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GRAVITY EVIDENCE FOR A POSSIBLE PLATE- TECTONIC ORIGIN OF NAMAQUA/DAMARA STRUCTURAL PROVINCE BOUNDARY IN NAMIBIA AND BOTSWANA

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ABSTRACT

Gravity anomalies in the vicinity of the Namaqua and Damara tectonic provinces in Southern Africa posses extensive pair of linear negative and positive anomalies straddling one another on the basis of which the structural boundary can be mapped. Gravity modelling of the boundary indicates considerable thrusting of about 50 km of Damara belt over the Namaqua block. Plate tectonic evolution is one of the ways in which the juxtaposition of these structural blocks of varying age and thickness can be understood.

KEYWORDS: Gravity anomalies, structural boundary, tectonic province, Gravity modelling and tectonic evolution

INTRODUCTION

This study was undertaken as part of the author's effort aimed at gravimetric investigation of major structural province boundaries within the African shield. Damara facies rocks occur mainly in two intersecting zones in Southern Africa, namely, to the northeast from the coast of Namibia to Kalahari and roughly north-south along Namibia coast (Fig. la). The province here includes all regions where the crust has been reworked during the Damaran tectonic episode dated at about 550 Ma. The Namaqua structural province, a typical province for the Eburnian Orogeny (1900±200 Ma), is mostly overlain by kalabari sands, thus, rendering the boundary with the Damaran tectonic province to the north cryptic.

However, some pre-Damara formations appear to mark the northern limit of the Namaqua tectonic province. The formations are distributed in an arc- like form (Fig. la) and are referred to as Rehoboth Magmatic Arc. Watters (1976) proposed that the arc separates the undeformed Precambrian deposits (Namaqua Group) of the stable platform (Kalahari Craton) to the south from the highly deformed metamorphic deposits of the Damara Orogenic Belt in the north. Gravity studies within and in the vicinity of the arc-like formations were undertaken to see if they have expression in the gravity field.

GEOLOGIC SETTING

Watters (1976) inferred that the trends within the Rehoboth Magmatic Arc such as major faulting parallel those of the Damaran and considered this as evidence of possible genetic relationship between the arc and the structures which consist of highly variable sequence of basic, intermediate and felsic lava and volcanic as well as thick sedimentary deposits. This volcano-plutonic belt is referred to as the Rehoboth Magmatic Arc (Waters, 1976).

Toen (1975) traced the presumed outline of the southern foreland to the Damaran Orogenic Belt as SW-NE belt from southwest of Namibia to the north of Kachikau in northern Botswana. A reference to figures 1a and 1b shows that this southern foreland is to the north of Rehoboth Magmatic Arc in Namibia, which has been proposed to mark the Damaran southern front.

GRAVITY EXPRESSION OF THE BOUNDARY REGION

The gravity data used in this study came from two main sources. Some 2,137 gravity data over Botswana were compiled by Reeves and Hutchins (1975) while about 1,420 others in Namibia was obtained from Geological map of Southwest Africa (South African Geological Survey, 1964).

In contouring the Bouguer anomaly map (Fig.2), only gravity data within and in the vicinity of north and south of the Rehoboth Magmatic Arc were utilised in the study since the objective of the study is to look for gravity changes across the arc. This involves some 1200 and 1000 actual data drawn from the two sources respectively.

A very striking feature of the Bouguer anomaly map is the presence of an extensive linear negative anomaly having a minimum value of 125 mgal at (22.3°S, 18.6°E) with a complex trend but broadly SW-NE between (23.2°S, 16.3°E) to (21.5°S, 22.4°E), a distance of over 700 km. This large gravity feature encloses an anomaly of limited areal extent over which the minimum anomaly occurs and has NW-SE trend between (22.5°S, 17.4°E) and (20°S. 20°E). Part of the larger gravity feature broadly coincides with the outcrops of the Precambrian Rehoboth Magmatic Arc. To the north of this feature is a linear positive Bouguer gravity anomaly of more or less similar trend and comparable extent. This positive anomaly occurs over the projected southern limit of the Damara Orogenic Belt (Toen, 1975) and maintains a close parallelism with it.

Co-extensive pairs of linear positive and negative Bouguer gravity anomalies have been found straddling the boundaries of structural provinces of remarkably different ages in the African shield (Emenike, 1986. Lecorche et al, 1983; Ponsard et al, 1882; Leco: :he and Claver, 1983). It is therefore probable that th linear positive anomaly here defines the southern limit of Damaran tectonic province while the flanking nega anomaly outlines the boundary zone with the Nama structural province.

