INTERPRETATION OF HIGH RESOLUTION AEROMAGNETIC SURVEY DATA OVER THE PROJECT LIMA AREA, STEELPOORT PUMPED STORAGE SCHEME ROOSSENEKAL LOCALITY, MPUMALANGA PROVINCE ON BEHALF OF BKS (Pty) LIMITED, ENGINEERING AND MANAGEMENT

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SUMMARY

High resolution aeromagnetic surveys along 524km of line over the $10km^2$ Project Lima area have mapped the distribution of Bushveld mafic rocks, plus younger dykes and structures with a high degree of confidence. Bushveld felsic rocks overlying the mafic units and capping the Nebo Plateau have not been mapped because of their essentially non-magnetic nature, and here recourse has been made to earlier geological mapping work plus the DTM elevation image generated as an ancillary survey project.

Magnetic units at or near the top of the mafic succession, including the target magnetite-rich bands, exhibit an arcuate N-S strike trend (concave to the west) following escarpment contours, while lower units are characterized by roughly linear NNE strike trends. The strike trace of the magnetic-rich horizon does not always spatially correlate with historical geological mapping information, and certain other contact locations also display discrepancies.

At least 2 WNW-striking dolerite dykes have been mapped over the Plateau area but not to the east, while faulting has been inferred over mafic rock terrane along NE and NW axes. The NE striking feature may offset the magnetic-rich horizon in a dextral sense to the west of the planned "outfall structure", and this plus a converging NW fault may constitute an area of geotechnical concern.

Recommendations have been made concerning the integration of present findings with surface and borehole geological mapping results, to better define zones of geotechnical concern, and these include further geophysical work.

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1. INTRODUCTION

During September 2006, low-level high resolution aeromagnetic surveys were flown by contractor FUGRO over the Steelpoort Pumped Storage Scheme Lima Project Area in the Roossenekal locality of Mpumalanga Province, on behalf of the Engineering and Management Division of BKS (Pty) Limited. Survey planning/commissioning were the responsibility of BKS, while data acquisition and processing QC plus interpretation were managed by GAP Geophysics. The aeromagnetic survey aimed at mapping features of geotechnical interest including certain stratigraphic units, dykes and faults.

The survey was flown over a rectangular-shaped block with dimensions of 5km (ESE) by 2km (NNE), falling some 10km NW of the settlement of Roossenekal (Figures 1, 2). This block extends from the northerly draining Steelpoort River Valley in the east to the top of the Nebo Plateau in the west, the easterly facing escarpment having a total elevation relief of some 700m (Figures 2, 3). The area is dissected by easterly draining channels from the plateau and, apart from agricultural development along the Steelpoort River, constitutes virgin Bushveld terrane.

Geological control was derived from 1:250 000 Geological Sheet "2528 Pretoria, 1:50 000 geological Mapping by Molyneaux (1970), detailed project area geotechnical mapping by Partridge, Maud and Associates (1999) and BKS (2006). The area is underlain by mafic and felsic units of the Rustenburg Layered Suite (RLS), which exhibit a generalized N-S strike and dip flatly to the west at between 5° and 15° (Figures 1, 4 and 5). They are cross-cut by NNE and WNW striking dolerite dykes and at least NE-striking faults. Diorite, magnetite-gabbro and gabbro / norite lithologies of the Bushveld Upper Zone outcrop over the eastern half of the area of interest up to an elevation of ~1300 amsl. They include an ~20m thick zone of banded magnetite / anorthosite which is of geotechnical concern because of its brittle nature. Mafic units are succeeded westwards by felsic rocks of the Rashoop Granophyre Suite, which form steep scarp slopes and cap the Nebo Plateau at an elevation of around 1700m.

Aeromagnetic interpretation objectives were to generate pseudo-geological outcrop and structural maps highlighting lithological contacts, including that of the magnetite-rich horizon, plus younger intrusions and possible fault zones, thus:

- High amplitude magnetic anomalies reflecting magnetite-rich horizons.
- Linear to curvilinear litho-magnetic horizons, whose lateral offsets in strike could indicate dip-faulting.
- Linear magnetic markers reflecting dolerite dykes, whose strike-traces may also reflect precursor fault zones
- Other magnetic lineaments possibly reflecting fault strike traces.

Qualitative mapping results were generated from a conventional (albeit exhaustive) image processing approach, complemented by magnetic modelling exercises providing estimates of source depth, width and apparent geological dip.

