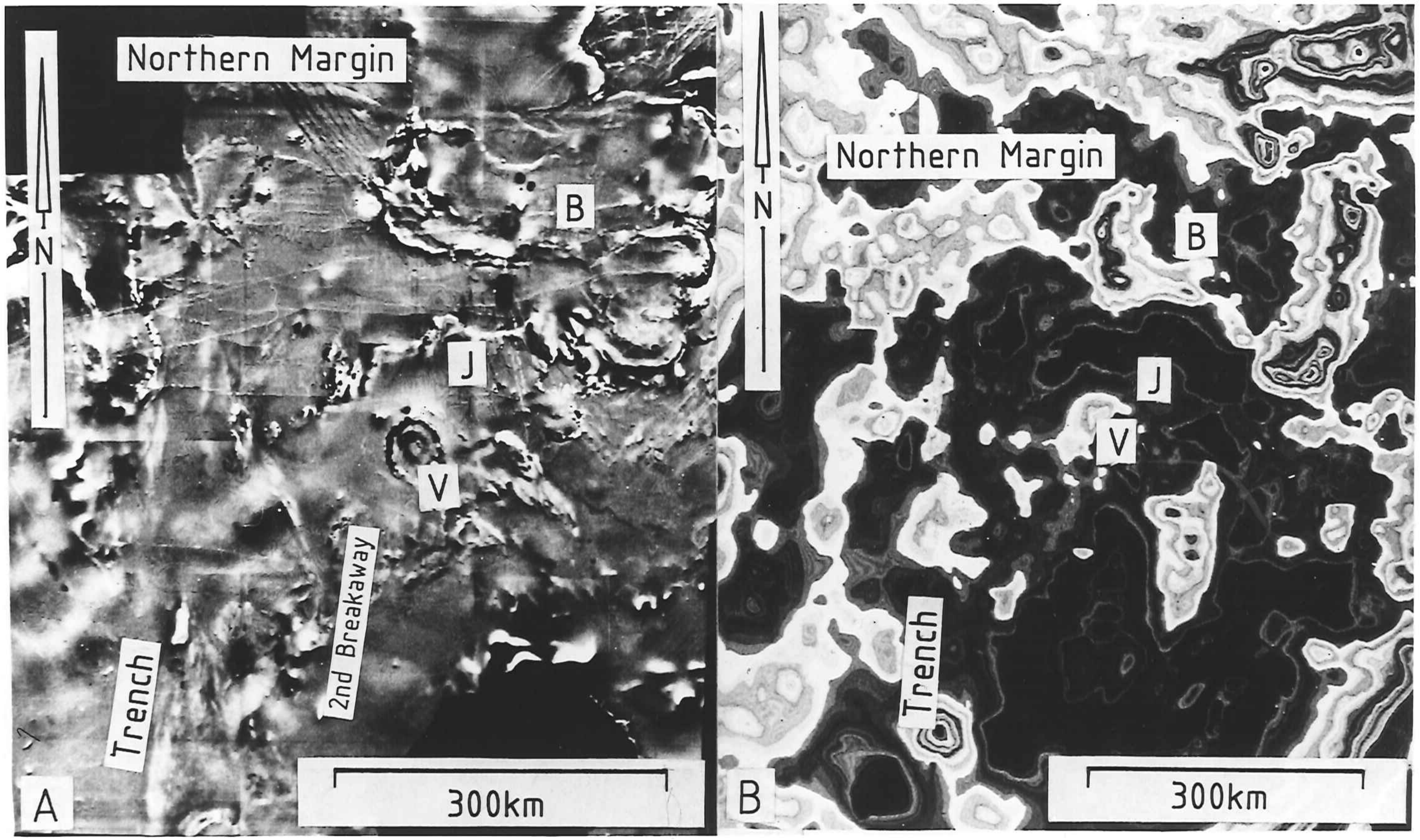


Figure 4a : Regional magnetic data over the central and western Transvaal. Location of trench and second breakaway are indicated.

Figure 4b : Regional Bouguer gravity field map over the central and western Transvaal. Relationship between trench structure and major gravity anomaly are indicated.

(J - Johannesburg; V - Vredefort Structure; B - Bushveld Igneous Complex) attenuation. Both Bouguer anomalies parallel the north-south striking magnetic break and both also terminate abruptly against the Thabazimbi-Murchison Line (Fig. 4b). Termination of the geophysical features against the Thabazimbi-Murchison Line suggests that it represents the northern limits of the Platberg Group graben.

