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PROGRESS REPORT ON A GRAVITY AND MAGNETIC INVESTIGATION OF THE MESSUM AND ERONGO IGNEOUS COMPLEXES

by

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1. BACKGROUND AND AIM OF THE INVESTIGATION

A group of post-Karoo igneous complexes forms a roughly defined belt within the Northern and Central Zones of the NE-trending arm of Hie Damara Orogen. Geological studies of some of these complexes have been carried out, e.g. by Blumel *et al*. (1979), Korn and Martin (1954) and Linning (1968). Geophysical methods have, however, not been applied in any of these studies.

Existing regional aeromagnetic and gravity data clearly indicate the association of gravity and magnetic anomalies with the Erongo, Messum and Cape Cross Complexes. A programme was initiated in order to supplement these data, to determine the three-dimensional form of the Erongo and Messum bodies and to explain their regional setting. The investigation is still in progress, but certain phases which have largely been completed are briefly described.

2. GRAVITY SURVEY

2.1 Field Procedures

The survey covered the area between latitude 21°00'S and 22°15'S, extending from the coast to longitude 16°30'E, as indicated in Fig. 1. Readings were taken at 1645 stations, using a Scintrex Model CG-2 gravimeter for the first 131 stations and a LaCoste and Romberg Model G gravimeter for the remainder.

In order to reduce travel time and distance, five gravity bases were established at selected localities within the survey area. A tie-in between these bases and the main gravity base in Windhoek was effected and their absolute gravity values in the IGSN-71 system were determined.

The influence of the mountain terrain on barometric pressure and the large extent of the survey area precluded the use of barometers in determining station elevations. Proposed stations were marked on 1:50 000 scale topographical maps in positions where spot heights existed, or alternatively where low topo-graphic relief enabled accurate determination of elevations from contours. It was estimated that no station value should differ by more than 5 m from the true elevation.

Depending on the horizontal gradient of the gravity field and the accessibility of terrain, a nominal station spacing of 3 km was applied in the Erongo area. Lack of topographic features and spot heights in certain parts of the Namib Desert made the location of selected stations impossible; here station spacing had to be increased. More detailed work was carried out in the Cape Cross area, where readings were taken along the high-water mark and at bench marks along the salt road. In the Messum area positions and elevations of 115 stations were surveyed by means of an AGA Geodimeter.

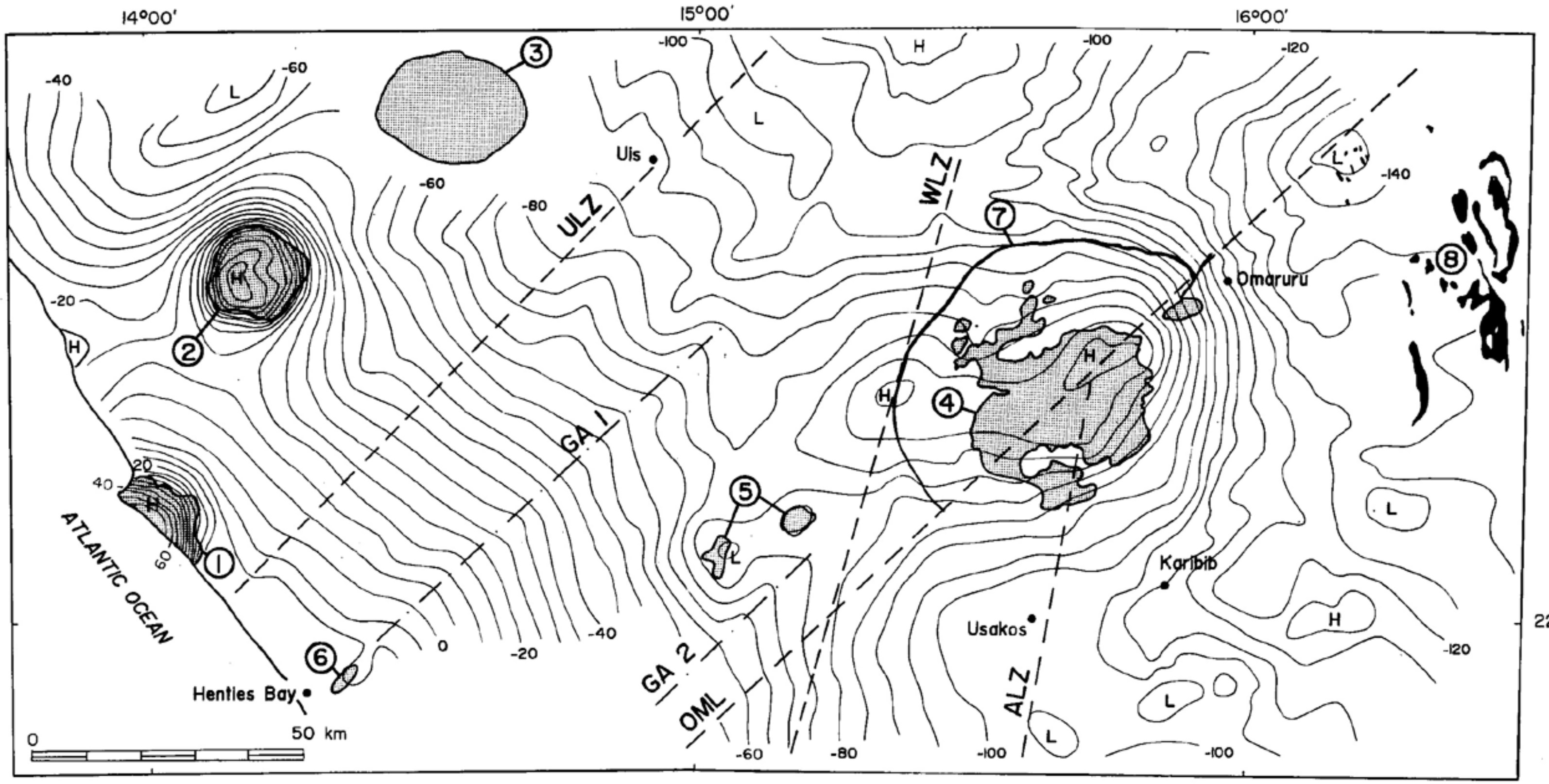
No attempt was made to correct for earth-tide variation, which was established not to exceed 0,3 mgal. With the Scintrex gravimeter, base readings were taken three times per working day. When the highly stable LaCoste and Romberg gravimeter became available, base readings were reduced to a minimum of one every three days. In addition the gravimeter was also read at the main base in Windhoek before and after field trips. Field work was carried out intermittently and data were processed after each field trip, enabling stations to be reread or filled in where needed.

