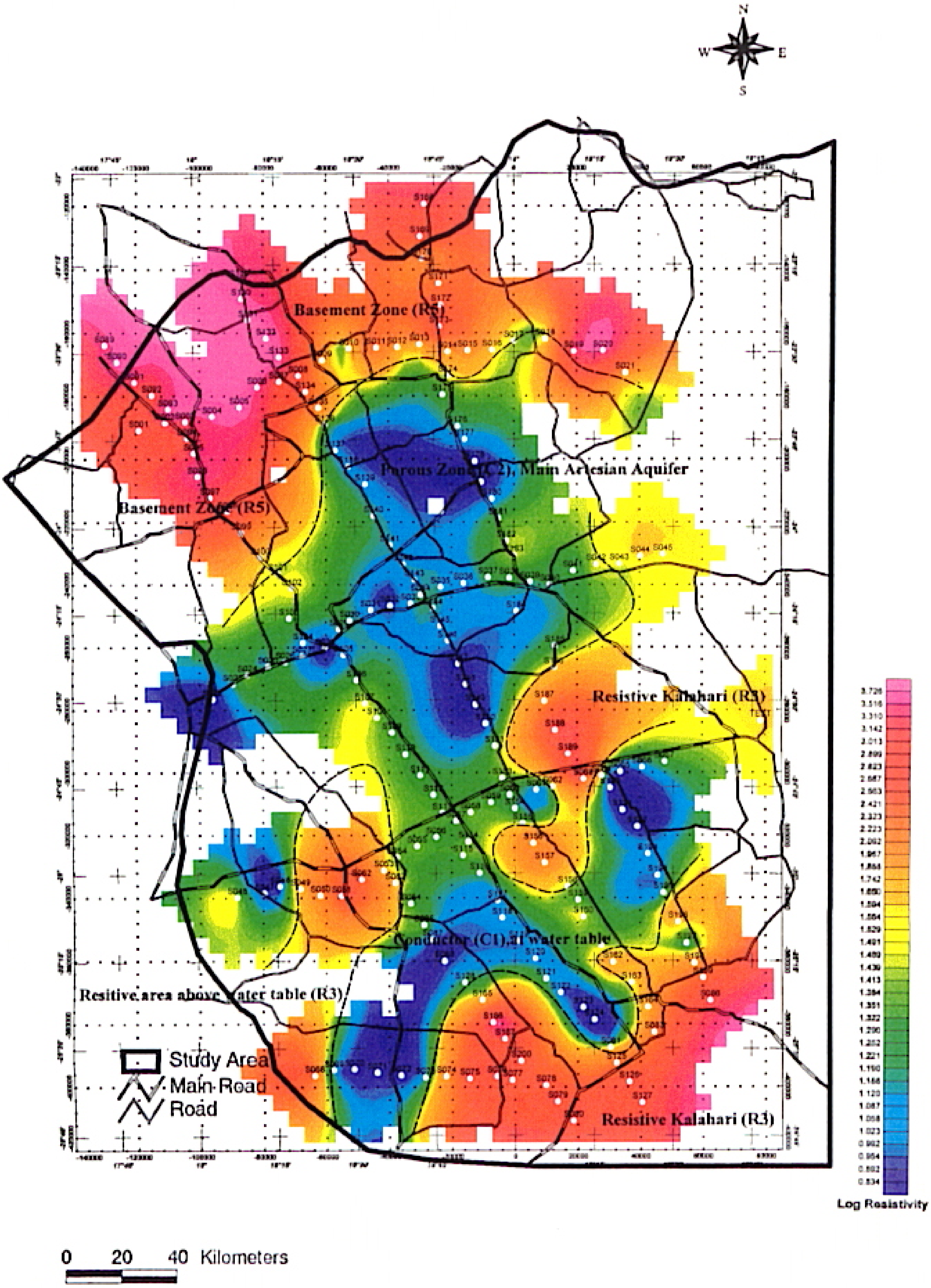

Fig. 5.2-5 Resistivity Plan at 1000m AMSL Based on Smooth Modelling

The first and second order effects represent clear and obvious features in the data, while the third order effects are subtle, appearing real and consistent, but on the limit of interpretability. A number of resistivity zones are also identified on the traverses presented. These resistivity zones are further classified according to whether they fit the first, second or third order effects.