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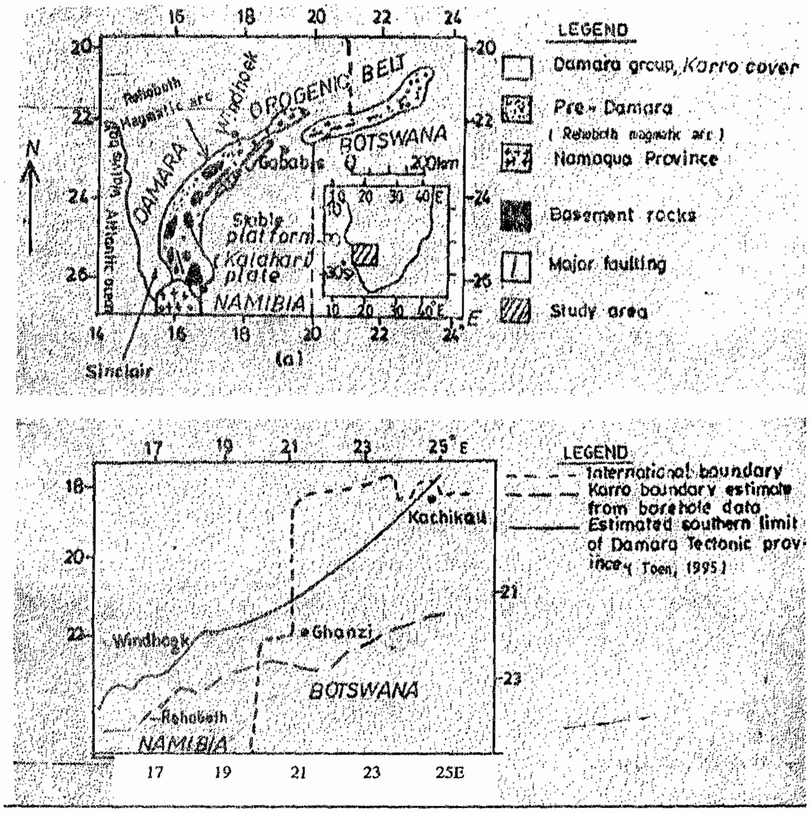

Fig 1 (a) : The distribution of pre-Damara, Damara and Namaqua formations in southern and central Namibia and western Botswana (Redrawn from Waters, 1976).
(b) The estimated southern limit of Damara Tectonic province (From Toen, 1975).

negative Bouguer gravity anomalies that coincides with outcrops of Rehoboth Magmatic Arc, the rest of the anomalies occur over Kalahari sands in Namibia and Botswana. There is, therefore, little correlation, except over the magmatic arc, of anomalies with geology. The extensive linear nature of the anomalies suggests that they are probably an expression of large-scale structure involving considerable thickness of the crust rather than a product of discrete lithological variations.

The Bouguer anomalies appear more complex over the younger Damara tectonic province than over the older Namaqua tectonic province. This state of affairs is at variance with the result of gravity studies over structural provinces of varying ages within African shield (Emenike, 1986, 1989; Hasting, 1977; Darrucott, 1972); and within Canadian shield (Thomas and Gibbs, 1977; Thomas and Keary, 1980) and over Australian shield (Wellman, 1978) which suggests that gravity anomalies are broadly more complex over older structural terrain. Although there appears to be no full explanation for this observation, nevertheless, a large part of pre-Damara structure has been found (Toen, 1975) within the Damara domain. The precise areal extent of these older structure is not discernible because of poor exposure.

The predominant trend of the presumed Bouguer gravity anomalies of the structural boundary is SW-NE. Several Bouguer gravity profiles were taken across it so as to derive a type gravity signature of the structural boundary. It is found convenient to consider gravity profiles lying along lines of Longitudes between 16°E and 20°E over which the boundary anomaly is best defined and extending from latitude 19°S to 24°S. Fig. 3 shows stacks of gravity profiles within half-a degree longitude strips between 16° to 20°E and extending from latitude 19° to 24°S. Fig. 4a shows the stack of average

