Natural Environment Research Council

BRITISH GEOLOGICAL SURVEY

Mineral Reconnaissance Programme Report

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No. 85

Geophysical surveys near Strontian, Highland Region

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On 1 January 1984 the Institute of Geological Sciences was renamed the British Geological Survey. It continues to carry out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects; it also undertakes programmes of British technical aid in geology in developing countries as arranged by the Overseas Development Administration.

The British Geological Survey is a component body of the Natural Environment Research Council.

Bibliographic reference
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SUMMARY

Reconnaissance VLF-EM and magnetic surveys have been carried out over Ba-Pb-Zn prospects in an area near Strontian in the Highland Region of Scotland. Rather than attempting to detect the economic minerals directly, which is unlikely to be practicable by geophysical methods, the trials concentrated on exploration for the crush zones and associated Permo-Carboniferous basic dykes which act as hosts to mineralisation. The results are encouraging, with the VLF-EM method proving effective in delineating crush zones while magnetic traverses detected the basic dykes. To the east of Bellsgrove mine a crush zone and dyke extend eastwards along the strike of the Strontian Main Vein; however, to the west of the Whitesmith mine the evidence of a westward extension of the Main Vein is insubstantial. A number of crush zones and associated dykes have been identified in the Corrantee-Whitesmith area. Probable extensions are indicated to a number of known veins in the vicinity of the Fee Donald mine. The results merit geophysical, geological and possibly geochemical follow-up.

INTRODUCTION

During June 1980 a geophysical survey was carried out in an area lying approximately 5 km north of Strontian in the Highland Region. Within the survey area are a number of known mineral veins (most notably the Strontian Main Vein) which were worked for lead and, to a minor extent, zinc during the 18th and 19th centuries. More recently the major veins have been investigated by a number of mining companies as a potential source of barite, and several drilling programmes have been undertaken to assess the potential reserves. The purpose of this survey was to assess the usefulness of geophysics in the exploration for extensions of the known veins and for further, previously undiscovered veins. In 1983 Strontian Minerals Limited commenced mining the Strontian Main Vein, principally for barite, and established a processing mill on site (Mason and Mason, 1984). The availability of such facilities improves the chances of any newly discovered deposit being economically viable.

The survey area is covered by the following maps:

Topography:	1:10 000 sheets NM 76 NE, NM 86 NW, NM 86 NE 1:50 000 sheet 40
Geology:	1:50 000 sheet 52 E

Some of the geological information referred to in this report was obtained from the original field maps at 1:10 560 scale.

GEOLOGY AND MINING (Figure 1)

The major mineral veins in the area lie just to the north of a tonalitic granodiorite intrusion which represents the initial phase of emplacement of the late Caledonian Strontian Granite Complex. The tonalite tends to overlie the Moine rocks to the north, with the contact typically dipping southwards at 60° - 80° (Sabine, 1963). Moine rocks comprise psammitic granulite and psammitic, semipelitic and pelitic schists and gneisses. To the NNE of the intrusion the country rocks have been heavily migmatised to produce granitic gneiss and augen-gneiss.

Eastward trending basic dykes of Permo-Carboniferous age are common and Gallagher (1958, p. 268) has observed that 'the structural environment most

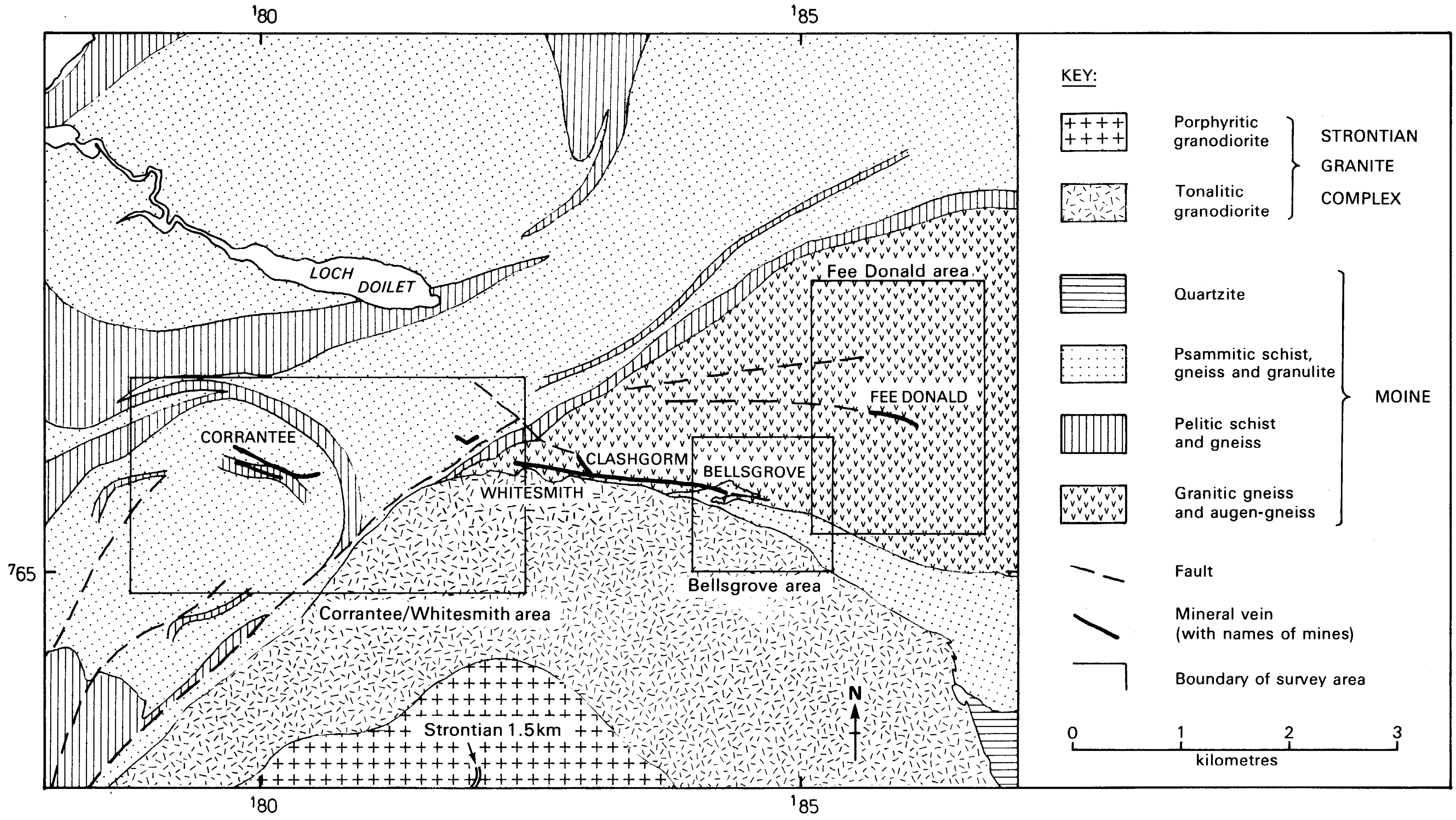


Figure 1 Geological sketch map of the Strontian area showing locations of geophysical surveys