2.2 Data Processing

Numerical processing of data was performed with the aid of an HP-9830 calculator and peripherals. Relevant data were stored on magnetic tape and Bouguer anomaly values calculated in the IGSN-71 system.

Terrain effects due to the Erongo Mountain were estimated to attain 5 mgal at certain stations and it was thus imperative to apply terrain corrections. A computer assisted method, based on the method described by Kane (1962), was developed for this purpose. A digital terrain model, consisting of a set of elevations obtained at the nodes of a square grid, was produced for an area of 70 x 70 km centred on the Erongo Mountain. Corrections could be calculated at any specified node or set of nodes of this grid. Since gravity stations were randomly spaced, corrections at stations not coinciding with grid nodes had to be interpolated by hand. Corrected Bouguer anomaly values were manually contoured at 5 mgal intervals on a scale of 1 :250 000 by applying linear interpolation between stations. A reduced and simplified Bouguer anomaly contour map is presented in Fig. 1.

To facilitate data manipulation and interpretation the



① Cape Cross Complex ② Messum Complex ③ Brandberg Complex ④ Erongo Complex

⑤ Spitzkoppe ⑥ foyaite body ⑦ Erongo ring dyke ⑧ dolerite outcrops

ULZ : Uis Lineament Zone, OML : Omaruru Lineament, WLZ : Welwitschia Lineament Zone, ALZ : Abbabis Lineament Zone

GA 1 : gravity axis, GA 2 : possible gravity axis

Fig. 1: Bouguer anomaly contour map in mgal, on which are superimposed the outlines of post-Karoo instrusions and major aeromagnetic and gravity lineaments.

TABLE 1:- Densities of the main rock types of the Messum and Erongo Complexes.

FIELD DATA, MESSUM AND ERONGO					PUBLISHED DATA, OTHER LOCALITIES	
Complex	Rock type	Number of samples	Mean density (gm/cc)	Standard deviation (gm/cc)	Average density (gm/cc)	Density range (gm/cc)
Messum	syenite	8	2,61	0,03	(+) 2,77	2,60 - 2,95
	foyaite	14	2,69	0,04	(*) -	2,51 - 2,91
	gabbro	38	3,03	0,18	(+) -	2,70 - 3,50
	porphyritic lava	17	3,03	0,10	(*) -	2,73 - 2,84
Erongo	granite	21	2,59	0,03	(+) 2,64	2,50 - 2,81
	granodiorite	15	2,69	0,01	(+) 2,73	2,67 - 2,79
	rhyodacite	25	2,62	0,04	-	-
	basalt	19	2,65	0,05	(+) 2,99	2,70 - 3,30
	gabbro	11	2,96	0,02	(+) 3,03	2,70 - 3,50

(+) Data from Telford *et al*. (1978)
(*) Data from Smit and Maree (1966)

randomly spaced data will be transformed to a square grid, followed by removal of the regional gravity field.