IV. INTERPRETATIONS OF NORMAL SIMPLE SHEAR

The structural style of Ventersdorp deformation led earlier investigators to interpret rifting (Bickle and Eriksson, 1982; Burke *et al.*, 1985) and one would assume their interpretations were based on the accepted pure shear or symmetric extension model. However, the COCORP 40° Transect, across the Basin and Range Province, western United States, has shown that the model of symmetric horsts and grabens can be largely ruled out when applied to large areas of continental stretching (Allmendinger *et al.*, 1987). The skewed geological and geophysical relationships of the Ventersdorp Supergroup, also, suggest that the pure-shear model is inadequate to explain observations and that Wernicke's (1985) simple shear or asymmetic extension hypothesis provides more insight. Although the COCORP 40° Transect did not completely support the Wernicke hypothesis, it did not rule it out (Allmendinger *et al.*, 1987). Moreover, interpretations of deep seismic reflection profiles across the North Sea (Beach, 1986); across the Gregory Rift (Bosworth, 1987); across the Ross Embayment, Antartica (Fitzgerald *et al.*, 1986/87); and across the Bay of Biscay (Le Pichon and Barbier, 1987) showing striking similarities between the extension geometries and the Wernicke hypothesis.

When Wernicke (1985) proposed his hypothesis, he defined five zones across a hypothetical extended terrane and simply named them as A, B, C, D, and E, with zone A being the most proximal to the controlling detachment or breakaway and zone E the most distal (Fig. 5). Misinterpretations of these zones have recently appeared in the literature; and thus a brief review of Wernicke's (1985) hypothesis is presented. Zone A and zone E are unstrained, but both zones undergo subsequent thermal subsidence. Footwall rebound of zone A may develop a structural barrier near the breakaway (Fig. 5). Zone B defines a region of crustal, but not mantle lithospheric extension and the zone undergoes both mechanical and thermal subsidence (Fig. 5). Zone C contains the locus of maximum crustal extension, and both the crustal and mantle lithosphere are thinned across the zone (Fig. 5). Zone C also contains the region of maximum subsidence and the distal margin of the zone defines where the crust is no longer involved in the thinning process. Zone D involves only mantle lithospheric thinning and uplift occurs because the zone contains the locus of maximum lithospheric thinning (Fig. 5). Uplift may manifest itself as doming and the juxtaposition of doming to zone C results in complementary, asymmetric thermal subsidence between the zones.

Integration of the available geological and geophysical data indicates that the Wernicke (1985) hypothesis can be applied to the extensional Ventersdorp terrane (Fig. 5). Extension began in late Central Rand Group, Witwatersrand Supergroup time, and was characterized by down-to-the-west faulting. This early period of normal faulting, without volcanism, would represent an initial stage of passive rifting and could have been associated with some uplift. The fairly rapid appearance of volcanics in the Klipriviersberg Group following this phase of faulting and the initial outpouring of komatiitic flows (McIver *et al.*, 1981) is an indication that extension faulting accelerated with time. The appearance of early komatiites clarifies