favourable to mineralisation in the Loch Sunart area has been provided by the associations of parallel seams of Permo-Carboniferous basic dykes intruded in one or more phases through crushed rocks marking a pre-existing zone of displacement'. The basic dykes tend to be more weathered in the mineralised zones, in places being altered to a soft clay (Wilson, 1921). Northward trending Tertiary dykes are also common, but are not associated with mineralisation.

The Strontian Main Vein is about 2 km long and trends roughly eastwards. Recent drilling by NL Industries Incorporated (1977) has indicated that, rather than being a continuous vein, the deposit consists of a number of lenticular mineralised bodies within, and parallel to, a well defined shear zone which is up to 30 m wide and dips steeply towards the south. The mineralisation comprises barite, calcite and quartz with erratic galena and sphalerite. There is evidence of a second parallel shear zone approximately 20 m to the north of the Main Vein at its western end.

The Main Vein has been exploited by both opencast and subsurface workings at three mines: Whitesmith to the west, Clashgorm or Middleshop in the centre, and Bellsgrove to the east. In the Clashgorm section the NW trending Armstrong Vein branches off from the north side of the Main Vein. About 400 m WNW of the Whitesmith opencast, trials have been carried out on two veins containing barite and a little galena.

Two kilometres west of the Whitesmith workings lies the Corrantee mine where there are two veins bearing barite and galena. The principal (northern) vein extends over an ESE distance of approximately 900 m and dips towards the south at 75°. The Scottish Canadian company conducted a programme of drilling at Corrantee in 1968 but the results of this exploration are not known.

About 2 km to the NE of the Bellsgrove workings lie the Fee Donald veins. A total of seven veins have been discovered (see Figure 7) but only the Smiddy Vein has been worked to any significant extent. Brief descriptions of the occurrences of mineralisation are given by Wilson (1921) who notes that the veins are generally associated with broken country rock and basic dykes. Calcite is the chief vein constituent although some galena, pyrites and barite are present.

SURVEY METHODS

It is unlikely that the mineral deposits in this area could be detected directly by geophysics. Barite has a high density (4.5 g/cm^3 compared with 2.7 - 2.8 g/cm^3 for the Moinian country rock) which suggests that detailed gravity traversing might be a useful exploration method; however, desk studies, using information from the NL drilling, show that the maximum effect likely to be due to barite is almost certain to have a smaller amplitude than the noise due to the rugged topography and variations in the thickness of the low density overburden.

The lead concentrations present are generally low and would not be a reliable target for the induced polarisation method.

Indirect exploration methods have a better chance of success. Although barite is a very poor electrical conductor, the water filled crush zones within which it is contained should be more conductive than the country rock. Taylor (1959) mentions trials in which an electromagnetic method was successful in detecting such a zone in the Strontian area. For the 1980 survey the Very Low

Frequency electromagnetic method (VLF-EM) was chosen, since previous studies have shown it to be very suitable for this application (Paterson and Ronka, 1971; Phillips and Richards, 1975; Coney and Myers, 1977). Measurements of the in-phase and out-of-phase components of the vertical secondary magnetic field were made at 10 m spacings along survey traverses using Geonics EM16 equipment tuned to the Maine transmitter (NAA), which had an operating frequency at the time of the survey of 17.8 kHz (now changed to 24 kHz). With this transmitter, the primary magnetic field lines in the Strontian area are approximately perpendicular to the E-W strike of the mineral veins, which is the optimum configuration for the VLF method.

A Geometrics G816 proton precession magnetometer was used to make total magnetic field measurements, normally at 10 m spacings but occasionally closer in regions of steep magnetic gradient. Readings were taken at base stations at intervals of about 3 hours to enable corrections to be made for diurnal variations. Basic dykes should produce magnetic anomalies, although these may be weaker in mineralised zones because of alteration of the magnetite. Parallel dykes will not normally be resolved unless they are more than 10 m apart.

Geophysical investigations were carried out in three areas (Figure 1). Brief reconnaissance investigations were carried out around Fee Donald and Bellsgrove mines, while an area lying to the west of Whitesmith mine and encompassing Corrantee mine was studied in more detail. In the Corrantee-Whitesmith area a 3 km long E-W base line was laid out and geophysical observations were made along a set of N-S traverses usually 100 m apart. Lines were surveyed in loops starting and finishing at the base line using tape and compass and estimating slope corrections by means of an inclinometer in the EM16 instrument: acceptable closure errors were achieved, the maximum error being 4 m. Relative magnetic field values were measured at each of the base line pegs and these points were subsequently used as magnetic base stations, provided the local magnetic gradient was not too steep.

RESULTS AND DISCUSSION

Data presentation

The in-phase VLF-EM data have been filtered by Fraser's (1969) method which converts downward inflections across conductors to maxima. The filtered data (just the positive values) have been plotted on plans of the survey grids to allow the mapping of conductive zones. Figure 2 shows an example of an unfiltered VLF-EM profile (both in-phase and out-of-phase components) along with the filtered in-phase profile. A complete set of unfiltered profiles is held on open file at BGS, Keyworth. Magnetic profiles have also been plotted on plans of the survey grids.

Corrantee-Whitesmith area

Both the VLF-EM and magnetic maps (Figures 3 and 4) show a more noisy response over Moine rocks than over granite, reflecting the more heterogeneous nature and greater magnetic mineral content of the former. Possible causes for VLF-EM anomalies are: conductive water-filled crush zones, resistivity variations within the country rocks and local thickening of relatively conductive overburden. The out-of-phase component of the VLF-EM anomalies generally follows the in-phase polarity with reduced amplitude (e.g. Figure 2) - a response typical of a poor conductor lying in non-conducting ground (Paterson and Ronka, 1971). VLF-EM and magnetic anomalies are often of short wavelength, indicating shallow depths to source.