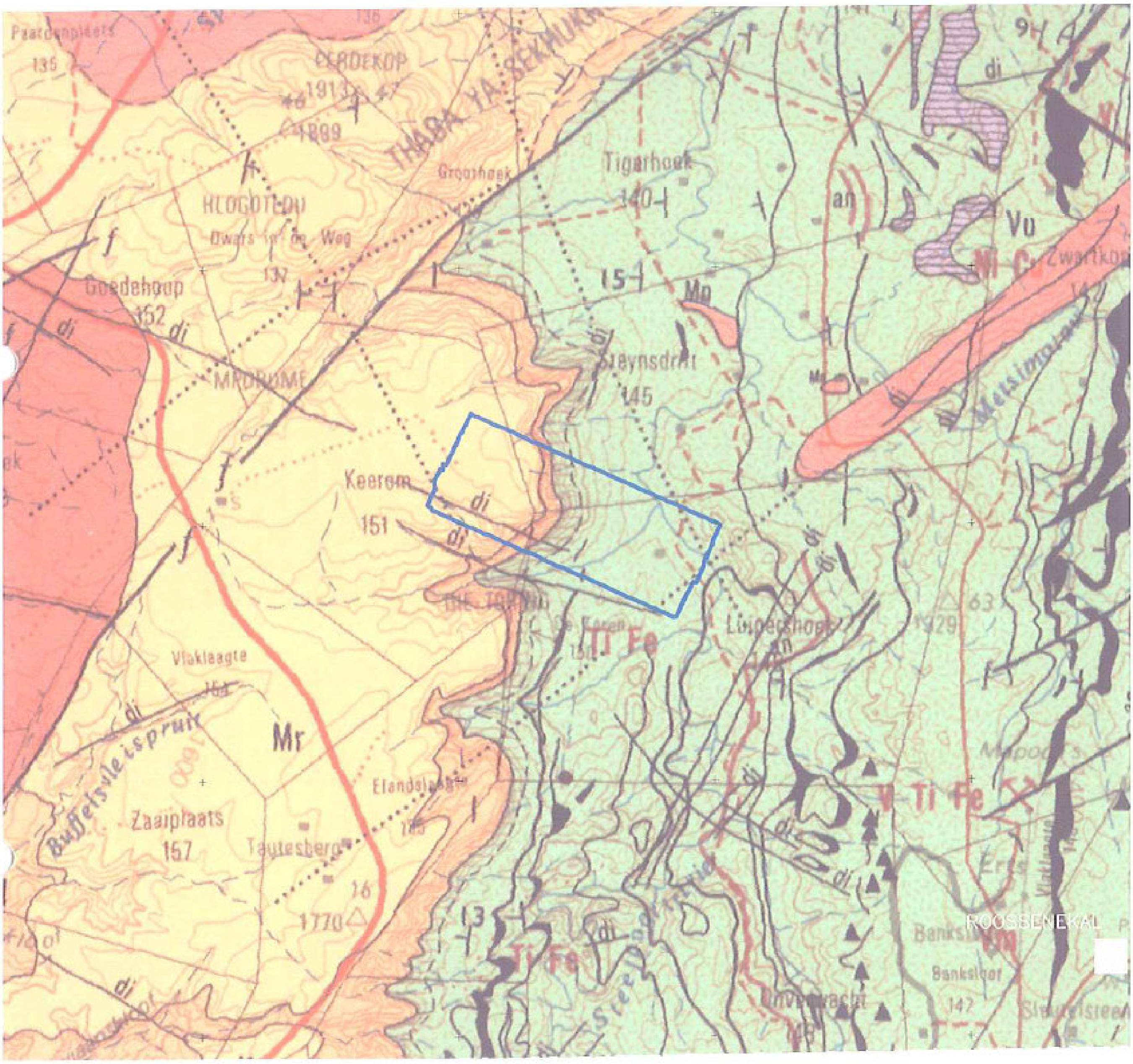


FIGURE 1 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY

Regional Geology Map

After 1:250 000 Sheet 2528 Pretoria

LEGEND

Survey Area

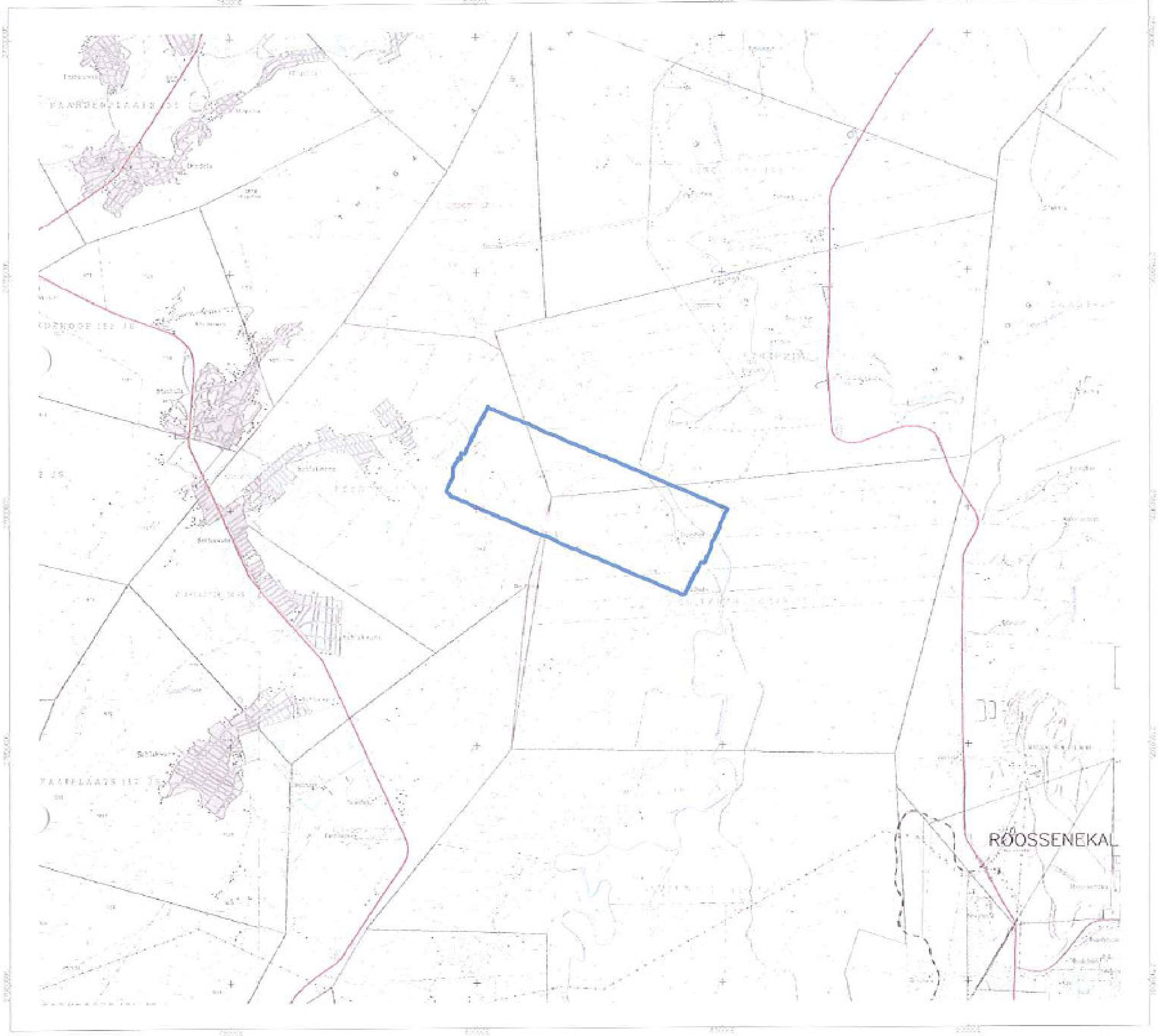


FIGURE 2 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
1:50 000 Topographic Map
After Sheets 2529BA & 2529BB

FIGURE 3 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
Greyscale Aerial Photography Image

250 0 250 500
(meters)
Hartebeesthoek94 / South African Survey Grid (N,E) zone 29

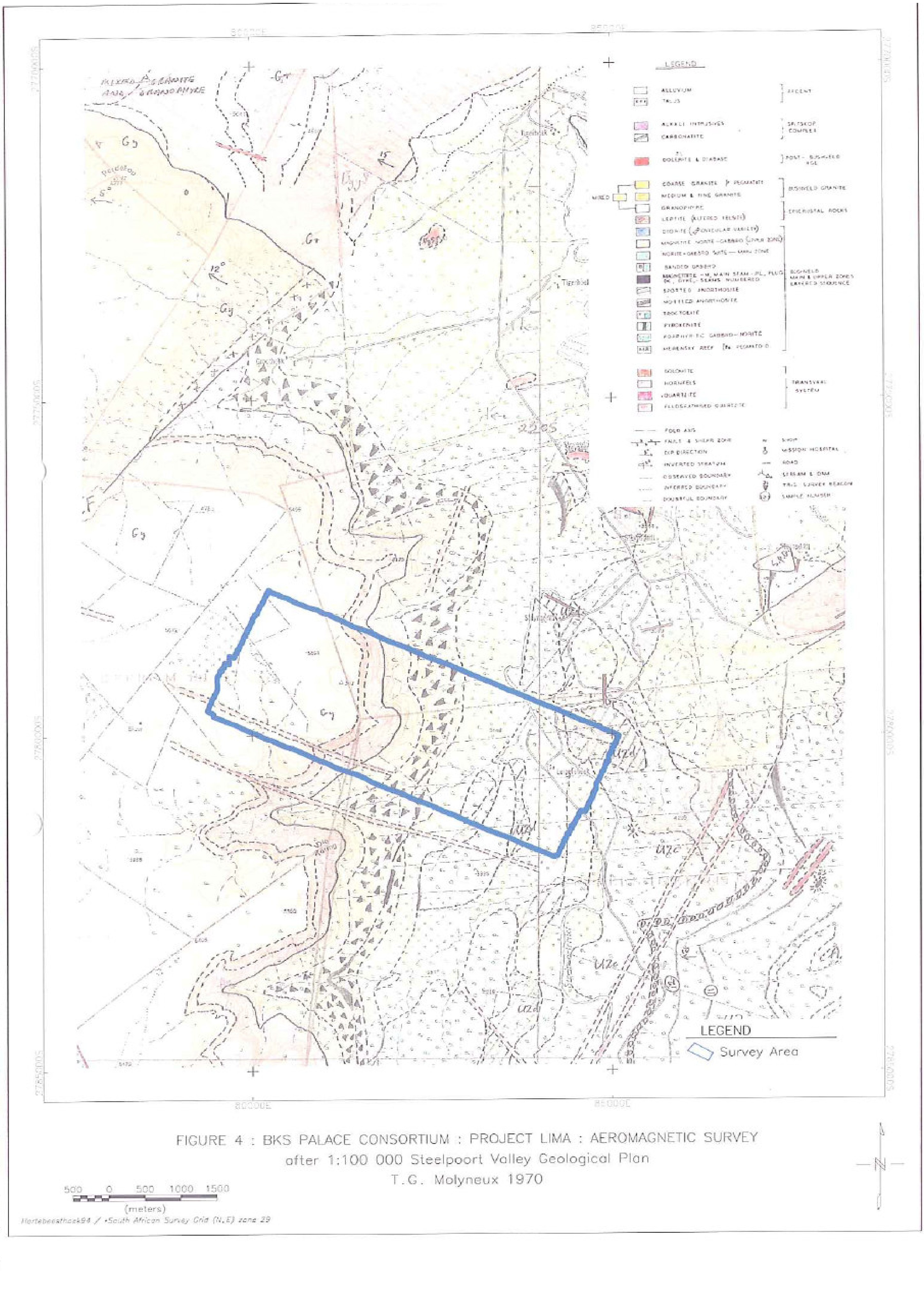


FIGURE 4 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
after 1:100 000 Steelpoort Valley Geological Plan
T.G. Molyneux 1970

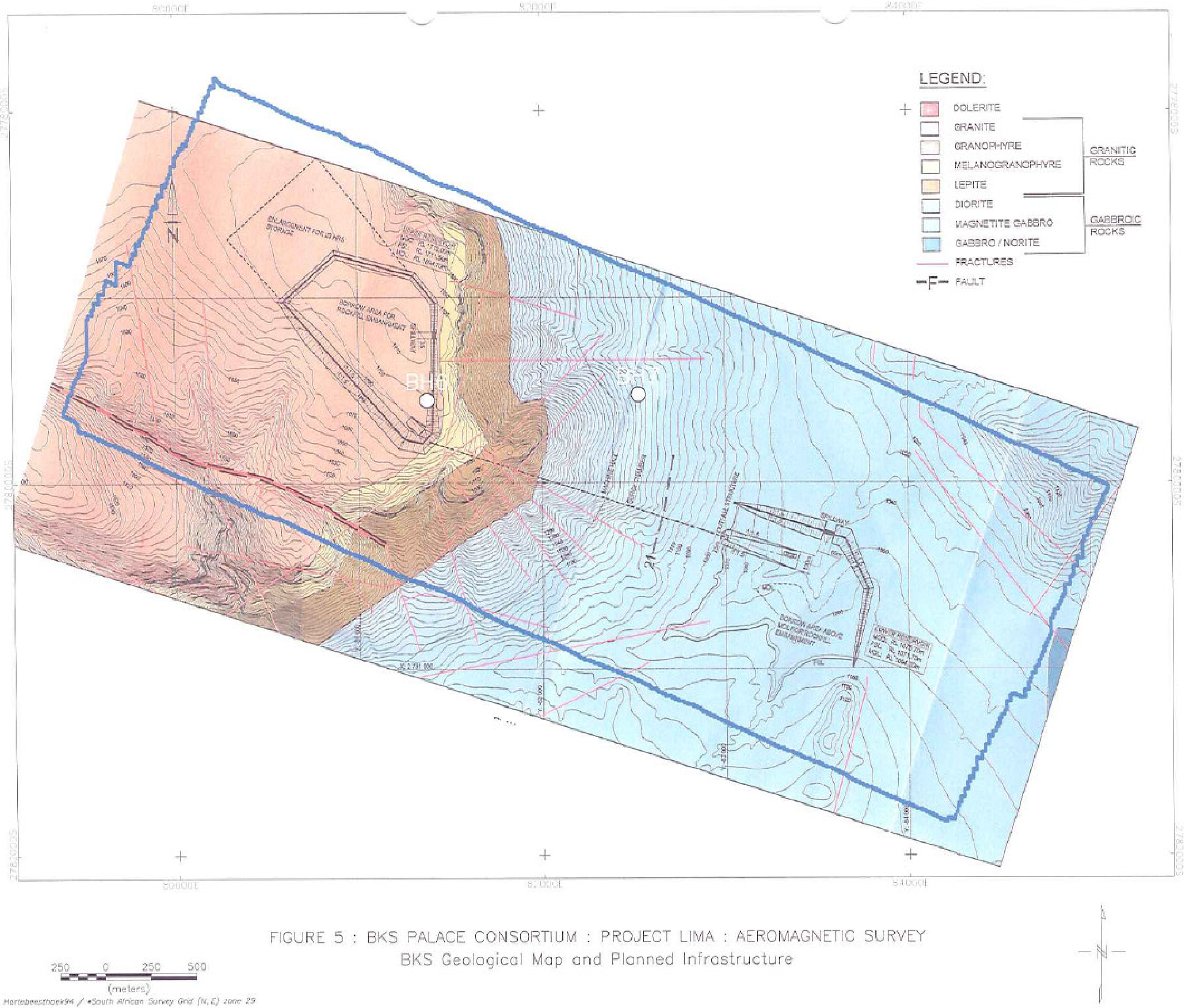


FIGURE 5 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
BKS Geological Map and Planned Infrastructure