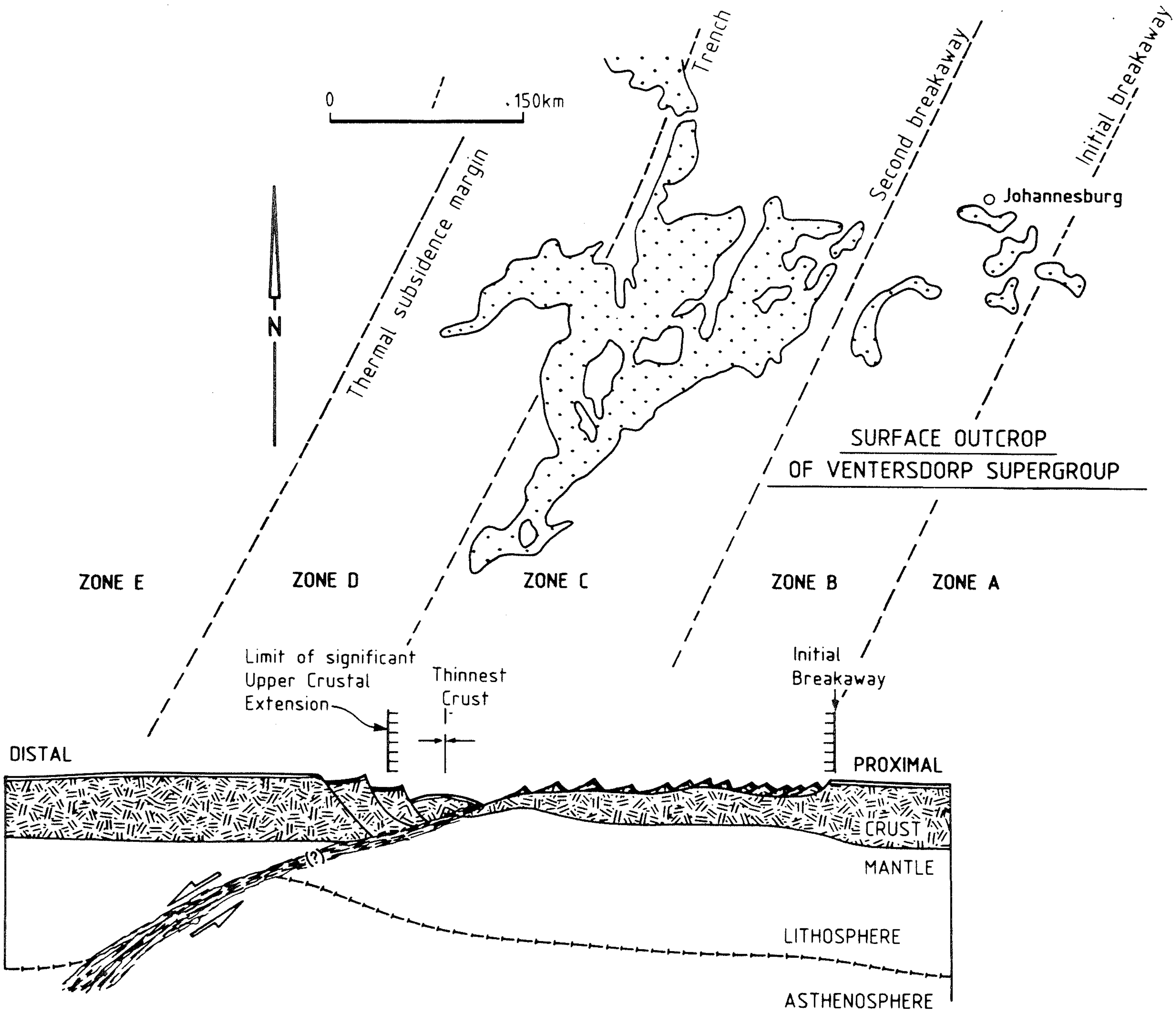


Figure 5 : Wernicke hypothesis as applied to the development of the Ventersdorp Supergroup. Graphic shows location of initial and second breakaway zones as described in text.

this relationship because Nisbet (1984) has pointed out that if extension was rapid enough during the early stages of an Archaean basin some komatiite liquid might ascend directly from depth. The occurrence of komatiites would also indicate that magma at mantle temperatures of up to 1650°C was erupted at the surface and that the geothermal gradient was radically reduced over the region as heat was pumped into the crust. This thermal pulse would have weakened the crust and set the stage for the sequence of rifting events which followed during the remainder of Ventersdorp Supergroup time.