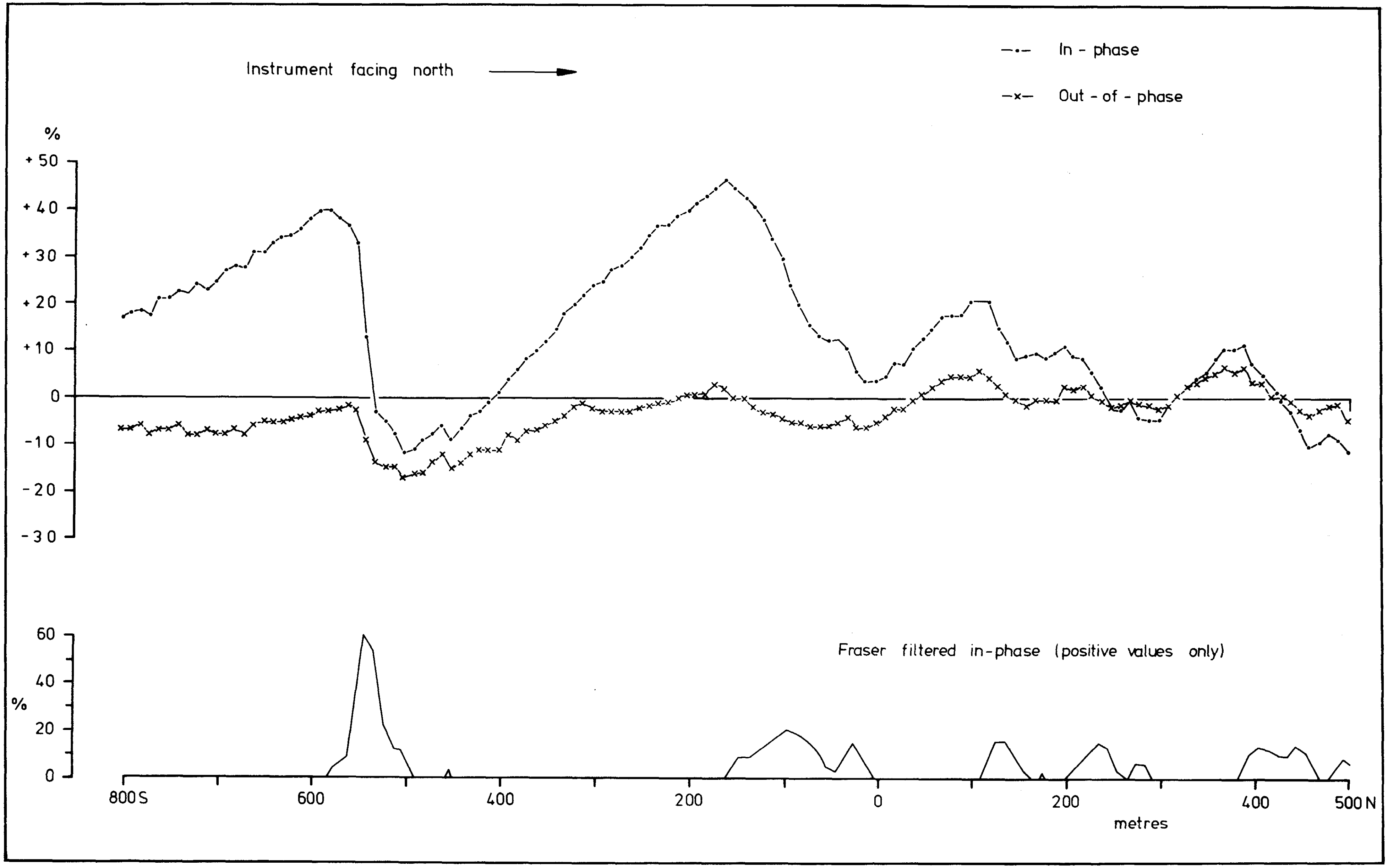
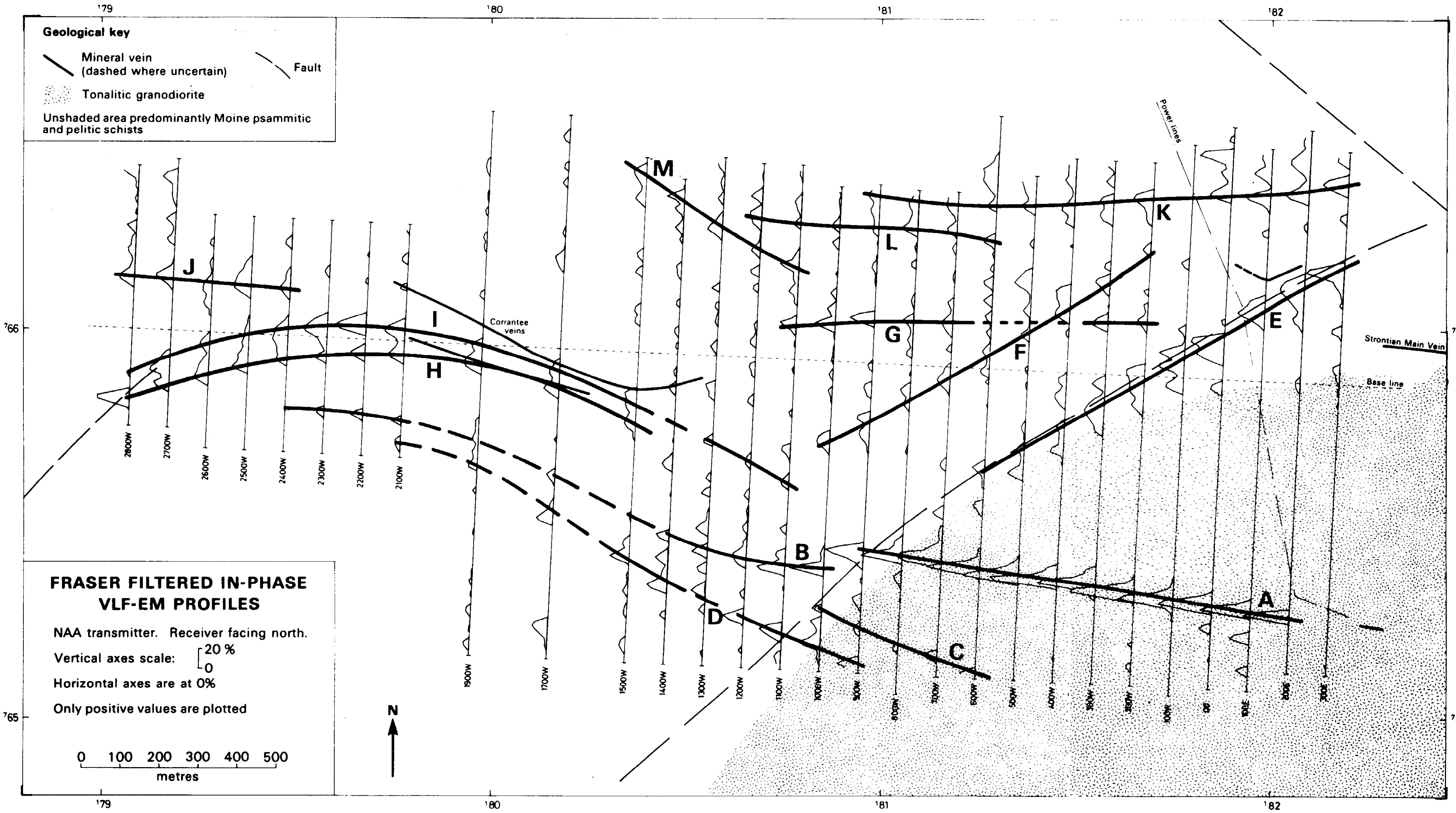