2. SURVEY METHODS AND INSTRUMENTATION

2.1 Aeromagnetic Survey Specifications

Survey parameters presented below are derived from the FUGRO logistics report for this project (FCR 2426); an abbreviated version follows below:

Survey Area	
Dimensions	: Longest dimensions of 5km (ESE) by 2km (NNE)
Area	: $10km^2$
Survey Lines	
Flight line direction	: 115°T
Flight line spacing	: 25m
Tie line direction	: 025°T
Tie line spacing	: 250m
Survey line coverage	: 524 line km
Survey Parameters	
Airborne Platform	: Bell 206 IIIB Jet Ranger
Platform Airspeed	: 160kmph
Sensor Terrain Clearance	:
Magnetometer	: 20m nominal
Magnetometer System	
Magnetometer	: Two Scintrex caesium vapour magnetometers
Sensor Configuration	: Horizontal (broadside) gradiometer system with 13m sensor separation
Data Sample Rate	: 0.1sec (ground equivalent 4m)
Magnetometer Sensitivity	: 0.01nT nominal
Total field noise envelope	: <±0.1nT
Navigation	: Real time differential GPS
GPS update rate	: 0.5 sec (ground equivalent 20m)

The close to 1:1 ratio for flight line spacing to magnetic source depth (source @ ~30m below sensor) allows for "3D" aeromagnetic mapping capabilities, in which all magnetic sources with anomaly amplitudes in excess of, say 2nT, are crisply imaged irrespective of their strike orientations. However, shallow E-W striking features will be imaged less crisply than their N-S counterparts.

2.2 Survey Instrumentation

The survey area was flown by contractor FUGRO using a horizontal gradiometer magnetometer system mounted on a Bell 206 IIIB Jet Ranger helicopter operating at airspeeds of 100 to 160 kmph. SCINTREX CS3 caesium vapour magnetometers with a basic (total magnetic field) sensitivity of ±0.01nT at a 10Hz sample rate are mounted at the ends of a 13m long horizontal boom rigidly attached to the aircraft at right angles to its centre-line and the flight-line direction. Conceptually, the acquisition of measured horizontal gradient data perpendicular to flight lines allows for the generation of superior gridded data sets and a significant reduction in the normal aliasing associated with single sensor surveys.

In-flight navigation and flight-path recovery were based on a real-time differential GPS system employing NovAtel GPS receivers in mobile and base-station modes. Plan position (X,Y) accuracies are around 2m at the 0.5sec sample rate used in this survey (a ~20m ground equivalent interval). Ancillary equipment included a MRA Mk1V radar altimeter and a ROSEMOUNT digital barometric altimeter with relative accuracies of 12.5cm and ±20cm respectively. A Scintrex CF1 caesium vapour base-station magnetometer sited close to the survey area provided a permanent record of magnetic field diurnal variations during the flying portion of the survey. Monitoring of this information confirmed that aeromagnetic data acquisition was restricted to periods of low diurnal activity (less then 10nT change over 10 minutes).

3. SURVEY DATA PROCESSING AND INTERPRETATION

3.1 Contractor Data Compilation

3.1.1 Aeromagnetic Data

Magnetic data compilation was undertaken by FUGRO using GEOSOFT OASIS and ECS software packages. Flight line data was first compiled in profile form, a procedure which included:

- Recovery of digital magnetic and GPS flight path data.
- Inspection of velocity reports for "speed" errors.
- Loading of fiducials and sensor data into database.
- Elimination of magnetic "spikes" using fourth difference operators.
- Removal of observed diurnal magnetic variations.
- Levelling of line magnetic data to a common datum via a polynomial surface (derived from tie-line intersections) fitted to the survey lines, followed by "random" levelling to correct for high frequency diurnal variations.

In gradiometer surveys data from the 2-magnetometer sensors is used to compute the cross-line horizontal gradient for later gridding purposes, and then averaged to provide a single, (helicopter) centre-line total magnetic field data set.

Line total magnetic field data was gridded on a 5m square cell basis via a bicubic spline algorithm with line-to-line correlation and horizontal gradient enhancement. The gridded data were then used to produce machine plots of standard contour plans and colour contour images at a scale of 1:10 000. Line and grid image data were initially generated using the Universal Transverse Mercarot Projection, UTM Zone

35S, WGS84 Ellipsoid, Hartebeesthoek 94 Datum. Data were subsequently transformed by GAP to a Gauss Conformable Projection (WGS84 Spheroid/Hartebeesthoek 94 Datum) with a Central Meridian of 29°E, in line with current BKS working standards.

3.1.2 DTM Data

Compilation of the digital terrain map was based on flight line elevation inputs from the radar altimeter and barometric altimeter plus the GPS system. Surface elevations below survey flight lines were computed by subtracting radar altimeter terrain clearances from GPS elevations amsl, data being interpolated via the barometric altimeter to the ground equivalent sample interval of 4m. Data were then conventionally gridded on a 5m square cell basis and produced as colour images.

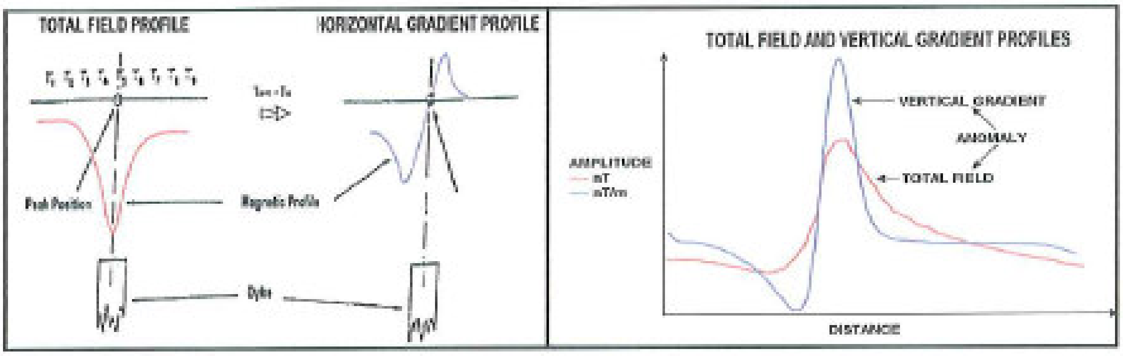
3.2 GAP Aeromagnetic Data Processing

3.2.1 Map Generation (Magnetics)

Several specialised magnetic mapping tools were generated from the conventional total magnetic field data in order to facilitate the interpretation exercise. These tools aimed at (a) improving the spatial mapping resolution of stratigraphic and intrusive units and (b) enhancing subtle structural features of limited amplitude and often-intermittent continuity. The following data transforms and filtering routines were effected using frequency and space domain filters in the GEOSOFT mapping package.

- **Reduction-to-the-pole:** This transform generates a total field data set whose magnetic anomaly signatures are commensurate with a -90° inclination of the earth's magnetic field (as at the South Pole), rather than the -60° for the induced magnetization of the prospect area. The effect is to simplify the magnetic map by rendering anomaly waveforms (their HI/LO ratios) independent of strike direction, and by generating positive, symmetrical anomalies over vertically dipping magnetic sources (dyke units), which are magnetized by induction only. Anomalies remaining with an asymmetric waveform (significant LO's) then reflect moderate to flatly dipping sources, or those with a large component of remanent magnetization not aligned in the present geomagnetic field direction. The latter condition holds for most of the litho-magnetic units within the present area, resulting in reduced-to-the-pole magnetic signatures which are more dependent on magnetic history than geological dip. This transform was of limited utility in the present area because of strong remnant magnetization of both negative and positive polarities.

- **Vertical/Horizontal Gradient Data**: Horizontal and vertical gradient data sets emphasise shallow source responses at the expense of broader regional responses, and allow for the recognition of low amplitude, short wavelength magnetic anomalies in areas of significant magnetic relief. Such features often reflect structural linears (and dykes). The resulting gradient anomalies are narrower than their total field counterparts, and display different waveforms as shown overleaf:



Total horizontal gradient data was used in the project as a relative indicator of source body width. Vertical gradient anomalies over steeply dipping magnetic sources are generally less complex than their horizontal gradient counterparts, and are preferred in map interpretation. Their waveforms are more asymmetric than the corresponding total field anomaly, and visual inspection of the resulting HI/LO ratios allows for a further check on the dip of a magnetic source. In this exercise, vertical gradient grid data was utilized widely for lineament and contact mapping.