A barrier of some sort retarded basin expansion during the second transgression of the Chuniespoort/Ghaap Group, and this barrier is interpretated as being at the site of the initial breakaway and the boundary between zones A and B (Fig. 5). East of this breakaway, Weder (1988, pers. comm.) has pointed out that the seismic lines are structurally quiet. West of this breakaway in the Central Rand, the low-angle imbricate thrusts which splay from a sole thrust (Weder, 1987) are believed to be reactivated low-angle listric normal faults which initially joined the basal detachment in zone B (Fig. 6a,b). Normal-fault systems, formed by substantial extension, may have identical thrust fault geometries; and under a suitably orientated compressive stress field, normal faults should be reactivated as thrusts (Ethridge, 1986) (Fig. 6a,b). These structures have been recognized in the West Rand Group, Witwatersrand Supergroup, and the location of such structures is consistent with faulting being restricted to the crustal lithosphere in zone B (Fig. 5). If these thrusts are reactivated listric normal faults, their vergence would indicate that initial normal faulting was down to the west-southwest (Figs. 5; 6b). Zone C is more interpretive, but two points argue for it existing west of the structurally preserved limits of the Witwatersrand Supergroup. These two points are that sedimentary thicknesses increase towards the basin centre (Badley *et al.*, 1984) and that opposite margins do not exhibit faults with identical throws (Lister *et al.*, 1986). It is noteworthy that Wernicke (1985) has pointed out that thermal subsidence should occur to some degree in all zones across the extended terrane with the maximum net subsidence occurring in zone C. The thickest accumulations of sediment overlie the trench-like magnetic zone in the western Transvaal. Gibbs (1987) has also pointed out that much of the basin floor is a fault surface and the distribution of facies and stratigraphic fill is skewed to one basin margin. The smaller Bouguer anomaly which is juxtaposed with the trench-like zone is overlain by the greatest accumulations of sediment (Figs. 2, 4b) and probably occurs because both the crustal and mantle lithospheres are thinned in the distal portion of zone C where the basin floor may have been only a fault surface. Although thermal subsidence might occur in all zones, Barr (1987) has pointed out that due to the complex interplay of upper- and lower-plate stretching, thermal subsidence can be partly or wholly decoupled in a geographic sense from the rift phase graben. This is an important point because in this investigation the larger Bouguer anomaly is interpreted as being due to asthenospheric upwelling in zone D which localized thermal subsidence along the western margin of the Platberg Group graben. Without the presence of regional seismics, the existence of a low-angle detachment fault which penetrates the entire thickness of the lithosphere is speculative (Fig. 5). However, Allmendinger *et al.* (1987) have indicated that such a structure may be healed relatively quickly by magmatic processes and ductile flow which would make it difficult to detect. The extension of the lower lithosphere due to asthenospheric upwelling west of the Platberg Group graben in zone D (Fig. 4b) and the pattern of thermal subsidence (Fig. 2) does provide the clues to the asymmetric crustal shear system. This interpretation