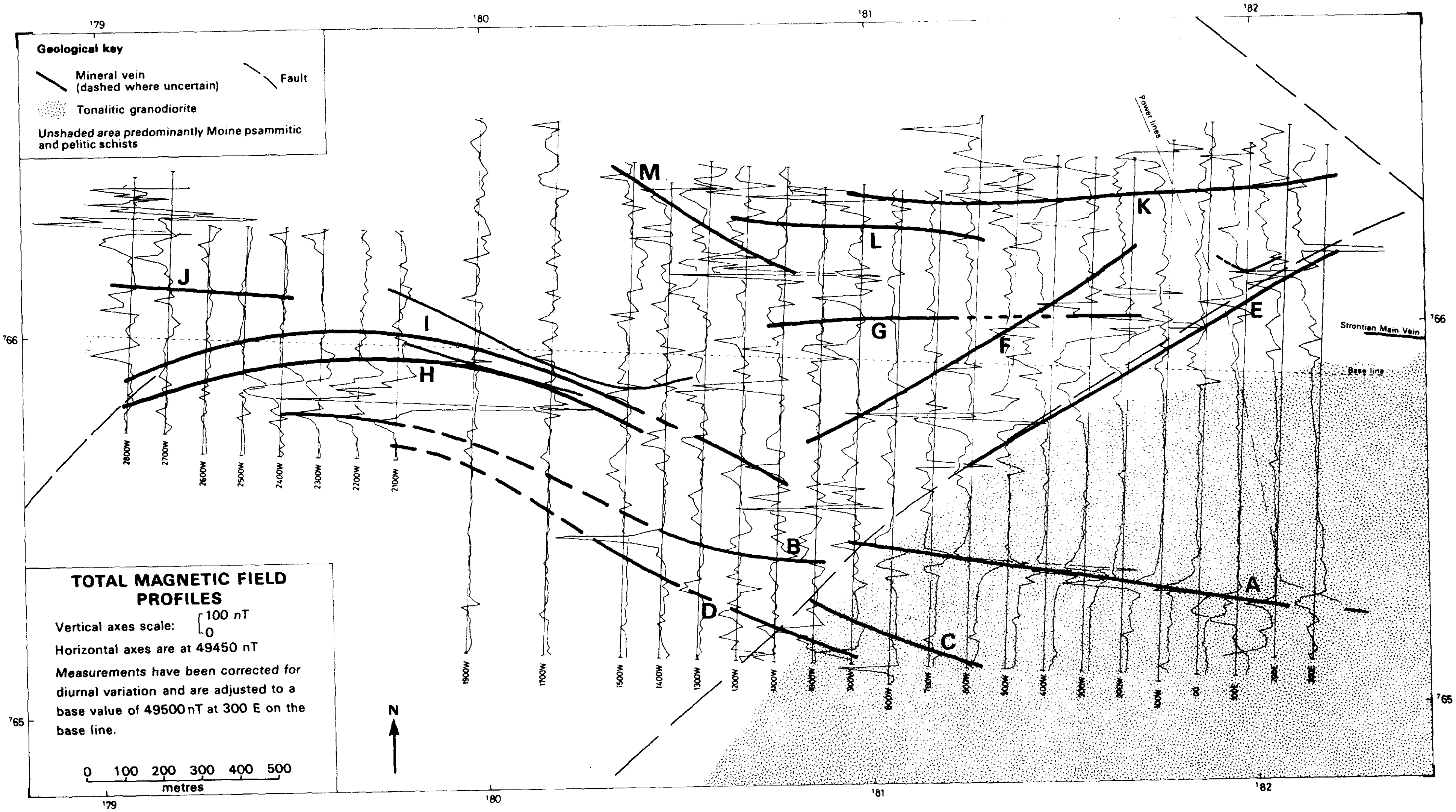