The calculated second vertical derivative further boosts the response of shallow targets but generally at the expense of higher noise levels than its first derivative counterpart, which is therefore preferred as a prospect-wide mapping tool. However, over isolated bodies second derivative data has the advantage that zero level contours roughly coincide with the contacts of the magnetic body, rendering this data of some significant use in semi-quantitatively outlining the plan positions of wide intrusive and stratigraphic units. Often "noisy" data precluded using this transform to its full potential.

- **Analytical Signal:** This "total magnetic gradient" parameter is the scalar sum of the vertical and horizontal gradients of the total magnetic field. In this case, use was made of calculated gradients, with horizontal gradients being computed along the Y (north) and X (east) co-ordinate directions via space-domain processing of the total magnetic field. Analytical signal data yields a wholly positive bell-shaped anomaly over any magnetic source irrespective of its geological dip or its remanent magnetization history. As such, the data is useful for mapping the strike trace of long magnetic sources or the centre of plug-like sources. In this exercise mafic rock contacts and the strike trace of the magnetite-band were effectively mapped from this transform.

- **Magnetic Tilt Angle**: This "amplitude free" parameter emphasises the continuity of both shallow and deep magnetic horizons, and is derived from ratio-ing the vertical and total horizontal gradients. It is generally used as a structural mapping assist and proved useful in this area for mapping strike-continuity through zones of noisy data.

- **Pseudo-Gravity Horizontal Gradient**: A conceptual transform which is used to better delineate edge locations for wide, anomalous source bodies. As the firststep pseudo-gravity transform calls, inter alia, for reduction-to-pole procedures, edge offsets may be expected where (as here) remnant magnetization is present.

- **Image processed data:** "Sun-shading" highlights short wavelength, low amplitude magnetic anomalies at shallow depths (dykes and structures) in total field and other data sets, on the basis of their high horizontal gradients in the "X" and "Y" co-ordinate directions. The effect is analogous to the low angle sun illumination of a digital terrain model: steep features generate sharp, intense shadows. Where the sun azimuth is at a large angle to geological strike, the process allows for the visual confirmation of strike continuity along sectors where anomalies are only poorly developed.

3.2.2 Magnetic Strike and Depth Estimation

EULER GRID-DEPTH: Euler deconvolution is a semi-automatic method applied to gridded magnetic data for the rapid delineation of magnetic boundaries and the estimation of depth of their upper edges. The method assumes point or line magnetic sources (pole or dipole) whose magnetic amplitude variation with depth is summarised by a "structural index (N)", thus:

GEOLOGICAL UNIT	MAGNETIC STRUCTURAL INDEX	
	TOTAL FIELD	VERTICAL GRADIENT
Contact	N=0.5	N=1.0
Dykes or Sill Edge	N=1.0	N=2.0
Pipe or Horizontal Cylinder	N=2.0	N=4.0

This approach involves dividing the data into a number of overlapping windows and computing the magnetic field horizontal and vertical gradients at each point in this window. For a given structural index, a series of simultaneous equations are than solved by least squares techniques to give estimates of source position and depth. In practice, all solutions are recorded, but only those whose standard (normalised) errors are less than the specified tolerance are plotted.

For the current data set, cell sizes of 20m and 30m were used in conjunction with a moving window of 10 by 10 cells. Depth and positional tolerances were set at less than 15% and 30% respectively, and solutions were obtained for structural index values reflecting sheet and contact sources. The middle diorite unit hanging-wall contact was well mapped from this transform, as were dyke strike traces.

MAGMOD PROFILE DEPTH: Quantitative interpretation of magnetic profile data was undertaken using standard MAGMOD inversion routines on "infinite" tabular sheet models (2D) reflecting stratigraphic and dyke-like anomalies and $2^1/_2$D models reflecting pipe-like bodies. These inversion routines yield best-fitting (in a statistical sense) model parameters which include source depth, width, apparent geological dip and magnetic susceptibility.

3.3 Presentation of Data

The following plates are presented with this report at a scale of 1:10 000:

Plate 1 : Digital Terrain Map

Plate 2 : Total Magnetic Field Map

Plate 3 : Geophysical Interpretation Map

Reduced versions of several of the 1:10 000 maps produced by GAP are presented as A4 figures in the main body of the report. All are available as 1:10 000 maps on request.

4. DISCUSSIONS OF RESULTS: AEROMAGNETIC SURVEY

4.1 Digital Terrain Data

Surface elevation profiles computed from the radar altimeter and GPS inputs show a noise envelope of up to 3m over a total elevation relief of some 710m. The digital terrain map (Figure 6) generated from the airborne data correlates well in a relative sense with the 20m elevation contours from 1:50 000 topographic map 2529BB. Although absolute elevation values are in agreement within ±2m over areas of low ground (<1100m amsl), the airborne DTM values over high ground (>1600m amsl) show a positive bias of around 11m. If necessary and where accurate spot heights are available, the airborne DTM data may be warped to better fit true elevation values.

Surface landform is dominated by the irregular, N-S trending escarpment fronting the Nebo Plateau in the west, whose highest elevation is ~1725m amsl. Between this level and the Steelpoort River (<1020m amsl), the escarpment shows two major breaks in average slope angle: some 35° between 1700m and 1300m amsl and 15° to 25° between 1300m and 1100m amsl, before further flattening out to the east. Plateau continuity is broken over the SW sector by a detached, NE-trending knob of high ground, and further south by a WNW trending, deeply incised drainage channel. Over the far eastern sector, isolated NNE-trending ridges map outcropping Bushveld mafic units. Between these a discrete, paired elevation "high-low" may reflect a recent excavation and spoil dump.

Correlations between bedrock geology and surface topography are evident over certain locales. The escarpment "break-in-slope" at ~1300m amsl maps the hanging-wall contact of the Bushveld *magnetic* mafic lithologies, while that at 1100m amsl maps same for the magnetite rich horizon. The deeply incised, WNW-striking Plateau drainage channel in the SW hosts a similarly orientated dolerite dyke. Aside from these, there are no compelling DTM lineaments which might reflect geological structures. There is some suspicion that the detached knob of high ground in the SW is structurally bounded, but this is not proven.

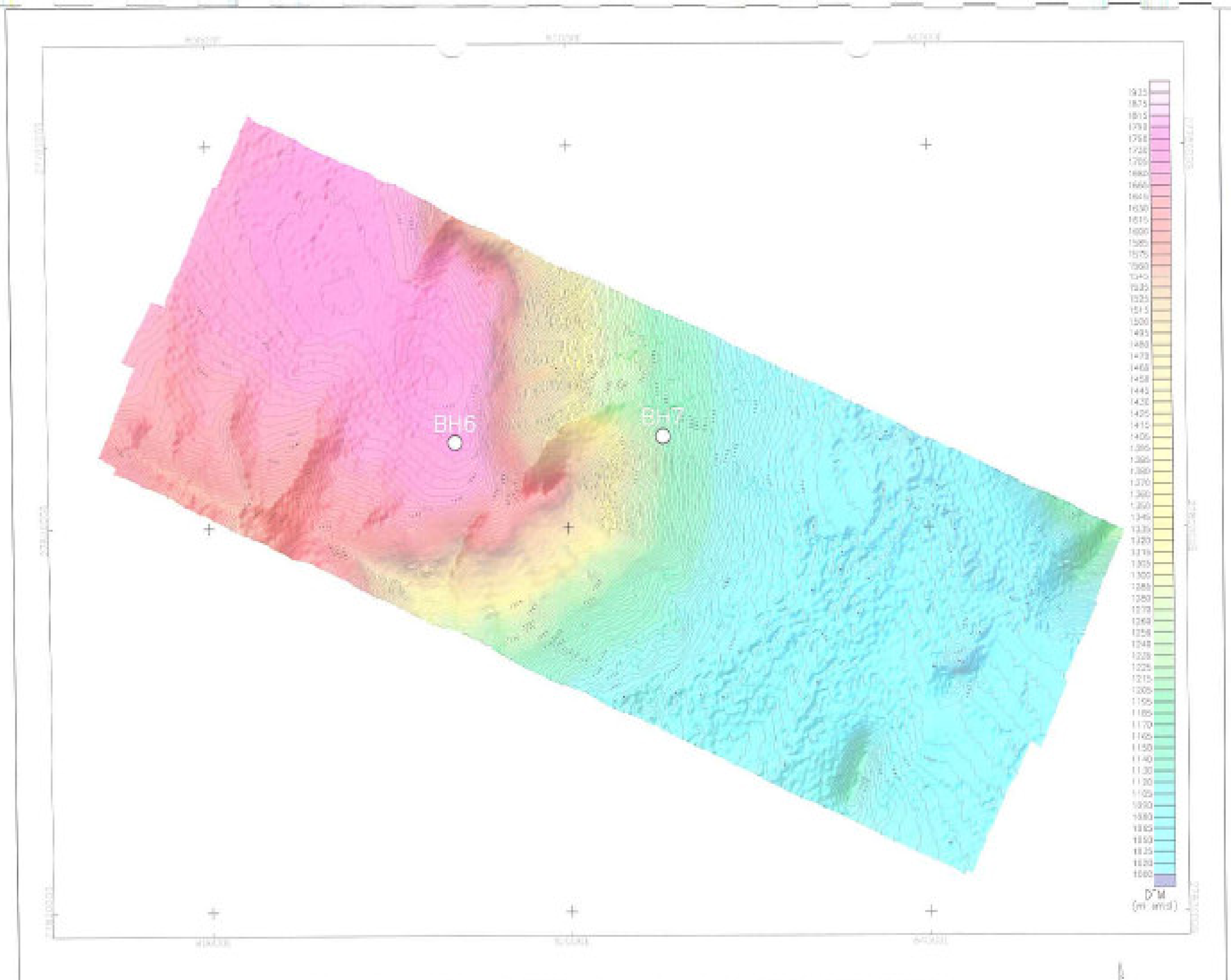


FIGURE 6 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
DTM Surface Elevation Image
Sunshaded from the SouthEast (135°T)

4.2 Aeromagnetic Data Quality

Aeromagnetic data quality is fair to good given the severe acquisition constraints imposed by massive variations in surface topography over this relatively small survey area. Line total magnetic field data falls well within the 0.1nT noise level specification. Survey terrain clearance specifications were not so well met because of the extreme topography factor, despite the best efforts of (in the senior author's opinion) the best helicopter pilot in Southern Africa. Median survey terrain clearance was 21m and over 80% of the area was flown within a terrain clearance range of 17m to 38m. Survey lines flown from east to west climbing up to the Plateau were often broken off just below the brow of the latter because of aircrew safety considerations, and infill sections flown from west to east. Such overlap sections included a range of aircraft terrain clearances whose variability has negatively impacted on overall data quality over the escarpment.