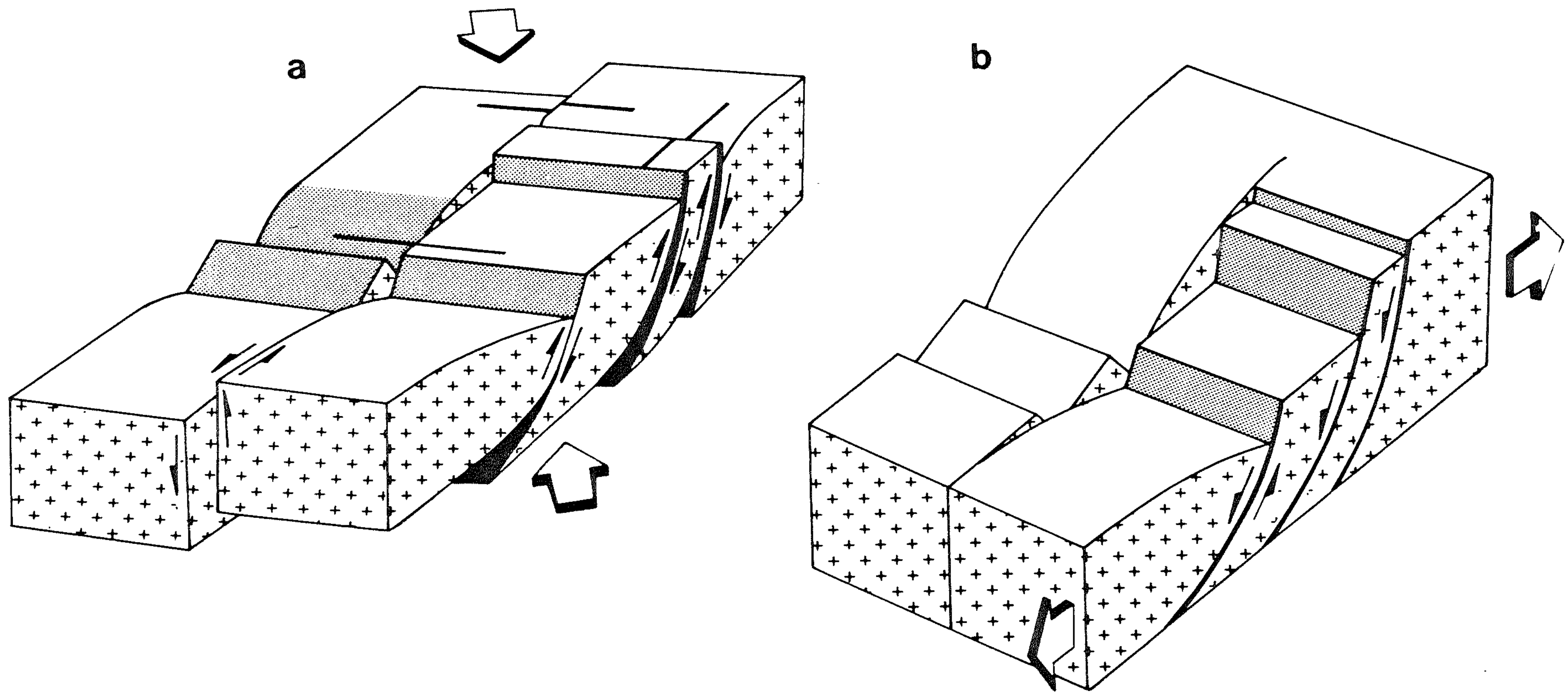


Figure 6a : Reconstruction of Weder's (1987) interpretation of low-angle imbricate thrusts.

Figure 6b : Interpretation of listric normal fault geometry prior to compressive stress reactivation. (graphic modified after, Etheridge, 1986) is also supported by the lithospheric deformation patterns Fitzgerald *et al.* (1986/87) have suggested for the uplift and subsidence in the Transantarctic Mountains and Rose Embayment, Antarctica (Fig. 7).

The Platberg Group graben is somewhat problematical because it developed only in the western half of the extended Ventersdorp terrane and implies that the detached terrane was overprinted by large fault-block ranges (Figs. 4a; 5; 8a,b). The increase in faulting with time suggests that stress amplification was at work and that antiformal warping of the basal fault geometry resulted in a second breakaway. Stress amplification should be expected because the western area would have had a lower geothermal gradient and thinner lithosphere due to deformation geometries. Gibbs (1984) has pointed out that the original form of the basal detachment may have an arch-like geometry with ramps and flats; and with high heat flow, antiformal warping of an arch-like geometry in the vicinity of the western margin of the preserved Witwatersrand structural basin resulted in the development of a second breakaway (Fig. 8b). The arch-like geometry of the basal detachment in this vicinity may have been where the flat West Rand Group detachment began to cut down through the entire crustal lithosphere (Fig. 8b). One-sided denudation could result due to the development of a second breakaway with maximum extension occurring at a significant distance from the initial one (Spencer, 1984) (Figs. 5; 8a,b). With the development of the second breakaway, faulting became inactive to the east preserving the Witwatersrand Supergroup and its major economic resources (Fig. 8a). Being detached from the active tectonic area and high heat flow to the west, zone B would have begun to cool and gain some degree of flexural rigidity (Fig. 5). Such a sequence of events would explain why the Platberg Group graben developed over the western half of the extended area and why zone B was only involved in a later stage of thermal subsidence (Figs. 2; 5).

Interpretation of antiformal warping of the basal detachment and the develoment of the second breakaway focused attention on the De Bron Horst. The De Bron Horst lies within the region of the second breakaway and it was buried until post-Bothaville Formation times (Buck, 1980). Continued warping, possibly due to rebound and heat flow, allowed the antiformal breakaway to reach surficial levels and is believed to have formed the De Bron Horst (Fig. 9). Associated footwall uplift and erosion imparts a characteristic rounded shoulder to extension blocks (Barr, 1987) and these relationships are clearly evident in published graphics of the structure by Buck (1980) (Fig. 9). However, it should be noted that the scales on Buck's (1980) graphic are greatly exaggerated and the graphic is presented true scale in Figure 9. The complex extensional fault array which formed the second breakaway dissected the arched basal detachment and left the De Bron structure as a footwall island as defined by Barr (1987). Reverse faults have been reported in the same area as the De Bron structure and have a minor component of strike-slip. Such oblique slip can develop on the detachment fault with strike-slip, reverse faults, and folding components of deformation in the hanging wall plate (Gibbs, 1987).