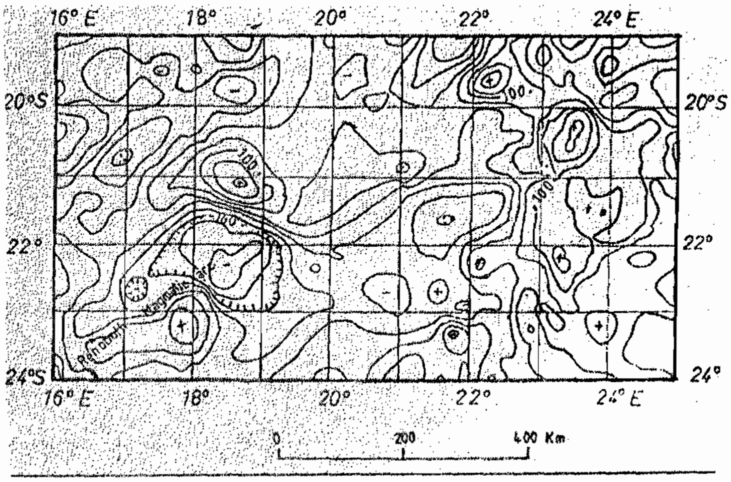

Fig. 2 Bouguer gravity anomaly map in the vicinity of Namaqua-Damara structural boundary. Contour interval: 10mgal.

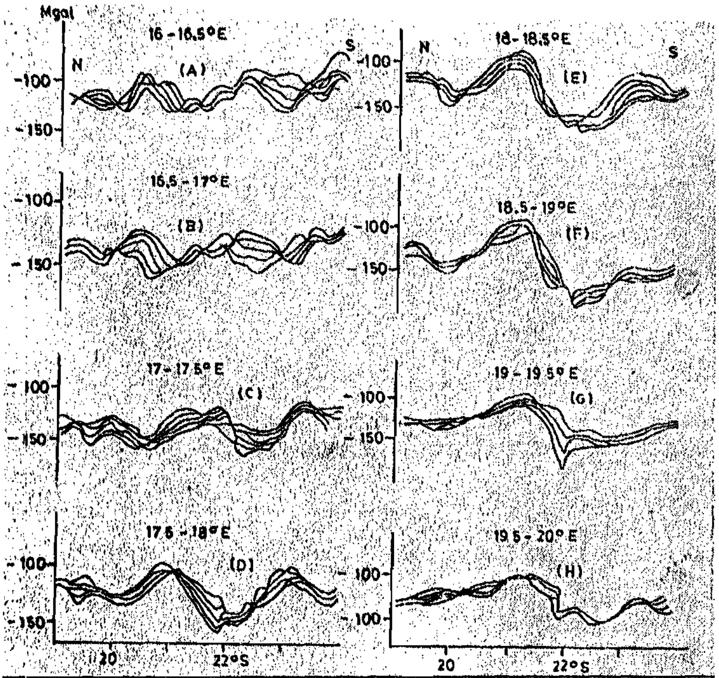

Fig. 3 Stacks of gravity profiles across the Namaqua-Damara structural boundary at 1/8° spacing. A-H profile sets within 1/2° longitude strips from 16°to 20° E.

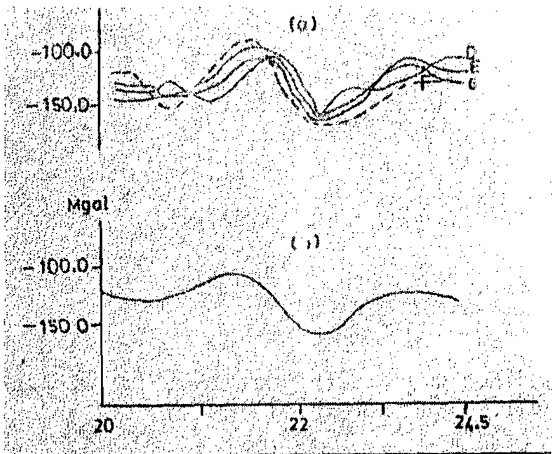

Fig. 4 (a) Stack of average profiles obtained by averaging the stack of profiles in fig. 3, D-G.
(b) Average of the profiles in Fig. 4 (a) or gravity signature of the structural block boundary

profiles derived by simple averaging technique from each stack of profiles in Fig. 3D to Fig. 3G over which the boundary anomaly is best defined. Fig. 4b is the average profile derived from Fig. 4a and can, therefore, be considered to be the gravity signature of the boundary of the two structural provinces.

CRUSTAL MODELLING OF THE BOUNDARY GRAVITY ANOMALY

Fig.5 shows a simple two-dimensional models used to interpret the type gravity signature. The models were constrained in a number of ways. A crustal thickness of 35 km is assumed to underlay the archean Namaqua block while the thickness of the Damara block was varied to obtain a fit between the field and the crustal model anomalies at about 42 km. The higher density over the Damara block is consistent with Toen (1975) observation that density of rocks within the Damara Belt are much higher than those at its southern foreland over Namaqua province.