Otherwise FUGRO data is well-levelled, but significant, parallel-to-line striping in first/second vertical gradient images (e.g. Figure 10) reflects these variable terrain clearances and degrades data quality.

4.3 Aeromagnetic Anomaly Signatures

Total field (Figure 8) and vertical gradient (Figure 9) images are dominated by moderate to strongly magnetic, arcuate N-S to linear NNE-striking zones of predominantly positive polarity over the eastern half of the survey area. They reflect outcropping mafic, Upper Zone lithologies of the RLS, whose wavelengths of generally less than 200m to 300m point to relatively shallow sources. Background magnetic responses over the western sector characterise outcropping felsic units of the Rashoop Granophyre Suite, which in the south are cross-cut by WNW-striking, weakly magnetic linears reflecting dyke systems.

Broad aeromagnetic correlations are thus:

- *Upper Zone Mafic Units*

  Diorite through gabbro to magnetite-gabbro lithologies are characterised by predominantly positive anomalies reflecting a spectrum of weakly to strongly magnetic source bodies. Magnetic textures vary from well-defined linear to curvilinear features reflecting sheet-like magnetite-bearing horizons, to areas of rugose activity reflecting heterogeneously distributed magnetite. Amplitudes and texture allow for the confident zoning of mafic rocks, the most important of which are (Figure 12, Plate 3):

  (a) Curvilinear diorite marker M1 which is continuously mapped across the survey area as a zone of variable width exhibiting peak-to-peak amplitudes of 100nT to 600nT.

  (b) Curvilinear magnetite-band marker M2 whose strike trace mimics that of M1 to the west but is of fairly consistent width and much more magnetic, exhibiting peak-to-peak amplitudes of 500nT to 2200nT.

  Elsewhere, zones of rugose magnetic activity and peak-to-peak amplitudes of up to 600nT over short strike-length sections, characterise mafic units in the east.

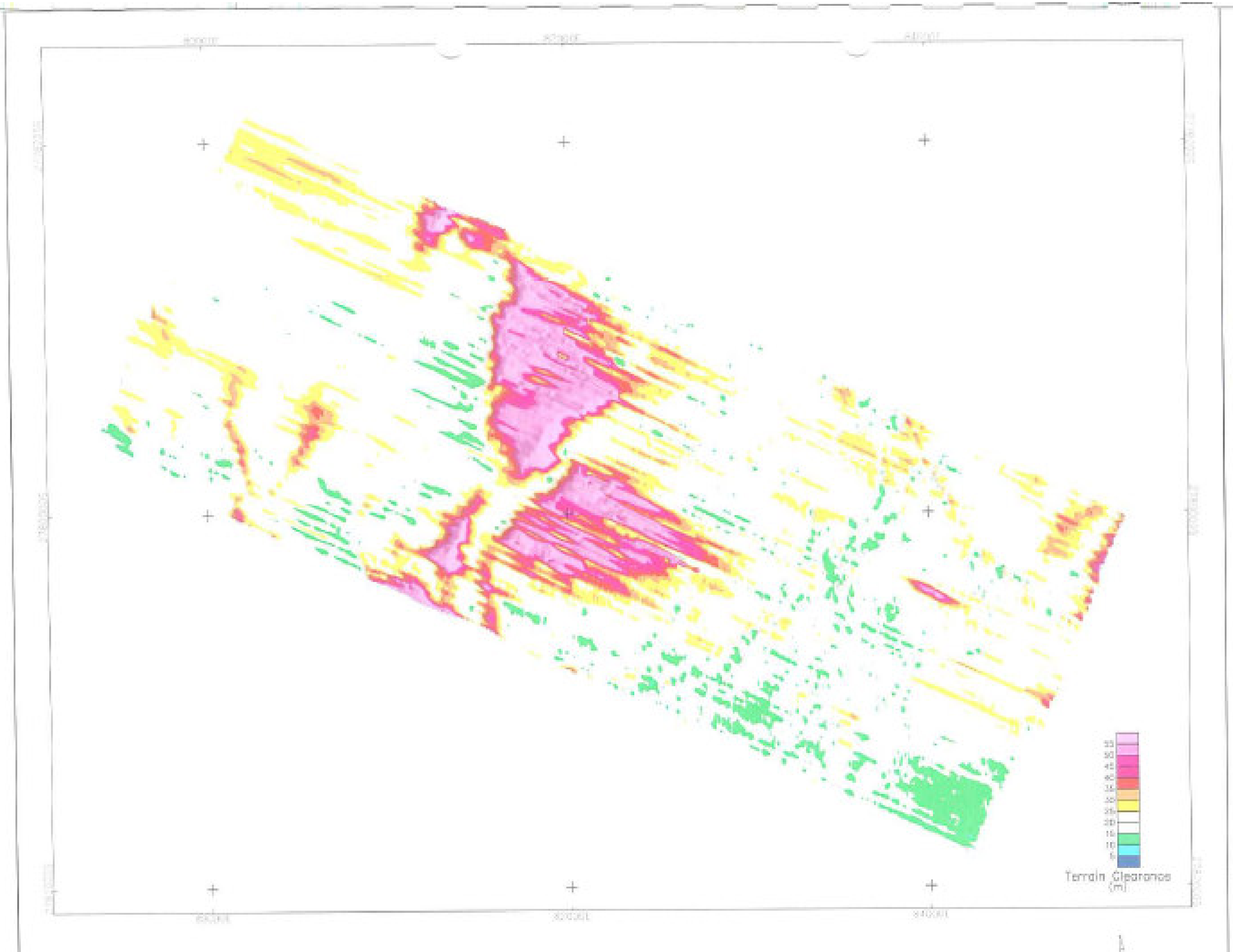


FIGURE 7 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY

Airborne Sensor Terrain Clearance Image

Sunshaded from the SouthEast (135°T)

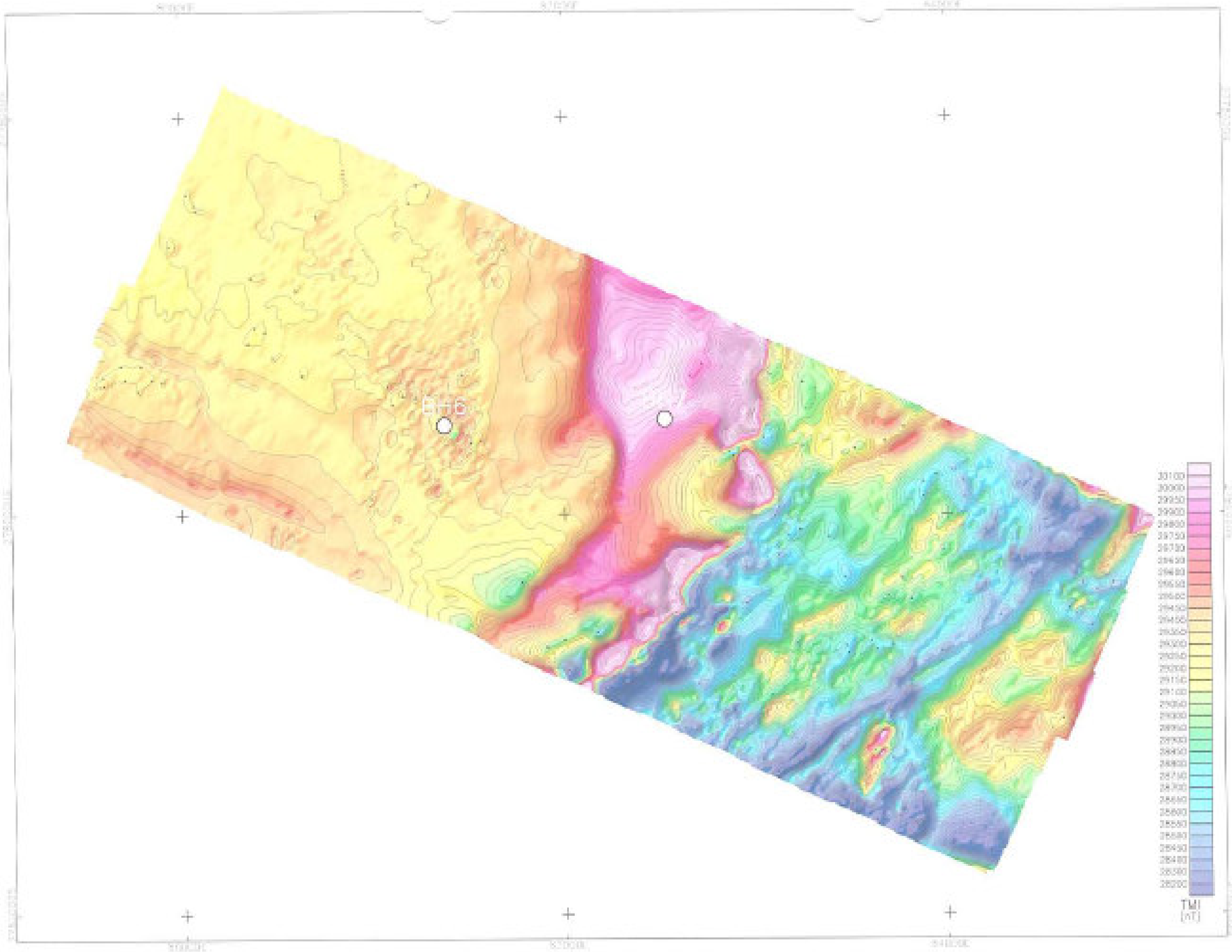


FIGURE 8 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
Total Magnetic Field Image
Sunshaded from the SouthEast (135°T)