2.3 Density Determination

Densities of the main rock types of the Erongo and Messum Complexes were determined from hand and core samples. The data are listed in Table 1, with density ranges and averages (Telford *et al*., 1978 and Smit and Maree, 1966) included for comparative purposes.

Samples of syenites, granodiorites and basalts have markedly low densities, the density of granites is lower than average, density of gabbros is typical, and the density of the porphyritic lava is high.

3. MAGNETIC SURVEY

3.1 Aeromagnetic Survey

The existing aeromagnetic coverage of the Erongo area comprised 4 different surveys, each covering part of the area. Terrain clearance varied from 100 m to 150 m and no digital data existed which could be used for upward continuation to a common level, or for advanced processing. Furthermore, due to the topographic relief of the mountain, which rises to about 1 000 m above the surrounding countryside, and the drape flying procedure employed, the elevation of the magnetometer above any arbitrary horizontal plane could have changed by as much as a kilometre during these surveys. It was accepted that the measured anomaly was significantly distorted and that it was therefore necessary to collect new data.

Due to a limited budget, the survey had to be completed within one day. Large ferry distances and refuelling time restricted the total possible survey distance to only 900 line kilometres. A survey with average flight and tie line spacings of 10 and 30 km respectively was carried out at a constant barometric elevation of 2012 m. Since the mountain rises to 2300 m in places, two flight lines had to be shifted in order to clear high ground. Maximum terrain clearance amounted to about 1 000 m, the largest that could be accepted for accurate visual navigation from aerial photographs at an aircraft speed of 240 km/h.

Data were recorded in both digital and analogue form at sampling intervals of 1,1 seconds, employing a Geometrics G-813 proton magnetometer and ancillary equipment, with the sensor installed in the tail boom of a Piper Navajo.

3.2 Data Processing

Standard procedures were employed in recovering and digitizing flight lines. Commercially available programs were used in data processing and contouring. A grid conforming in orientation to the Lo system, with a cell spacing of 1 000 m, was applied in all processing. Total field data were levelled and gridded, and prior to contouring a second order polynomial filter with a radius of 2 mesh points was applied. Resultant grid data were upward continued to 6 000 m and subsequently reduced to the pole, employing a declination of 16,5°W and an inclination of -62°. The relevant contour maps are illustrated in Fig. 2.

3.3 Remanence and Susceptibility Determination

Corner (1982) reported that rocks in the Cape Cross, Brandberg and Erongo areas had remanent magnetization directions significantly different from that of the earth's present day field. Since Corner (1982) only sampled two sites at each complex, a more detailed study of the magnetism of the Erongo and Messum Complexes was initiated.

Core samples of 2,5 em diameter, orientated with a sun compass, were collected by means of a portable drill. At each site a number of cores were drilled, with a total length yielding at least 10 laboratory samples. At the Messum Complex, gabbro sheets were sampled at 11 sites, porphyritic lava at 5 sites, and foyaite and syenite at 3 sites each. The Erongo granite was sampled