2) First Order Resistivity Effects

The first order effects discussed above in the main reflect vertical resistivity features.

(1) Surficial Zone (R3)

All profiles show a resistive overburden layer. The resistivity is above 100 Ohm-m irrespective of the lithology present at surface. Referring to Archie's law, this zone is interpreted to be above the water table and to thus obviously have a water saturation (S_w) that is low, and hence the higher resistivity. The water saturation in this zone is the overriding variable controlling the resistivity. The depth to this contour is variable showing changes in the water table due to either natural or man-made reasons. It is expected that this level would obviously change with time, especially after major rain events such as the exceedingly good rains that occurred in March 2000.

(2) Surficial zone (C1)

Bellow the water table S_w should obviously increase drastically to close to its maximum value. It is interesting to note that the resistivity is sensitive to the square of the water saturation. This sudden change in resistivity below the water table is obvious in the profiles presented. The sadden change in the water saturation would affect all lithologies in the study area similarly. Resistivity features that cross cut lithology can thus be expected as are observed.

(3) Basement zone (R5)

Resistive Damaran basement is seen on all the north-south profiles especially where basement is shallow enough for the TDEM sounding to have detected it. It appears as if the current TDEM setup is able to detect this basement below the Karoo Sequence lithologies to a depth of approximately 350m. In terms of our theoretical approach, the basement is assumed to consist of lithologies with low porosity containing resistive pore waters, thus producting the high resistivities detected. Saline basement water in an assumed low porosity environment would again imply high resistivity, as resistivity is more sensitive to porosity than to pore water resistivity.

3) Second Order Resistivity Effects

The second order effects appear to describe resistivity changes along strike and not depth effects as above. In examining the north-south sections a define resistivity pattern is observed for those areas below the water table. In the north a low resistivity area is postulated. In the far south, low resistivities are again observed. This area correlates with the “salt block”, an area of known saline groundwater. In between these two conductive areas, an area of higher resistivity is found. These three areas are clearly labelled along the top portion of each of the resistivity depth sections presented, so that they can be easily recognized and perused. Each of the three area is described below with the addition of the Dolerite Zone.

(1) Dolerite Zone (R1)

The Dolerite Zone is a high resistivity area that correlates well with dolerite detected in boreholes. The high resistivities again indicate the presence of low porosity, to be expected from a dolerite mass of this size and distribution.

(2) Porous Zone (C3)

The Porous Zone is a low resistivity area that occurs within the western, central and northern parts of the artesian basin area under study. This low resistivity zone is underlain by resistive basement (R5) in the north and appears to terminate in the south against the Contact or Barrier zone (R4), still to be described below.

The geology within this zone is made up of the Rietmond Shale, Auob Sandstone, Mukarob Shale and the Nossob Sandstone. Shales are usually observed as conductive units due to their large porosities and matrix (cation) conduction and the Rietmond and Mukarob Shales seems to be no exception to this rule. The Rietmond Shale appears to be more resistive than the Mukarob but this may just be a depth distortion effect.

(3) Contact or Barrier Zone (R4)

The contact or the more aptly called Barrier Zone (R4) is a higher resistivity feature situated between the Porous Zone (C3) and the Saline Zone (C2). The following geological features appear to be present in the area:

- The Auob formation becomes much thinner. This may be due to erosion of the Karahari into the Auob formation or due to sedimentological reasons.

- The Rietmond Shale that usually overlies the Auob Formation is in the main missing.
- There appears to be more structural deformation in the area. At least one fault can be postulated as well possible folding.