In the models it was necessary to use a density

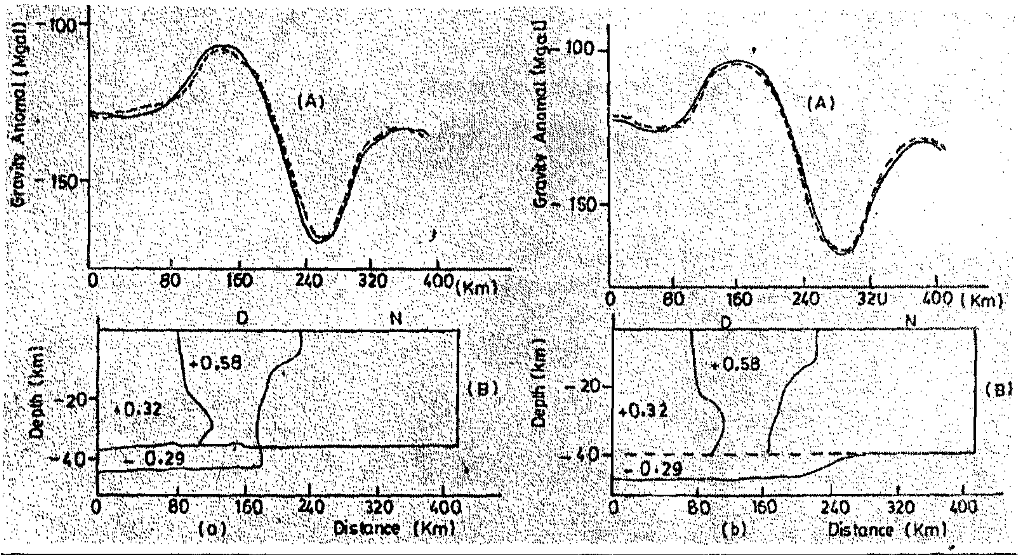

Fig. 5 The interpretation of type gravity signature across Damara (D) and Namaqua (N) crustal blocks. In (a) local compensation of Damara block is assured and in (b) the compensation is assumed to be regional. In (A): —— type gravity signature across the blocks
------ computed gravity profile based on the crustal model in (B)
Density contrast in g cm^{-3}

contrast between Damara and Namaqua crustal blocks decreasing away from the Damara block boundary from +0.58 to +0.32 g/cm^3 to account for higher gravity field over the Damara block. Fairhead and Scovell (1976) report densities of 2.5- 2.79g/cc for Archean granites which dominate Archean terrain such as the Namaqua province and densities of 2.8-2.95 g/cc for young crystal belts such as the Damara. It does appear that density contrasts used in the crustal model are probably of the right order. The density contrast between the mantle and the compensating root of anomalously dense block is computed to be -0.29 g/cm^3. A better overall fit between the observed and computed anomalies is obtained in Fig 5b over which the compensation of the crustal root is assumed to be regional than in Fig. 5a which assumes local compensation.

The inherent ambiguity associated with interpretation of potential fields suggests that other crustal models may exist that can explain the observed gravity signature. However, there is no doubt that the form of the gravity signature here is due to the juxtaposed crustal blocks of different density and thickness,

DISCUSSION AND CONCLUSION

The structural boundary between Namaqua and Damara provinces in Namibia and Botswana has been shown to be characterised by distinct gravity signature on the basis of which the boundary could be delineated. The crustal models employed to interpret the gravity signature assumes a thicker and denser crust beneath the Damara province than beneath the Namaqua province. A difficult that arises is the nature of mechanism that is responsible for the development of a crustal block such as Damara that is significantly denser and thicker than the adjacent block throughout its entire length. Although there is no seismic information on the crustal thickness in the study area, however, seismic refraction data (Mereu and Hunter,1969) indicated that crustal thickness beneath Churchill structural province is at least 6 km thicker than that beneath the adjacent archean Superior structural province in Canada. A possible origin of the type gravity signature here could be plate tectonics. Watters (1976) reported the existence of miogeo-synclinal and eiogeosynclinal sediment facies within the southern front of the Damara Orogenic Belt. Burke et al (1977) proposed that the Rehoboth Magmatic Arc of amphibolites and minor ultramafics close to the Damara southern front in Namibia may be emplaced fragments of the ocean floor.

While the evidence of tectonic origin of the boundary may be strong, it does not enjoy universal acceptance. For example, Kroner (1977) suggested "ensialic" evolution of the Damara province siting the presence of large pre- Damara basement within Damara structural province as evidence of its "ensialic" development.

Nevertheless the presence of a pair of linear positive and negative Bouguer gravity anomalies extending to a distance of over 400 km probably reflects the effect of a deep rooted phenomenon rather than that of a surfacial discrete lithological variation. A plate tectonic origin of the boundary is consistent with the gravity evidence in this study.

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