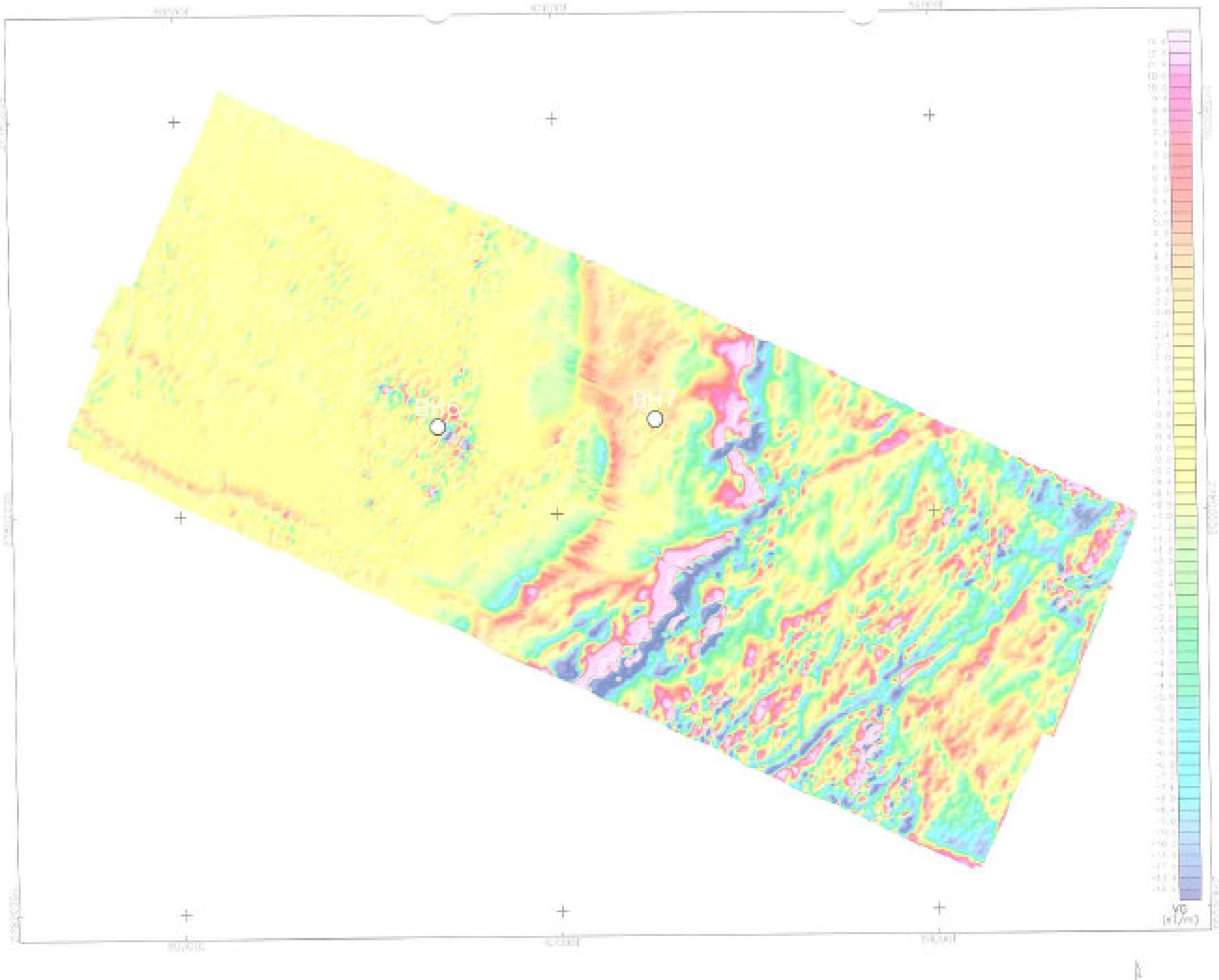


FIGURE 9 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
Vertical Magnetic Gradient Image
Sunshaded from the SouthEast (135°T)

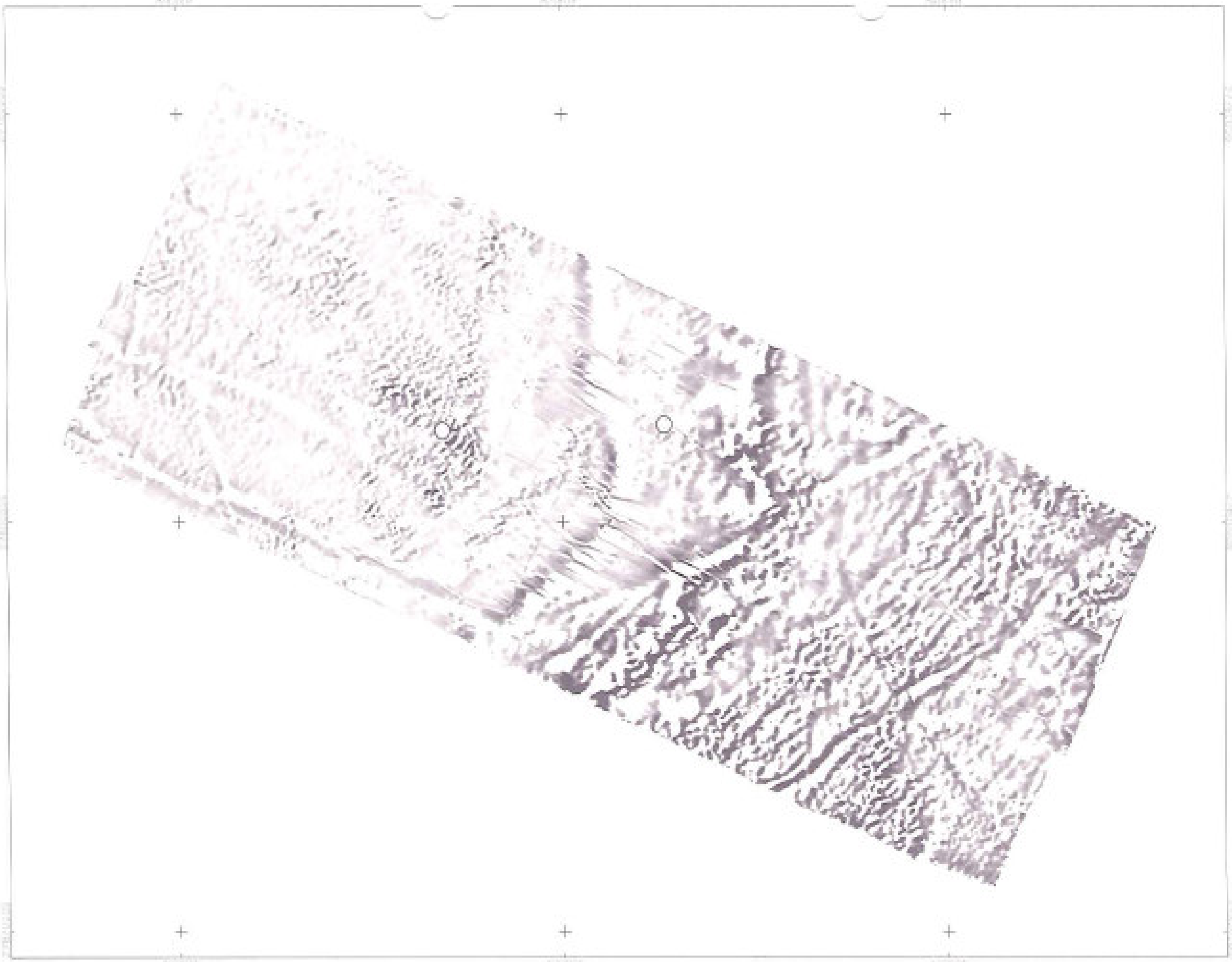


FIGURE 10 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
Greyscale Second Vertical Magnetic Gradient Image

- *Rashoop Granophyre Suite/Leptite*

These granophyre/felsic lithologies are very weakly to non-magnetic and the general absence of continuous magnetic foliation features does not allow for mapping of internal contacts. While the Leptite unit is non-magnetic and presents a smooth magnetic background, the granophyre unit capping the Plateau is characterised by irregularly distributed zones of rugose magnetic activity (peak-to-peak amplitudes less than 100nT to 200nT). By default the latter have been ascribed to outcrop (versus soil-covered) zones.

- *Dykes*

Dyke-like features are only confidently mapped over the SW Plateau area, where they are characterised as WNW-striking, weakly magnetic linears with peak-to-peak amplitudes of less than 100nT.