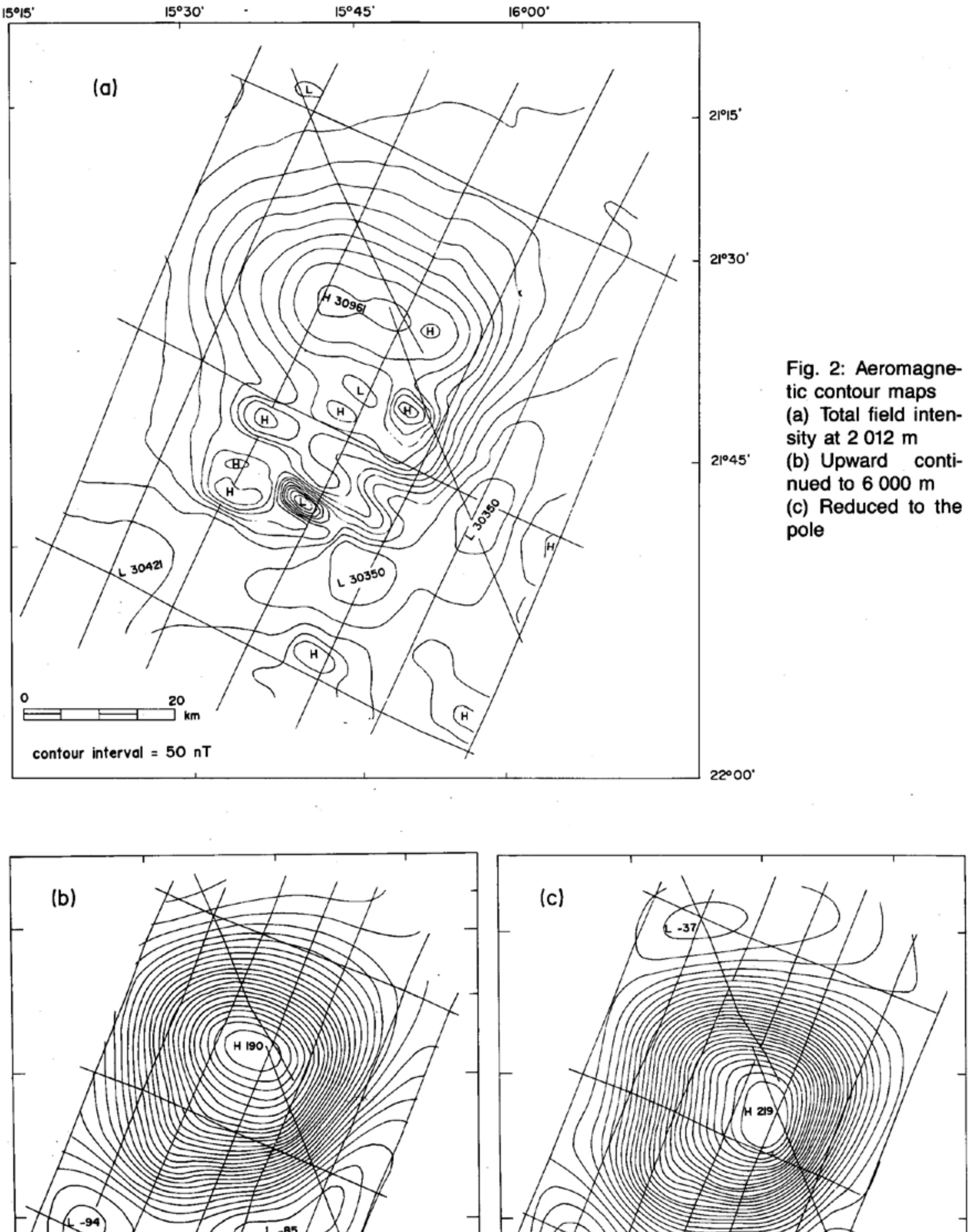


Fig. 2: Aeromagnetic contour maps
(a) Total field intensity at 2 012 m
(b) Upward continued to 6 000 m
(c) Reduced to the pole

at 6 sites, the Erongo granodiorite at 5 sites and the lava that caps the Erongo Mountain at 3 sites.

No laboratory work has as yet been carried out, and it is intended to complete this investigation before any magnetic modelling is attempted.

4. DISCUSSION

4.1 Gravity, Excluding Erongo Complex

The gravity contour map in Fig. 1 exhibits a number of distinctive features. These include a smooth coastal gradient, positive anomalies caused by the Cape Cross, Messum and Erongo Complexes, and a number of regional highs and lows.

An area with a fairly constant gravity gradient of about 1,1 mgal/km extends from the Messum Complex to the southern boundary of the survey area. A sudden change in direction of the contour lines occurs along an axis which is parallel to the Omaruru Lineament and the Uis Lineament Zone (Corner, 1982). To the north of this axis, the contour lines are sub-parallel to the coast line, but to the south of it they approach the coast line at an oblique angle. It is of interest to note that the foyaite body to the east of Henties Bay, which causes a local gravity low, is situated on this axis. Another axis may exist further south; here, in addition, the area of smooth gradient broadens quite suddenly from about 70 km to 110 km.

At first glance it is evident that the anomalies related to the Cape Cross and Messum Complexes are caused by bodies situated at a much shallower depth than the Erongo Complex. The Cape Cross anomaly is only partly delineated, as the bulk of this complex lies off shore, but it is estimated to have a residual amplitude of at least 50 mgal and a maximum gradient of 4,3 mgal/km. Similarly, the Messum anomaly has an amplitude of 53 mgal and a gradient on the south-western side of about 4,4 mgal/km. Contrary to expectations, a local gravity low coincides with the core of the Messum Complex, and the rather flattish peak of the positive anomaly is situated on the western side and just within the innermost of the two enclosing gabbro sheets described by Korn and Martin (1954). Although the outer shape of the anomaly conforms to the outline of the complex, the anomaly as a whole is asymmetrical. This could be entirely due to the uneven distribution of gabbro sheets within the two parts of the complex, or may indicate that the gabbro lopolith and its feeder pipe are not situated vertically below the core.