Figure 2 VLF-EM profiles for line 300W (Corrantee-Whitesmith area)



A-M = Principal VLF-EM features

Figure 5 Corrantee-Whitesmith area: main VLF-EM features



A-M = Principal VLF-EM features

Figure 6 Corrantee-Whitesmith area: main VLF-EM features superimposed on magnetic profiles

VLF-EM anomalies can arise over topographic features even if the ground is electrically uniform (Whittles, 1969; Karous, 1979; Baker and Myers, 1980; Eberle, 1981). This is because the ground has a finite conductivity, hence a secondary magnetic field exists and, since this tends to be orientated parallel to the ground surface, a convex change in slope can cause a downward inflection in the VLF-EM profile comparable with that due to a deep buried conductor. In this report the VLF-EM features selected for discussion appear to have geological causes but no quantitative topographic corrections have been applied.

An overhead power line in the east of the area produced strong artificial VLF-EM responses (not plotted) which will have masked any genuine anomalies in the vicinity; the magnetic profiles however are not seriously affected.

The identification of trends of the VLF-EM anomalies in this area is to some extent subjective, but some of the more distinct trends are labelled in Figure 5 (and superimposed on the magnetic map in Figure 6) and these are used as the basis for the following discussion.

A This is a linear WNW trending zone which produces strong VLF-EM and magnetic responses. There is a coincident topographic feature and basic dykes are exposed in the west, where the zone crosses the granite margin, and in the east, about 100 m east of line 300E (the VLF-EM anomaly does not appear on 300E because of the influence of the power lines). The eastern exposure is in a ravine where galena-bearing veins are associated with two to four closely spaced, steeply dipping Permo-Carboniferous basic dykes occupying a fault line (Gallagher, 1958). It appears that the VLF-EM method detects the more conductive fault zone while the magnetic method responds to the associated basic dykes. Both methods indicate a shallow depth (less than 10 m) to source, which probably lies immediately beneath the thin overburden. The continuity of the geological feature between the eastern and western exposures is clearly demonstrated by the geophysical data. The magnetic anomalies indicate that the dykes generally have a strong reversed remanent magnetisation component - conforming with a Permo-Carboniferous age for the dykes, since the earth's field had predominantly reversed polarity during this period (McElhinny, 1973, p. 127; Creer and others, 1959). The form of the magnetic anomalies changes along strike; this may be due, to some extent, to changes in geometry but it is considered likely that the change is largely due to variations in the intensity and direction of the remanent magnetisation of the dykes. Assuming steep structural dips throughout, the anomalies on the easternmost traverses (100E-300E) indicate total magnetisation in the approximate direction of the Earth's present field, while further westward the anomalies indicate a total magnetisation vector directed southwards, near horizontally on lines 0-300W and at negative angles of inclination west of 300W.

At the eastern end of feature **A** a minor branch on the south side is indicated on lines 00 and 100E,while the west end appears to terminate at 900W against a NE trending fault.

B This is possibly a continuation of zone **A** displaced by movement along the intervening fault. The feature may terminate at 1400W (against a possible continuation of fault **F)** but a tentative extension as far as 2500W is indicated in Figure 5, although the response is in places very weak. A coincident magnetic anomaly sometimes occurs (particularly noticeably on 1400W and 2100W-2500W) indicating the likelihood of basic dykes within the crush zone.

C Small amplitude VLF-EM and magnetic responses indicate a minor crush zone intruded by a thin dolerite dyke and terminating at the major NE trending fault.

D VLF-EM and magnetic results indicate a dyke and a crush zone which is not greatly displaced by the fault that interrupts **A** and **C**. The magnetic response disappears to the west of 1500W - possibly this feature is terminated by an extension of **F** or alternatively it may continue further westwards but with the absence or extreme alteration of the basic dykes (if alteration is the case there is a greater chance of mineralisation). The presence of a coincident topographic feature in the vicinity of 1700-1900W supports the continuation of the crush zone through this area. The VLF-EM results show no anomaly where this zone should cross line 800W although the magnetic results clearly indicate the continuation of the dyke (presumably intruded into reasonably unfractured ground).

E and **F** In the east of the survey area the distinct NE-SW trending VLF-EM anomaly **E** coincides with a major mapped fault. A boundary between pelitic and psammitic Moine rocks lies just to the south of and parallel to this fault in the NE of the survey area (Figure 1), and it is possible that the resistivity contrast between these rock types contributes to the observed anomaly. Certainly the anomaly amplitude decreases to the west of 300W, where the geological map shows the pelitic rocks terminating against the granite intrusion. It is not possible to distinguish unambiguously a fault related anomaly west of 600W; however, the anomaly pattern in this area is complicated by intersecting features and the fault adopts an orientation which is less favourable with respect to the VLF transmitter. The small barite and lead-bearing veins explored in the West Whitesmith trials lie close to **E** between 00 and 200E; the power line interrupts the profile on line 00 but it is possible that small VLF-EM responses on 100W and 200W are due to a continuation of the vein which diverges from the main fault in a roughly WNW direction.

F lies parallel to **E** and approximately 250 m to the NW. The anomaly may be due to a belt of relatively conductive Moine pelites or to a fault zone; the latter alternative is preferred because topographic features suggest the extension of this lineament towards a mapped fault which lies to the SW of the survey area (Figure 1). The southwestward passage of the fault through intersecting westward trending features is not clear in the VLF-EM data but its continuation may be indicated by the anomaly at the southern end of 1700W. Gallagher (1958) records a small barite vein which lies on **F** at about 300W and some relation between the two seems likely, although the vein has a westward trend while **F** trends southwest.

The correlation of individual magnetic anomalies with VLF-EM anomalies **E** and **F** is not consistent but there does appear to be a magnetically more disturbed (and electromagnetically less disturbed) block sandwiched between the two features.

G The Strontian Main Vein lies just to the east of the survey grid but only a weak VLF-EM anomaly is indicated opposite the vein on 300E and this feaure appears to terminate at **E** (although the presence of the power lines causes some ambiguity). Anomaly **G** lies along the extrapolated trend of the Main Vein and there is a slight possibility that it represents a continuation of the fracture system that is mineralised in the mined area. This is an indistinct VLF-EM feature lying in a noisy area of the map and hence is only proposed tentatively. The magnetic map indicates a possible basic dyke lying between **E** and **F** and coincident with **G**.

H and **I** A strong arcuate VLF-EM anomaly runs westwards from the vicinity of the Corrantee mine. The anomaly often shows a twin lobed nature suggesting two parallel conductors and hence has been marked as two trends **H** and **I**. On the evidence of line 1700W alone it would be tempting to suggest the twin Corrantee veins as the cause of the anomalies, however, the northern vein clearly diverges from the trend of the VLF-EM anomalies although a relationship with the southern vein is still possible. A westward striking band of pelitic Moine rocks is exposed around the Corrantee mine (Figure 1) and if there is a strong enough resistivity contrast between this and the psammitic rocks, such VLF-EM anomalies could result. Between 1500W and 2100W the twin lobes of the anomaly appear to define the northern and southern margins of a conductive pelitic zone. The extension of this zone westwards beneath the featureless drift west of 2100W is well defined. There is some ambiguity at 2800W, since the VLF-EM anomaly crosses this line where an eastward trending belt of pelitic rocks meets a north- eastward trending fault zone (Figure 1). Further traverses would be useful to assess the relative VLF-EM responses of the two features, as would laboratory measurements of the resistivities of the Moine psammites and pelites.

H and I are not generally associated with strong magnetic anomalies. Small responses over the known veins on 1400W to 1700W are probably due to the basic dykes associated with the mineralisation. A sharp magnetic anomaly at 1900W over the southern vein may be due to a man made structure as it occurs over old mine workings. From 2100W to 2500W basic dykes are indicated by a line of magnetic anomalies between **H** and the possible extension of **B** (which also shows a magnetic response). The most persistent anomaly lies about 50 m south of **H** and indicates normal magnetisation but a strong reversed anomaly also occurs 110 m south of **H** at 2100W.