(4) Saline Zone (C2)

The Saline Zone is characterized by low resistivities in an area that corresponds with the position of the so-called “salt block”. Within this area old saline groundwater is present. The lower resistivities thus appear to be controlled by R_w and not by any changes in porosity. The area is also distinct from a geological point of view as the Kalahari is well developed in this area. The Kalahari also appears to have eroded down into the Karoo, and in most areas the Rietmond Shale Formation is missing and in some cases the Auob Formation as well.

4) Third Order Resistivity Effects

These effects as described below are reasonably subtle. They may be real, but could also be caused by geophysical noise or be modelling induced, thus the third order classification.

(1) Porous Dolerite Zone (R2)

The Dolerite Zone (R1) appears to undergo a slight change in resistive zone near and at the contact with basement, which is termed the Porous Dolerite Zone (R2). This change in resistivity is ascribed to the development of a secondary porosity, possibly structurally induced. This zone appears to dip to the south and possibly forms a conduit to waters entering the Auob and Nossob Sandstone Formations from the north.

(2) Mixing Zone (I2)

This zone is found between the Contact or Barrier Zone (R4) and the Saline Zone (C2), and may indicate that some fresh water from the Contact or Barrier Zone is mixing with saline waters in the Saline Zone.

(3) Intermediate Porous Zone (I1)

This zone could be incorporated with the Porous Zone (C3) except that the resistivities are slightly higher indicating either a slight change in porosity or in R_w.

5.2.4 Conclusions

- The data indicates the presence of resistive over burden in the entire study area, which is caused by unsaturated sediments above the water table.

- A large decrease in resistivity is observed at and below the water table as should be expected. This resistivity remains low at depth due to shale and porous the study area, and due to saline waters in the “salt block” in the south-eastern portion of the area.

- Between the “salt block” and the normal aquifer area, an area of poor permeability and porosity trending in a north-easterly direction is postulated, based on an increase in resistivity. The Gochas Magnetic Body and north-easterly trending magnetic features at depth may have caused these permeability changes. This Contact or Barrier Zone may be responsible for the lack of recharge from the normal aquifer areas to the north to west. The “salt block” is thus an area where little or no recharge can occur due to the position of the Contact or Barrier Zone.

5.3 Aeromagnetic Survey

5.3.1 Survey area

The survey area is bounded by latitudes 22°45’S and 26°S, and longitudes 17°E and 20°E. It covers the Stampriet Artesian Basin, situated in the central-eastern Namibia.

5.3.2 Survey method and interpretation procedures

The software and interpretation techniques outlined below were used for the production of the accompanying interpretation images and map.

- The GEOSOFT software was used for all data processing, image map production and compilation of the interpretation map.

- The GEOPAK RTICAD image processing software, which allows apparent sun-shading to be conducted in real time, greatly facilitated the identification of structures. It should be noted that the images accompanying this report represent only one sun-shaded direction, rather then the infinite number of apparent sun inclinations and declinations available during the interpretation process. No single image can thus enhance all of the mapped structures.

- Data sets and transformations used for the interpretation include: total-field magnetic data, reduced-to-the-pole total-field data, analytical signal first vertical derivative, and depth analysis. The depth analysis was conducted using the Euler deconvolution technique of Geosoft's Gridepth software.

5.3.3 Survey Results

Aeromagnetic colour image map and aeromagnetic interpretation map of the study area are shown in Fig.5.3-1 and 5.3-2 respectively.

1) Mapped faults

The faults and fault-lineaments shown in the interpretation map were mapped on the basis of their relative clarity of manifestation in the various data sets. The fault-lineaments, identified as being of regional scale, have also been identified in past regional interpretations of the area and environs. The following subjective categories of faults and fault-lineaments are used in the interpretation map:

- Distinct faults, i.e. those which are clearly evident in the data sets;
- Less distinct or diffuse faults, i.e. those which are still evident but which are more diffuse in appearance; in areas of no data these faults are inferred by virtue of apparent continuity of faults on either side of the data gaps;
- Lineaments - these are faults which are also evident on a regional scale outside the study area, i.e. they are hallmarked by regional scale continuity and/or faults within the deep magnetic basement interpreted from long wavelength anomalies;
- Kudu Lineament Zone (KULZ) - the term lineament zone is used to encompass a broad swath of features such as, continuous or discontinuous faults of similar direction, structural disruption or termination of geological units, as well as possible intrusions which may lie along the zone; the Kudu Lineament Zone has been identified from other studies by the author and is schematically indicated in the interpretation map as the locus of a much broader zone than indicated, perhaps 60km, also encompassing the north-northeast set of faults in the vicinity of Gibeon.