It does not appear as if the Brandberg Complex gives rise to any large-scale gravity anomaly. Stations were read up to 5 km from the foot of the mountain; these data indicate the extension of a gravity high from the Messum Complex towards the Brandberg Complex and it is possible that the latter has a slightly positive effect on the Bouguer values on the southern side.

No evidence was found for the presence of a large-scale gravity feature which might directly connect the Erongo Complex with the other post-Karoo complexes.

4.2 The Erongo Complex

In outline the Erongo gravity anomaly is elongated in an east-north-easterly direction, with a residual amplitude of about 65 mgal and anomaly half-widths of 40 km and 70 km. Two maxima are indicated by the contours in Fig. 1, but in profile it is clear that the residual anomaly amplitude increases from west to east and that the western "peak" constitutes only a relative high. On the north-eastern side the anomaly slopes down at a maximum gradient of about 3 mgal/km, while it is lower on all other sides.

It is noteworthy that both maxima are situated on large-scale lineaments described by Corner (1982) and depicted in Fig. 1. The western one plots directly on the Welwitschia Lineament Zone, which at this locality coincides with the Erongo ring dyke described below; the eastern one corresponds with the intersection of the Omaruru Lineament and the Abbabis Lineament Zone. The eastern part of the anomaly coincides with the mountain and appears to be elongated in a north-easterly direction, with the peak of the anomaly situated at the northern part of the mountain.

The aeromagnetic contour map in Fig. 2(a) exhibits a group of high frequency anomalies, mainly caused by the rhyodacite that caps the mountain, as well as a large low frequency anomaly consisting of a high to the north of the mountain and its accompanying low on the southern side. Contrary to the gravity anomaly, the positive part of the low frequency magnetic anomaly is elongated in a north-north-westerly direction. This feature diminishes with upward continuation to 6 000 m, yielding the roughly circular anomaly in Fig. 2 (b), with an amplitude of 1275 nT and a maximum to minimum separation of 35 km. The upward continuation effectively removes the group of high frequency anomalies.

Reduced to the pole, the anomaly in Fig. 2(c) coincides with the large eastern peak of the gravity anomaly. Although possible remanent magnetization has been disregarded, it appears reasonable to accept that both the magnetic anomaly and the eastern part of the gravity anomaly are caused by the same body, situated at depth below the Erongo Mountain.

No corresponding magnetic anomaly is associated with the western part of the gravity anomaly. This can either mean that the western part of the body is too deep to give rise to a magnetic anomaly, or that the material is different in composition to that which causes the eastern part of the gravity anomaly.

The above appraisal, the partial separation into two parts of the gravity anomaly on the northern side and the fact that a lengthwise profile of the gravity anomaly can be subdivided into two symmetrical anomalies, suggest the existence of two different bodies. If true, then the western body will be situated about 40 km west of the centre of the complex and at a greater depth than the body which lies directly below the complex.

The roughly circular outline of the complex is reflected by the Erongo gabbro ring dyke to the north and west of the complex, which forms an arc with a diameter of about 30 km. The magnetic anomaly related to the dyke is quite prominent, displaying in places an amplitude of up to 120 nT at a terrain clearance of 100 m. No quantitative interpretation has as yet been carried out, but the dyke appears to be included towards the complex. It is noteworthy that the Erongo ring dyke does not cut across the Omaruru Lineament. Dolerite crops out in a zonal pattern, which appears to be concentric with the Erongo Complex, towards the NE and east at a distance of between 65 km and 80 km from the centre. As with the ring dyke, this zone terminates at the Omaruru Lineament, but in this case it is restricted to the area on the SE of the lineament.

Korn and Martin (1954) stated that "the irregular outline of the Erongo (Complex) appears to be due to the complicated structure of the basement which, on subsidence, disintegrated into several irregular blocks." Lineaments on Landsat images and lineations on the drape flown aeromagnetic contour map seem to support this deduction. Little doubt remains that the development of the Erongo Complex is closely related to the Omaruru Lineament.

It is expected that interpretation of the new magnetic and gravity data will yield the three-dimensional form of both the Erongo and Messum Complexes and thereby facilitate a clearer understanding of their evolution.

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