J This VLF-EM anomaly is associated with a linear topographic gulley and probably indicates the presence of a crush zone. The position suggests a possible relationship with the northern Corrantee Vein but this is made less likely by the lack of a marked VLF-EM response over and immediately to the west of the vein itself. Magnetic anomalies are not associated with this feature although peaks do occur just to the south of it on lines 2700W and 2800W.

K, L and **M** These are three of the more distinct VLF-EM trends in a northern part of the survey area which is characterised by strong VLF-EM and magnetic anomalies. The VLF-EM anomalies to the north of **K** are probably due to (or at least much distorted by) topographic effects, since there is a sharp break in slope at the northern ends of the survey lines; however the labelled features are considered more likely to be due to crush zones than to topography. Anomaly **K** lies along the trend of E-W striking faults which lie about 1 km north of the Bellsgrove workings (Figure 1).

It appears from the magnetic results that basic dykes are intruded into zone **K**, in particular at 300E-200E and west of 300W; there is good evidence of a considerable westward extension of the basic intrusives, perhaps as far as 1700W. The magnetics also show a possible parallel dyke about 60 m north of **K** in the northeast corner of the survey area. The correlation of magnetic anomalies with **L** and **M** is not as striking as with **K**. A strong double anomaly at the southeast end of **M** appears to be related to a magnetically disturbed zone lying to the south of this feature; possibly this is due to Moine rocks with a higher magnetite content.

Some anomalies have not been labelled in the figures but may be worthy of further investigation. For example there is magnetic evidence of at least two small basic dykes north of and roughly parallel to the Corrantee veins. Also, there is an area of considerable magnetic disturbance and VLF-EM anomalies in the northwestern corner of the survey grid; further survey lines would be required to define the form of the anomalous zones. On the more easterly survey line there is evidence of a VLF-EM response at the northern margin of the granodiorite.

Fee Donald area

Figures 7 and 8 show the VLF-EM and magnetic results respectively while the main anomalous trends are labelled in Figure 9. Trends **A** to **E** are defined