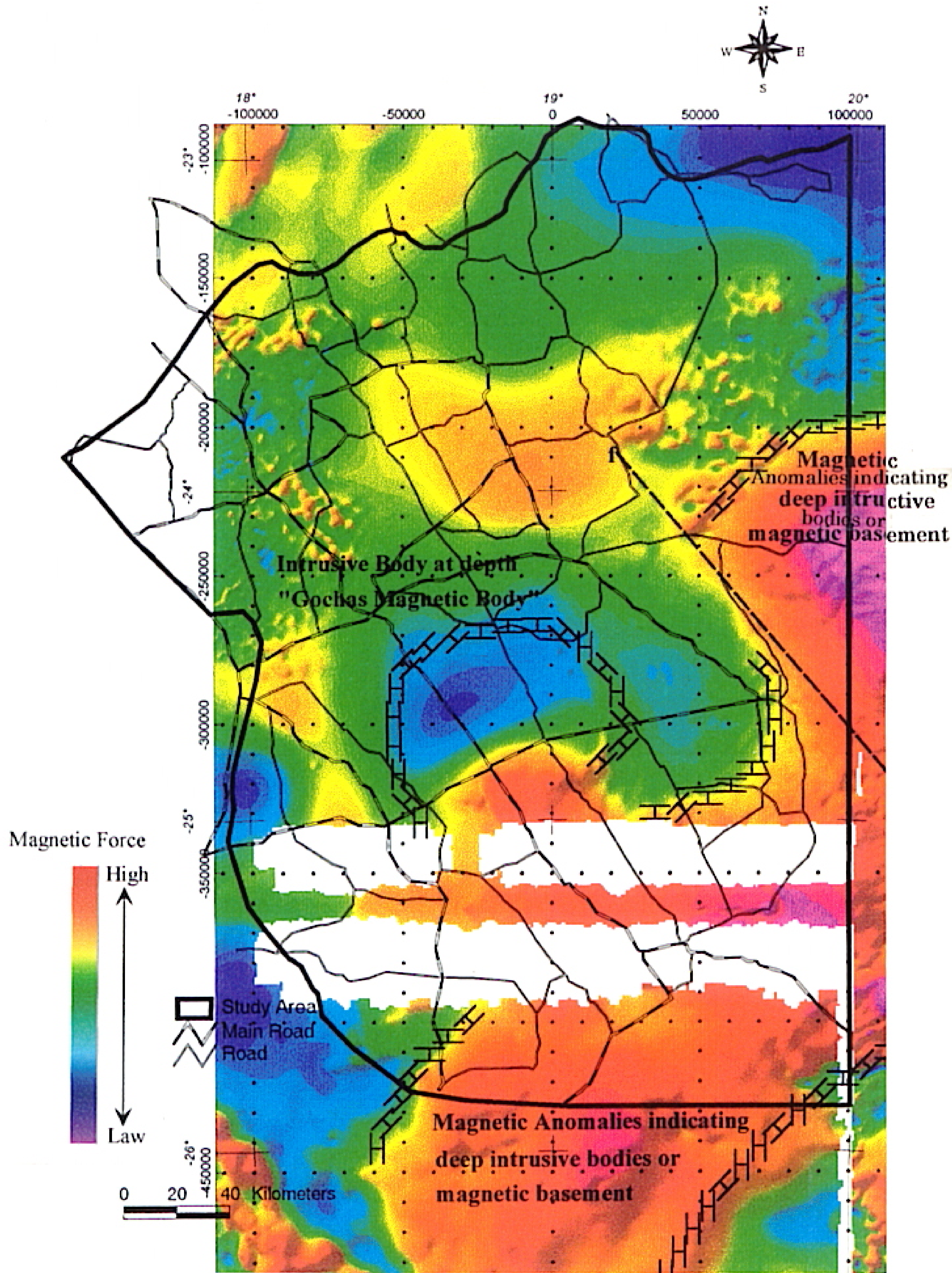

Fig. 5.3-1 Aeromagnetic Anomaly

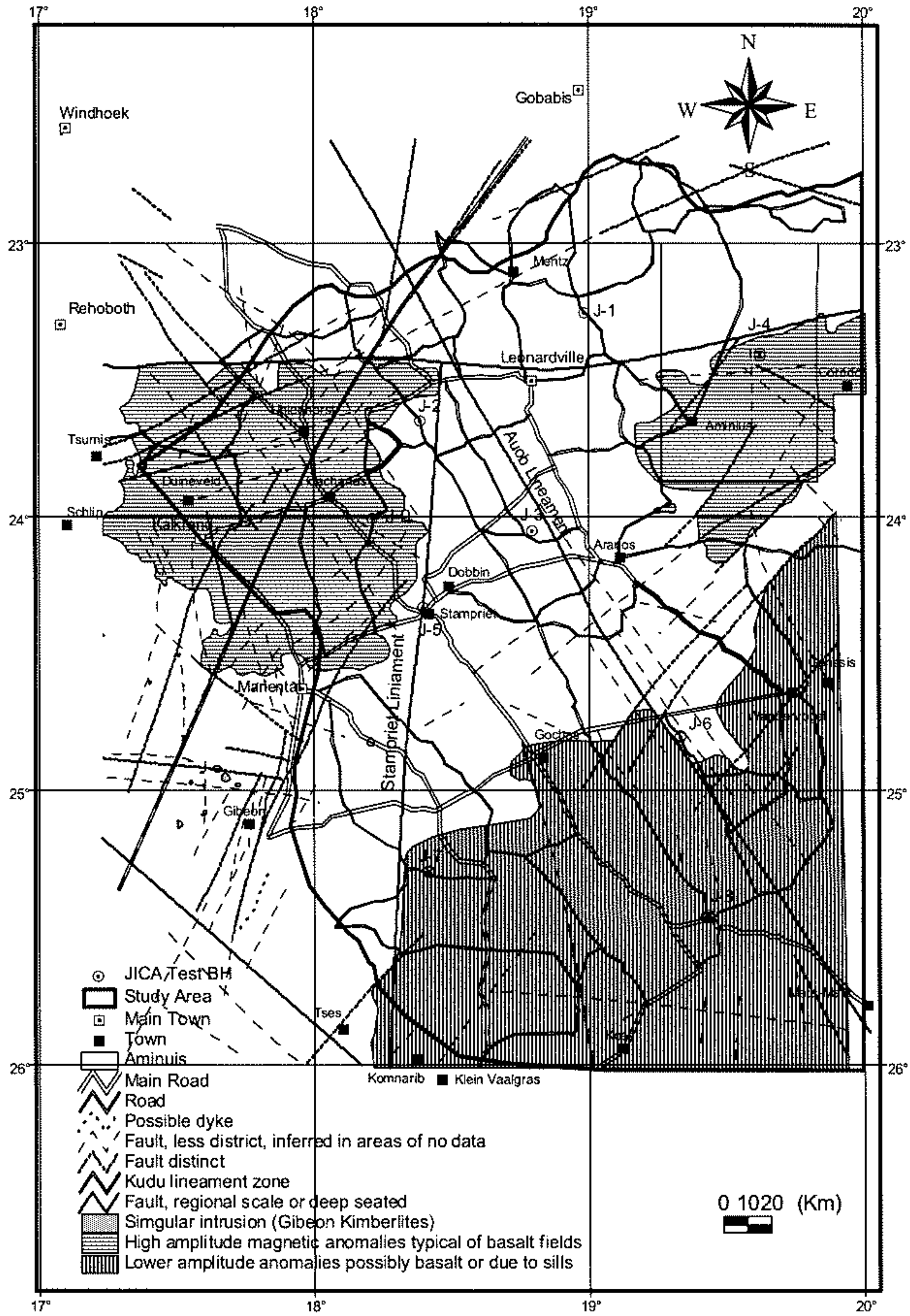

Fig. 5.3-2 Aeromagnetic Interpretation Map

The names of the indicated lineaments are mostly derived from previous regional studies (e.g. Corner, B. Crustal Framework of Namibia derived from magnetic and gravity data, in preparation, Special Commemorative Henno Martin Volume of the Geological Society of Namibia). Two lineaments have, however, been newly named in this study for the sake of discussion, i.e. the Stampriet and Auob Lineaments.

2) Fault significance

The significance of the mapped faults to the groundwater studies in the area cannot be ascertained from the magnetic data alone. The faults are, in the first instance, relatively old, ranging in age from pre-Damara to Karoo times. However, it is known that many older faults have been continuously reactivated through geological history up to present times (e.g. the Hebron fault in western Namibia which forms part of the Nama Lineament). Which faults in the study area have been reactivated in recent times, to constitute secondary aquifers potentially linking primary formational aquifers, can only be determined by comparison of the aeromagnetic interpretation with satellite imagery, mapped geology, borehole data, and the disposition and quality of known aquifers derived from the hydrocensus study. This comment applies equally to the role of the faults in controlling horizon thicknesses during sedimentation.