V. CONCLUSIONS

The size, structural style, and depositional systems of the Ventersdorp Supergroup indicate that normal down-to-the-west simple shear influenced its development and that Wernicke's (1985) hypothesis can be

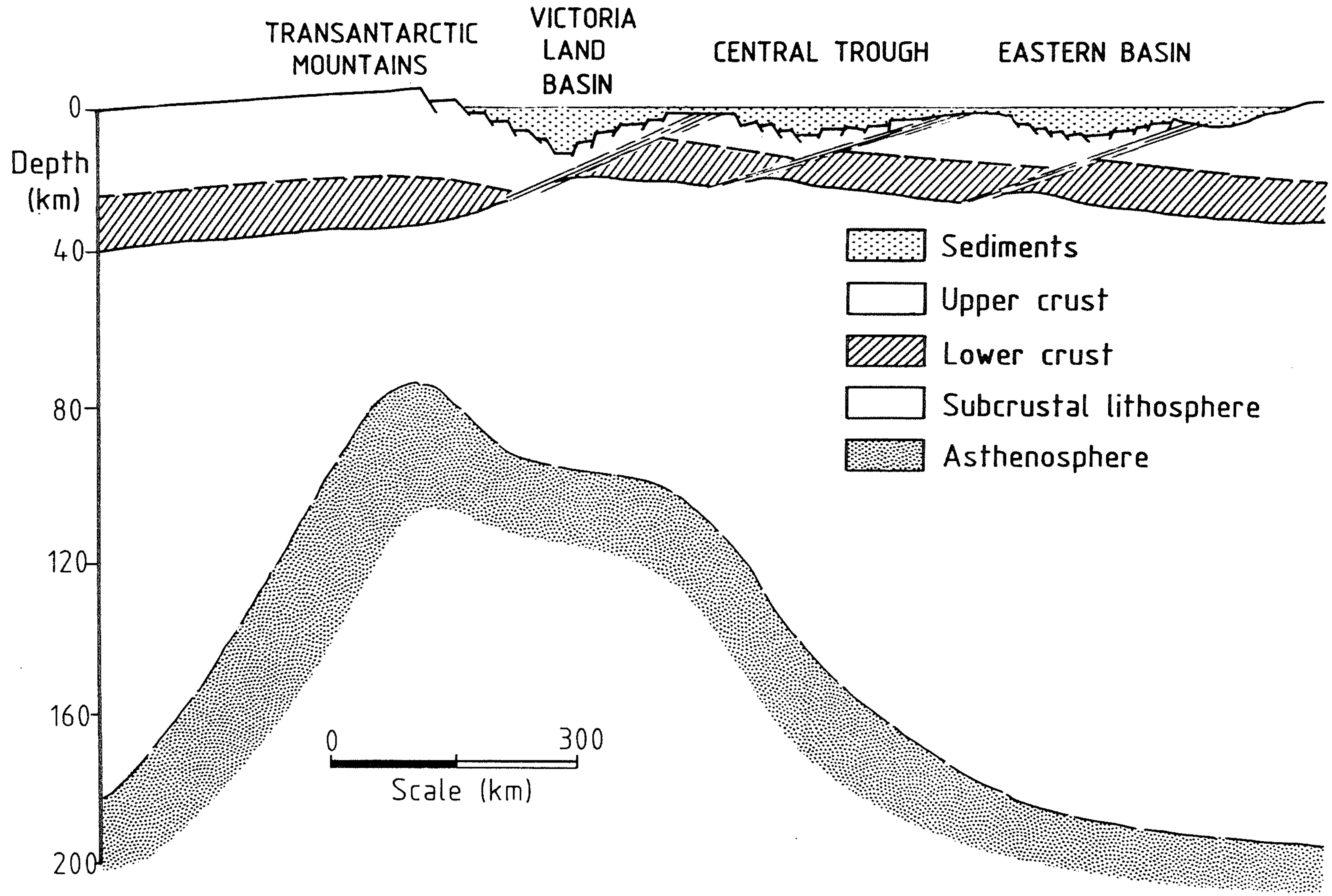


Figure 7 : Cartoon of deformation patterns and extensional geometry interpreted from deep seismic profile across Transantartic Mountains and Ross Embayment (modified after Fitzgerald *et al.*, 1986/87).