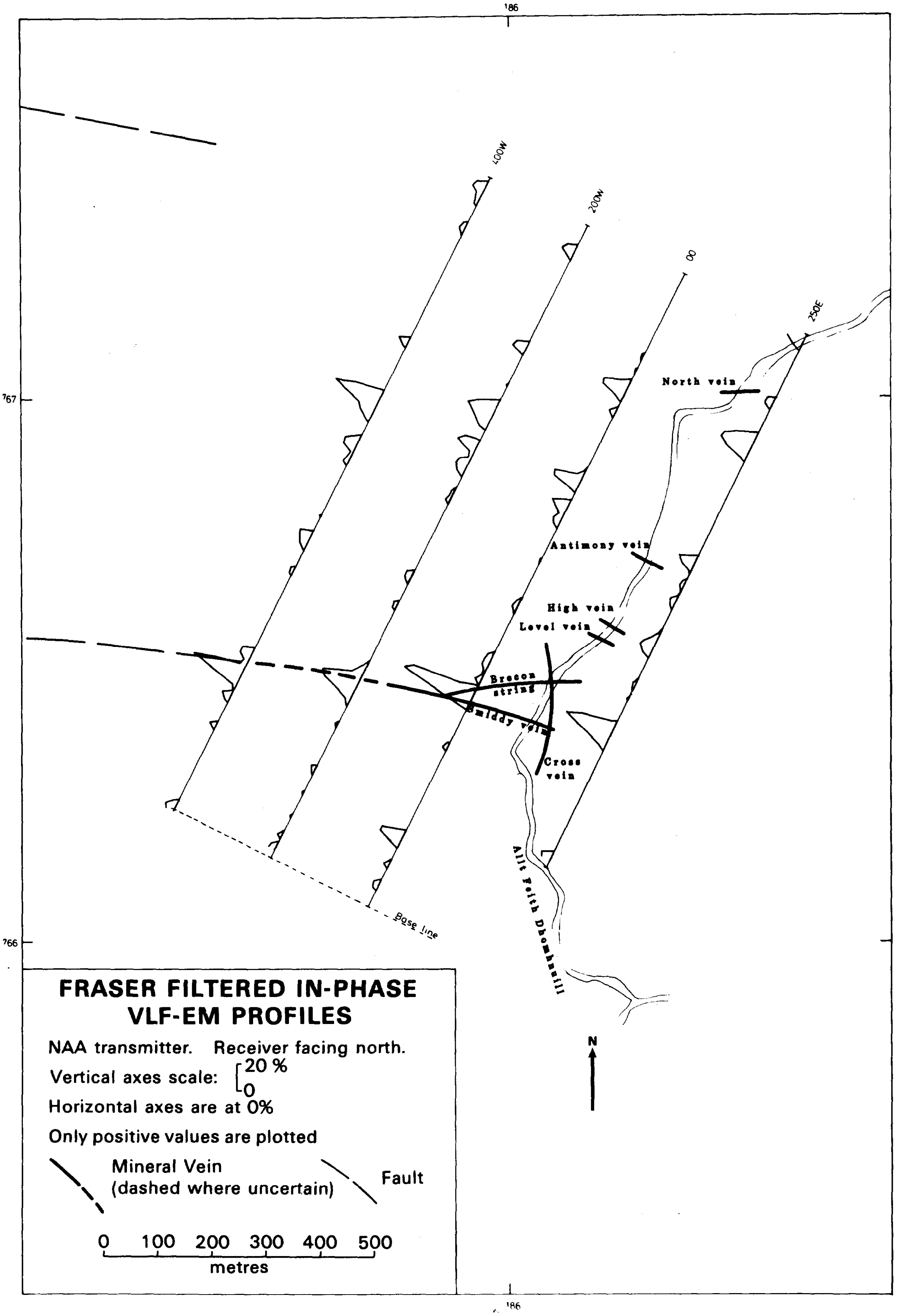


Figure 7 Fee Donald area: Fraser filtered in-phase VLF-EM profiles

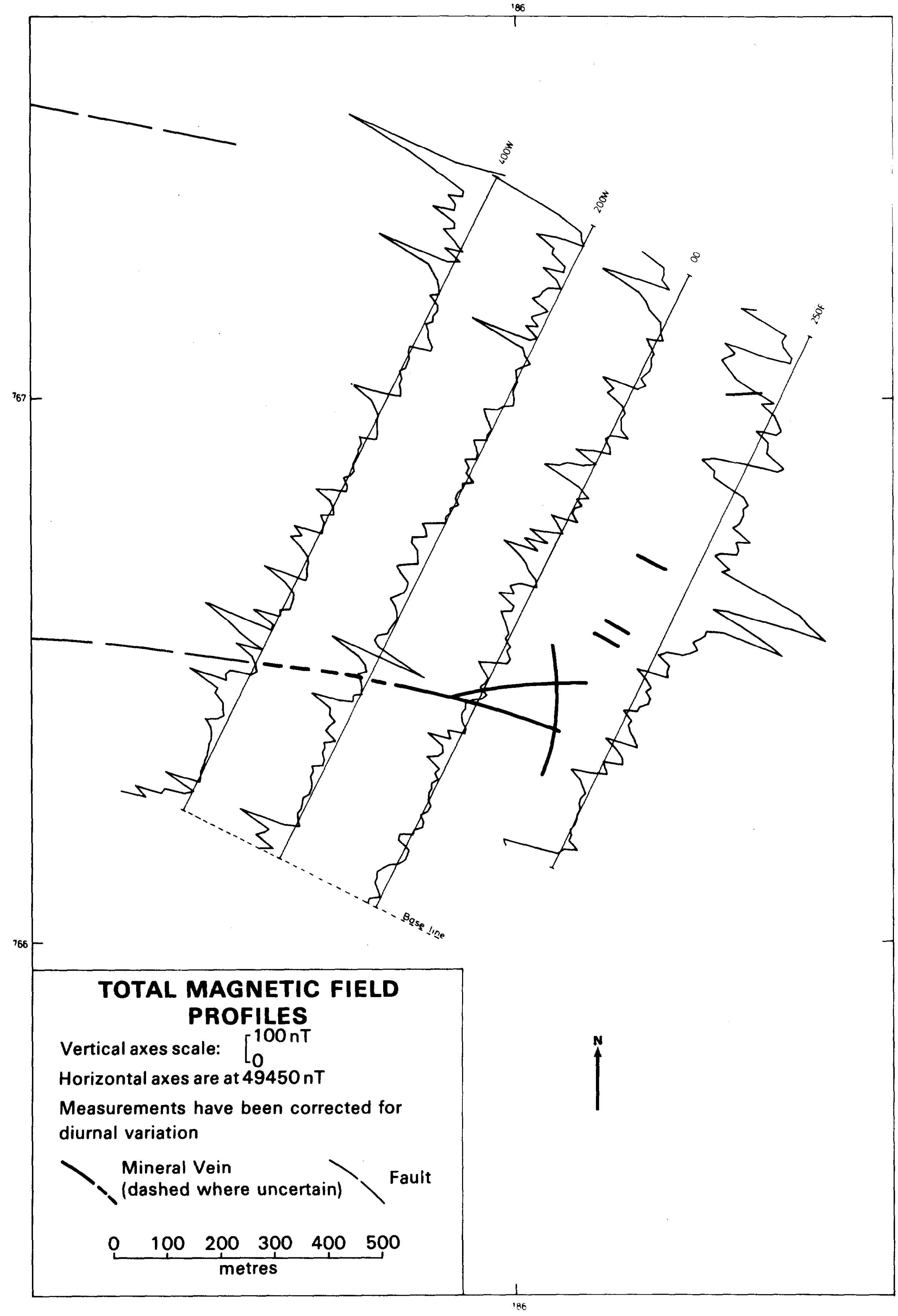


Figure 8 Fee Donald area: total magnetic field profiles

principally from the VLF-EM map and **F** to **H** are additional magnetic trends. As in the Corrantee/Whitesmith area, the VLF-EM anomalies suggest shallow, poorly conductive zones in a non-conducting host rock; the magnetic anomalies are also indicative of shallow sources. The VLF-EM map (but not the magnetic map) shows a less noisy response than at Corrantee-Whitesmith, presumably because of the more uniform resistivity of the granitic gneiss country rock in the Fee Donald area.

The most pronounced VLF-EM anomaly **(A)** correlates well with the Smiddy Vein; the westward extension of the fault zone has been mapped previously on geological evidence and the geophysics suggests that there is also an eastward extension. The magnetic profiles do not show a strong response over the vein, probably because of the decomposition of the basic dykes present (Wilson, 1921), but parallel dykes lying to the south and north are indicated by features **F** and G respectively.

A weak but persistent VLF-EM feature **B** is possibly due to a crush zone associated with the High or Level Veins. The magnetic profiles are noisy but small anomalies, presumably due to basic dykes, correlate with this feature.

The features **C** and D indicate two or possibly three parallel crush zones. The Antimony Vein appears to lie on the northern of the twin lobes of **C.** A swing from a northwest to a westward trend is shown between 200W and 400W but more detailed work is required to define the pattern of anomalies in this area; possibly the apparent change is due to faulting or **C** may actually link with the feature on 400W labelled as part of **D** in the present interpretation. Strong magnetic anomalies are associated with C and D on line 250E, while on the remaining traverses only **D** is marked by distinct magnetic anomalies.

E indicates a WNW trending crush zone which does not directly correlate with any of the mapped veins, although the North Vein may be an offshoot (a small anomaly lying 100 m north of **E** on 250E may be related to this vein). As with C and D there is an apparent swing to a westerly trend at the western end of this feature. Coincident magnetic anomalies are evident although the pattern is ambiguous at the western end because an alternative northward swing is suggested by the magnetics.

H is a line of strong magnetic anomalies indicating a basic dyke; VLF anomalies on 200W and 400W may be due to an associated crush zone. A parallel dyke appears to lie at the extreme northern ends of the survey lines.

The VLF-EM map indicates possible minor crush zones to the south of the Smiddy Vein and there is also evidence of basic intrusives at the southern ends of the survey lines.