4.4 Aeromagnetic Anomaly Source Parameters

MAGMOD estimates of source depth, thickness, apparent dip and apparent susceptibility-thickness product for litho-magnetic and intrusive magnetic sources are reported on the geophysical interpretation map (Plate 3), and briefly reviewed below.

Source parameters were obtained over suitably isolated magnetic anomalies using 2D tabular body models of infinite strike extent for litho-magnetic and dyke units. Assumptions relating to source magnetization parameters ranged from credible to pragmatic (Remanent magnetization parameters are of critical importance in the modelling of geological *dips*; reliable source depth/width estimates can still be obtained without any a priori knowledge of remanence). All Bushveld mafic rocks exhibit a dominant remanent ("fossil") magnetization component whose vector geometry varies markedly depending on age of emplacement and hence stratigraphic interval. Remanent magnetization polarity (and declination) vary cyclically from positive through negative to positive in the transition fro Critical through Main to Upper Zone, and an a priori knowledge of this remanence is required for confident modelling of geological dips. No palaeomagnetic work has been undertaken over this locality and while published Upper Zone data from elsewhere within the Bushveld is available, recent extensive experience has shown that this does not "fit" observed anomalies to known dips. Consequently, modelling was carried out on the following, best-effort basis:

- Stratigraphic and dyke anomalies were both modelled on the assumption of induced (or pseudo-induced) magnetization.
- For dyke anomalies this may be acceptable as the dykes are reportedly of late-Karoo-age and such dykes are generally characterised by pseudo-induced magnetization. As such, dyke dips have been reported on the interpretation map (Plate 3).
- For stratigraphic anomalies this assumption is patently incorrect (apparent dips are moderate to steep to the west) and dips are accordingly not reported on the interpretation map. However, depths and widths should be representative.

Modelling mainly focused on dyke and linear stratigraphic units because of their tractability. Dyke anomalies were picked from original tie-line data and stratigraphic anomalies from flight-line data or synthetic profiles interpolated from gridded data. Over 60 individual anomalies were modelled. Independent depth estimates were also obtained from the semi-automatic EULER GRID-DEPTH method using the structural index for a tabular body: results were generally in agreement after allowing for the usual depth overestimation of the EULER technique.

MAGMOD depth, width and dip estimates are generally correct to ±20% given the appropriate choice of geological model and some constraints on source width. However, it is not possible to reliably estimate cross-sectional widths when these are close to or less than the source-magnetometer separation (the "thin dyke" problem). That is, for width/depth ratios of <1 there is not unique width solution, and in this area all geological units will appear to have minimum widths of at least ~20m – 40m (i.e. terrain clearance plus weathered zone depth). However, the susceptibility-thickness product is a uniquely determined geological parameter, and from a magnetic mapping viewpoint its magnitude often serves to "type" certain formations and monitor variations in thickness and/or magnetite content along strike.

While there is some scatter, analysis of magnetic source depths indicates a combined overburden plus weathered zone maximum thickness of up to 30m or 40m; for the area as a whole the median value is around 10m.

Stratigraphic markers exhibit significant widths, with median values of 170m and 60m respectively for M1 and M2. Dyke dips are moderate to steep to the south.

4.5 Lithology (Figure 12, Plate 3)

4.5.1 Rashoop Granophyre Suite/Leptite

Geophysical mapping of the Rashoop Granophyre Suite and Leptite assemblages is largely precluded by the absence of continuous magnetic markers, and contacts shown on the interpretation map were largely taken from the work of Molyneaux (1970) as modified by Partridge, Maud and Associates (1999). These contacts correlate well with topographic contours. The "mixed Granite" unit underlying Plateau granophyre rocks has a slope outcrop width of some 150m and a footwall contact which largely follows the 1600m amsl contour. Further downslope, the footwall contact of the Leptite unit is less confidently mapped (due to extensive talus cover) between the 1380m amsl and 1460m amsl contours. Consequently the precise location of the felsic-mafic rock contact is not immediately available.

Rugose, weak magnetic activity over irregular zones within the Plateau granophyres has been tentatively interpreted as reflecting outcrop areas across the latter. There is a broad correlation with the work of Partridge, Maud and Associates (1999).

4.5.2 Upper Zone Mafic Rocks

Based on magnetic amplitudes and textures, Upper Zone lithologies have been classified thus (from top to bottom):

- Diorite #4 (at Leptite footwall) : non-magnetic
- Diorite #3 : moderately magnetic : sheet-like horizon M1
- Diorite #2 : non-magnetic

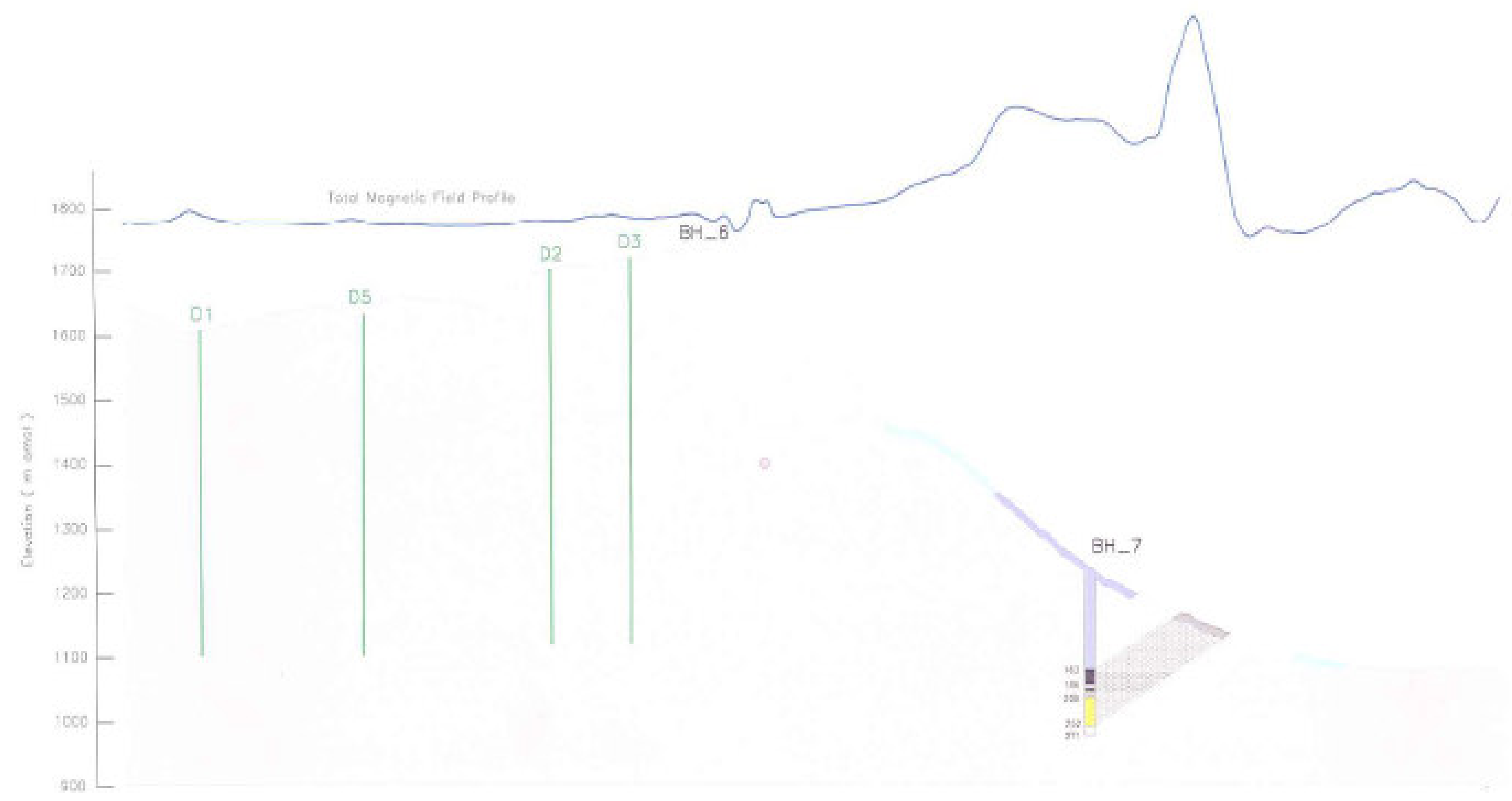
- Interbedded Magnetite and anorthosite : highly magnetic : sheet-like horizon M2
- Diorite #1 : weakly magnetic, rugose activity
- Gabbro #3 : very weakly magnetic
- Gabbro #2 : moderately magnetic, foliated
- Gabbro #1 : weakly magnetic

There is some ambiguity in the provenance of Diorite #4 which notionally occupies the Leptite footwall contact. Mapping by Partridge, Maud and Associates (1999), but not BKS (2006), shows the Leptite unit extending further downslope than on the geophysical interpretation map. This may or may not be so. In any event, the hanging wall contact of Diorite #3, as traced out unequivocally by marker M1, supports diorite outcrop up to at least the locale of this magnetic marker (see downdip borehole BH7 of Figure 11, which intersected at least 163m of diorite above the magnetite/anorthosite assemblage. The arcuate, N-S strike trace of M1 mimics local topography and falls along the ~1300m amsl elevation contour at a significant break in slope angle, supporting its status as a major mafic rock contact. This contact does not appear to have been mapped in full from previous work. The footwall contact of Diorite #3 is mapped with a lesser degree of confidence than its hanging wall contact, and the bulge to the NE in the locale of BH7, while apparently real, is somewhat anomalous in that it cuts across elevation contours. This feature should be followed up on the ground.