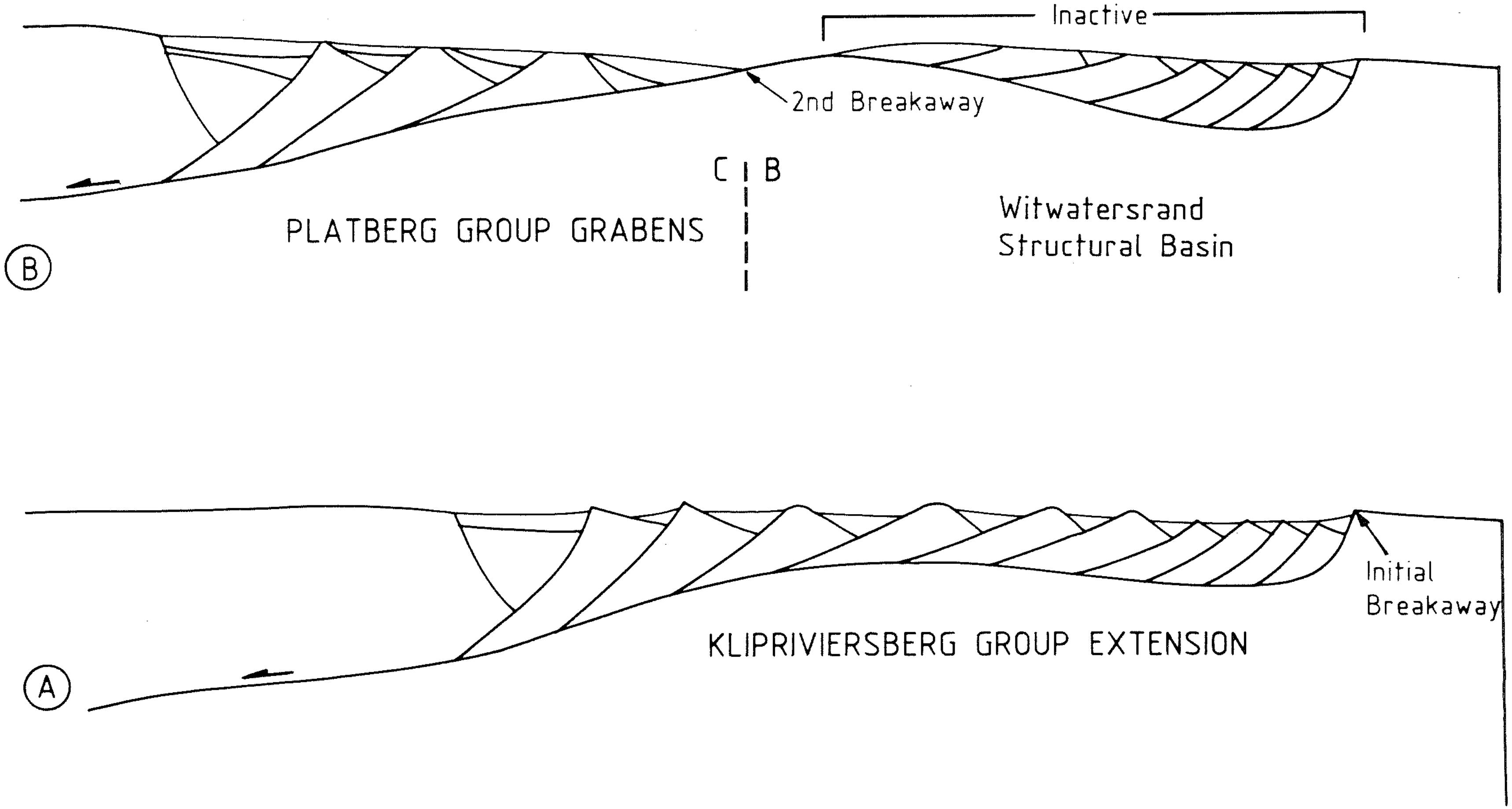


Figure 8a : Extension deformation of the Klipriviersberg Group showing down-to-the-west, listric normal faulting prior to development of second breakaway.

Figure 8b : Overprinting of the detached terrane by large fault-block ranges due to the development of second breakaway which produced the Platberg Group grabens.