It is nevertheless worthy of mention that the northeast-trending faults may hold potential as secondary aquifers since they lie on the projected south-westward extension of the Boro and Thamalakane faults (as examples) which bound the Okavango Delta in Botswana, and which are currently seismically active. Further north, in the Eiseb area, Kalahari sand dunes are seen to be faulted by this direction of faulting.

The rivers and larger drainages (GSN data base) have been superimposed on the interpretation map to see what correlations might exist between these recent features and the underlying mapped faults. The Auob Lineament has clearly controlled the direction of the three major rivers in the eastern part of the area, i.e. the Nossob, Olifants and Auob rivers. Satellite imagery may reveal faults, not evident in the coarse aeromagnetic data, parallel to the Auob Lineament which have directly controlled the course of these rivers. The course of the Fish river also appears to be controlled by faulting, i.e. by the set of north-northeast trending faults associated with the KULZ passing through Gibeon. Sub-parallel to these faults is the north-south Stampriet Lineament which passes through Stampriet itself. This lineament was interpreted from the displacement or termination of deep-seated anomalies occurring in the magnetic basement. Whether the Stampriet Lineament has a recent surface expression which has in some way controlled the Stampriet artesian water cannot be ascertained from the magnetic data alone. Its influence, if any, can only be determined by co-analysing all the other data sets.

3) Basalts and sills

A number of basalt fields and areas underlain by sills are evident in the data. Variations in data resolution have compromised the clear identification and categorisation of these areas into basalt and sill types. In broad terms three categories of anomaly types, taking cognisance of resolution variations, are identified, i.e.

- two distinct northern basalt fields, bounded in the north by the Sandwich Bay Lineament, are evident by virtue of typically localised and "stringy" high amplitude anomalies (or undersampled versions thereof in the coarse resolution data);

- immediately south of the easternmost of these two basalt fields is an area of very low amplitude anomalies which is bounded by clear margin anomalies; this is indicated as an area of possible sills in the interpretation map, but could also be a basalt field either with a different magnetic petrology or more deeply buried;

- further south, encompassing the southern and south-eastern portion of the study area is a region of variable amplitude anomalies, generally lower in amplitude than those of the northern basalt fields but with some clear sill-like anomalies.

Correlation of the above three basalt/sill areas, as well as specific anomalies, with existing borehole data should help to map detail within these areas.