Curvilinear magnetic marker M2, some 500m to 700m downslope from M1, exhibits a somewhat "broken" strike-trace which largely follows the 1300m amsl elevation contour at a second, significant break in slope. This, the most strongly magnetic horizon within the area, has been correlated with the interbedded magnetite/anorthosite package intersected in BH7 on the basis if a 15° westerly dip (Figure 11). Aeromagnetic profiles often indicate multiple (2 or 3) source bodies within the zone of interest (e.g. M2C, M2D), and since the width resolution of the airborne data is no better then 20m to 30m (c.f. Section 4.4), it is likely that additional magnetite-rich units underly the 23m wide magnetite/anorthosite package intersected in BH7. Interpreted widths along M2 range from 50m to 120m, with a median of 60m. Changes in geological dip and slope angle may account for some of these variations.

Partridge, Maud and Associates (1999) map the magnetite horizon (as "MA") intermittently over the area of interest. There is good spatial correlation over aeromagnetic unit M2D, but to the south their MA unit falls some 150m east of aeromagnetic unit M2B. However, magnetite pipes may be present over the latter locality.

Gabbro units 3, 2 and 1 underlying low ground to the east revert to an overall NNE strike trend. A disconformity may characterise the contact between gabbro units 2 and 1.



NOTE : Vertical Exaggeration is 2 X

FIGURE 11 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
Fence-Line Through Boreholes 6 and 7 Intersections, and Aeromagnetic Profile

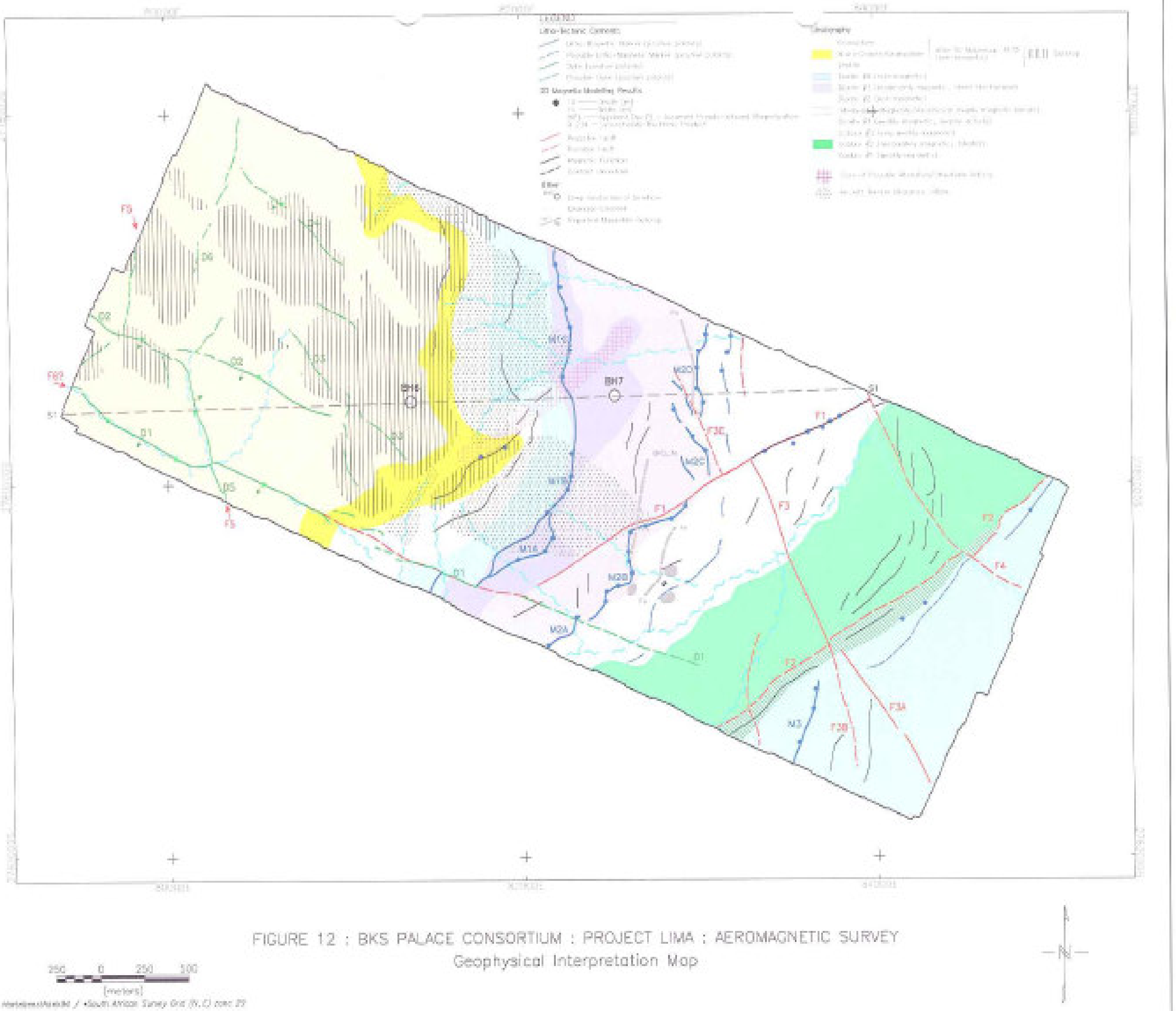


FIGURE 12 : BKS PALACE CONSORTIUM : PROJECT LIMA : AEROMAGNETIC SURVEY
Geophysical Interpretation Map

4.6 Dykes (Figure 12, Plate 3)

Up to 6 probable to possible dyke-like features (D1 through D6) of late Karoo-age have been mapped along WNW to NNW strike trends over the Plateau area, where they exhibit moderate to steep southerly dips and apparent widths of up to 30m. The latter may greatly overstate true widths, which in reality may be as low as 5m to 10m. However, even low level aeromagnetic surveys cannot *resolve* dyke widths at this level, and follow-up field geological mapping or ground magnetometer surveys are required to better fine tune width estimates.

Units D1, D2 and D5 are the most confidently interpreted dykes, with D2 and D5 being hitherto unmapped. Any or all of these may reflect dyke-infilling of precursor fault zones. Neither D1 nor D2 can be traced with any degree of confidence eastwards into Upper Zone lithologies, leading to some speculation as to their age. Syn-Bushveld dyke emplacement is evident elsewhere within the Eastern Bushveld.

4.7 Structure (Figure 12, Plate 3)

The relatively small size of the project area and litho-strike dependency on surface topography precludes confident mapping of structures from aeromagnetic data alone. Faults shown on the interpretation map are thus inferred only along NE (F1, F2), NW (F3, F4 and F5) and more speculatively, E-W (F6) trending axes.

NE-striking faults F1 (probable) and F2 (possible) parallel a mapped fault coming off the Plateau to the NW (Figure 4) and could bound a granite outlier to the NE (Figure 1). F1 was selected on the basis of possible right-lateral displacement and dragging of the M2 magnetite-anorthosite horizon over the centre of the area, and if verified may be an area of geotechnical concern. F2 was interpreted because of an apparent disconformity between gabbro units #1 and #2 (Figure 10). NW striking faults F3 (probable) and F4 (possible) fall along unequivocal magnetic lineaments cross-cutting stratigraphy in the NW sector of the area (Figure 10). F3 is the more confident pick of the two but is not readily mapped north of F1. If verified it could constitute an area of geotechnical concern. Fault F3 follows the local course of the Steelpoort River. Fault 5 in the SW falls along dyke D5 and may be responsible for sinistral displacement of WNW dykes D1 and D2.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Major findings from an interpretation of high resolution aeromagnetic data over the Lima Project Area are listed below in order of geotechnical significance:

- Granophyres, mixed granites and Leptite lithologies underlying the Nebo Plateau in the west are largely non-magnetic, precluding contact mapping thereover.
- Mafic rocks of the Upper Zone of the RLS are weakly to strongly magnetic, with response amplitudes and textures allowing them to be geophysically subdivided into at most 8 sub-groups across a spectrum of diorite, magnetite-gabbro and gabbro lithologies.

- The diorite hanging wall contact with the overlying Leptite unit is mapped only with some ambiguity although a proxy contact is mapped further updipwith a high degree of confidence along magnetic marker M2. This contact shows little correlation with historical mapping results.

- The interbedded magnetite-anorthosite assemblage has been continuously mapped with a high degree of confidence along magnetic marker M2. Historical, discontinuous mapping results are in need of revision based on geophysical results, with mislocations of up to 150m or more being apparent in the locality of the planned underground structures.

- Inferred NE striking fault F1 and NW striking fault F3 converge in the above locality, and if field-verified may constitute areas of geotechnical concern.

- At least 2 ~WNW striking (D1, D2) and one NW striking (D5) dykes have been mapped over the SW sector of the Plateau area, in contrast to the single WNW dyke located from historical mapping. However, none of the WNW dykes can be projected eastwards in to mafic rock terrane.

5.2 Recommendations

Findings from the present interpretation exercise should be merged with historical and ongoing surface mapping/drill-hole information in the BKS data-base, to better define:

- The strike-trace of the magnetite-anorthosite package with respect to planned infrastructural development

- Likewise for the top diorite contact.

Considerations should be given to geophysical wireline logging (magnetic susceptibility, acoustic televiewer) of BH7 in order to better characterise diorite, magnetite-anorthosite and anorthosite lithologies, and measure fracture plus formation dips.

Additionally, further field mapping and borehole investigations should be undertaken to confirm or deny the fault status of interpreted faults F2 and F3.

Respectfully submitted

Geoff Campbell
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Senior Geologist

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