(graphic modified after Spencer, 1984)

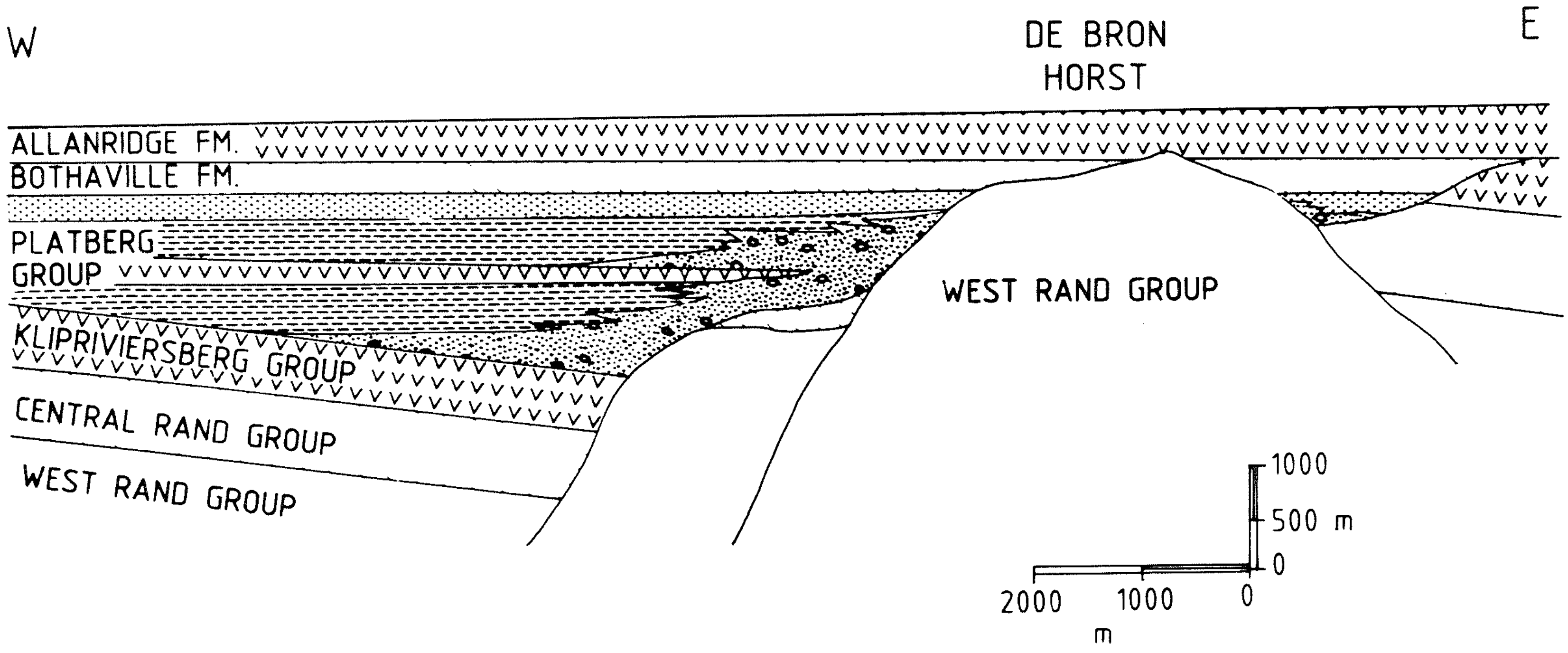


Figure 9 : True scale graphic of the De Bron horst showing asymmetric horst development (modified after Buck, 1980).

used in its interpretation. The various features described are not characteristic of a narrow continental rift system; but they do compare to both the Cenozoic Basin and Range Province, western United States, and the Permian Rotliegendes troughs, central Europe. These systems have been called foreland rifts and the main characteristics include: extensive crustal thinning, bimodal igneous activity, normal to listric faulting, high heat flow, regional uplift, and immature clastic and evaporitic sediments rapidly deposited within subsiding rift grabens (Jowett and Jarvis, 1984). Major block faulting and graben formation follow a main period of volcanism, and extension in the foreland follows an earlier period of compression which is produced by the geometry of an associated subducting slab (Jowett and Jarvis, 1984). Again, these patterns are closely comparable to the Ventersdorp Supergroup. The character of transmitted stress in the Kaapvaal Craton changed from compression to tension just prior to Ventersdorp time and has been interpreted as due to the geometry of a subducted slab following collision (Clendenin *et al.*, 1987). If these comparisons between foreland rifts and the Ventersdorp Supergroup are valid, it would imply that geodynamic processes associated with extending terranes can be correctly compared between the Precambrian and the Phanerozoic.

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