Bellsgrove area

VLF-EM and magnetic anomalies at 50N on line 700E of the Bellsgrove grid (Figure 10) mark the location of a Permo-Carboniferous quartz dolerite dyke intruded into a pre-existing crush zone (Gallagher, 1958). Assuming a steep structural dip, the form of the magnetic anomaly indicates a strong remanent magnetisation component directed southwards at low angles of inclination. This is in agreement with, for example, the remanent magnetism of the Permo-Carboniferous Whin Sill (Creer and others, 1959). Strong VLF and magnetic anomalies are obtained over the quartz-dolerite boss crossed by line 350E. Assuming horizontal southward magnetisation, computer modelling shows that such a magnetic response can be caused by a 190 m wide, vertical sided boss cut by two 30 m wide non-magnetic zones centred 90 m and 140 m respectively from the

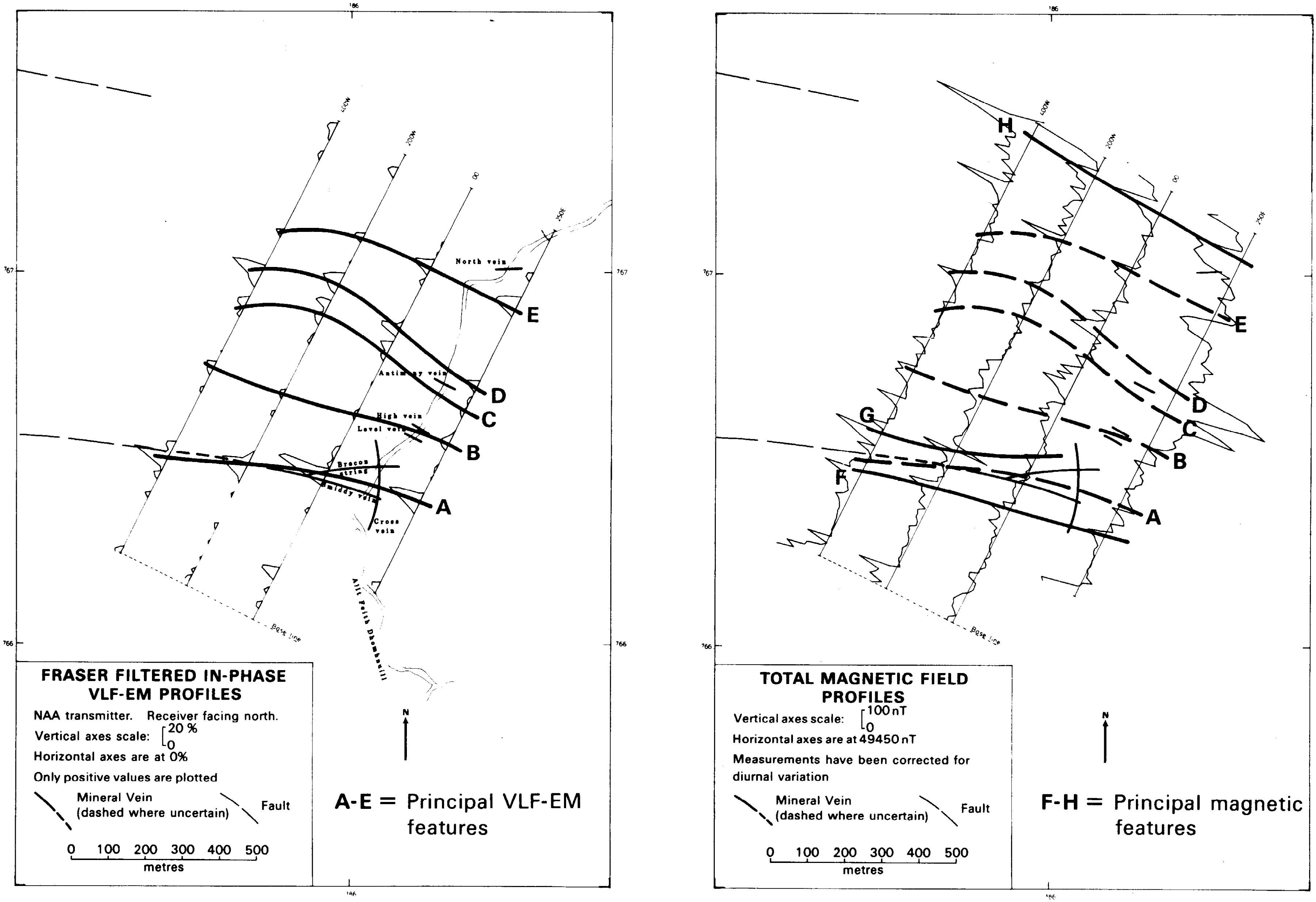


Figure 9 Fee Donald area: main anomalous trends

southern edge. The VLF-EM anomalies agree well with such an interpretation and indicate that the non-magnetic belts are also electrically conductive and are, therefore, most probably belts of fractured rock in which alteration of magnetite has occurred. One of these belts may be a continuation of the crush zone which contains the quartz-dolerite dyke to the east, or perhaps the dyke extends through the stock and has crush zones at its northern and southern edges. Such an interpretation requires that the intrusion of the boss pre-dates that of the dyke but this is not the only solution - it is quite possible that the conductive zones within the boss may be due to movements post-dating both intrusions or perhaps to fractures formed during the cooling of the boss. Geological evidence on the relative ages of dyke and boss is not conclusive (Gallagher, 1958).

VLF-EM and magnetic responses are also obtained over the fault (containing a dyke) which is an eastward extension of the Strontian Main Vein: the magnetic anomaly indicates normal magnetisation, contrasting with the reversely magnetised quartz dolerite dyke to the north. Both dykes are of probable Permo-Carboniferous age so it would appear that the more southerly one has a weak remanent magnetisation component or possibly that it was intruded during one of the relatively short periods of normal magnetic field polarity during the Permo-Carboniferous.

A small VLF-EM response is obtained on line 00 over the northern margin of the granodiorite.

CONCLUSIONS

It is unlikely that Ba-Pb-Zn deposits in the Strontian area could be detected directly by geophysical methods, but the results of this survey suggest that geophysics can provide useful indirect information. The VLF-EM method has been used to map crush zones which may contain mineralisation while the magnetic method has been used to detect basic dykes which also appear to be important in providing sites for mineralisation. The lack of a magnetic anomaly cannot be taken as indicating the absence of mineralisation, however, since a basic dyke in a mineralised zone may well have undergone considerable alteration.

Possible extensions to the Strontian Main Vein are clearly of interest: to the east, in the Bellsgrove area, there is evidence of a crush zone and dyke continuing along the strike of the Main Vein; however, there is no strong evidence of a westward continuation in the Whitesmith area, although such a feature may have been obscured by interference from power lines and intersecting structures.

It is not clear, from the present data, whether certain of the VLF-EM features at Corrantee-Whitesmith are due to crush zones or lithological variations; laboratory testing of rock samples from these areas is recommended to assess whether sufficient resistivity contrasts exist to admit the lithological explanation. It is probable that resistivity and magnetic susceptibility variations within the Moine country rock are the reason for the noisy VLF-EM and magnetic pattern found in parts of the Corrantee-Whitesmith area; such noise impedes the identification of some anomalies. VLF-EM anomalies at Fee Donald are more easily identified against a relatively quiet background, and several such anomalies appear to indicate extensions of known mineral veins; however the low concentrations of barite present in these veins may prove a disincentive to further exploration.

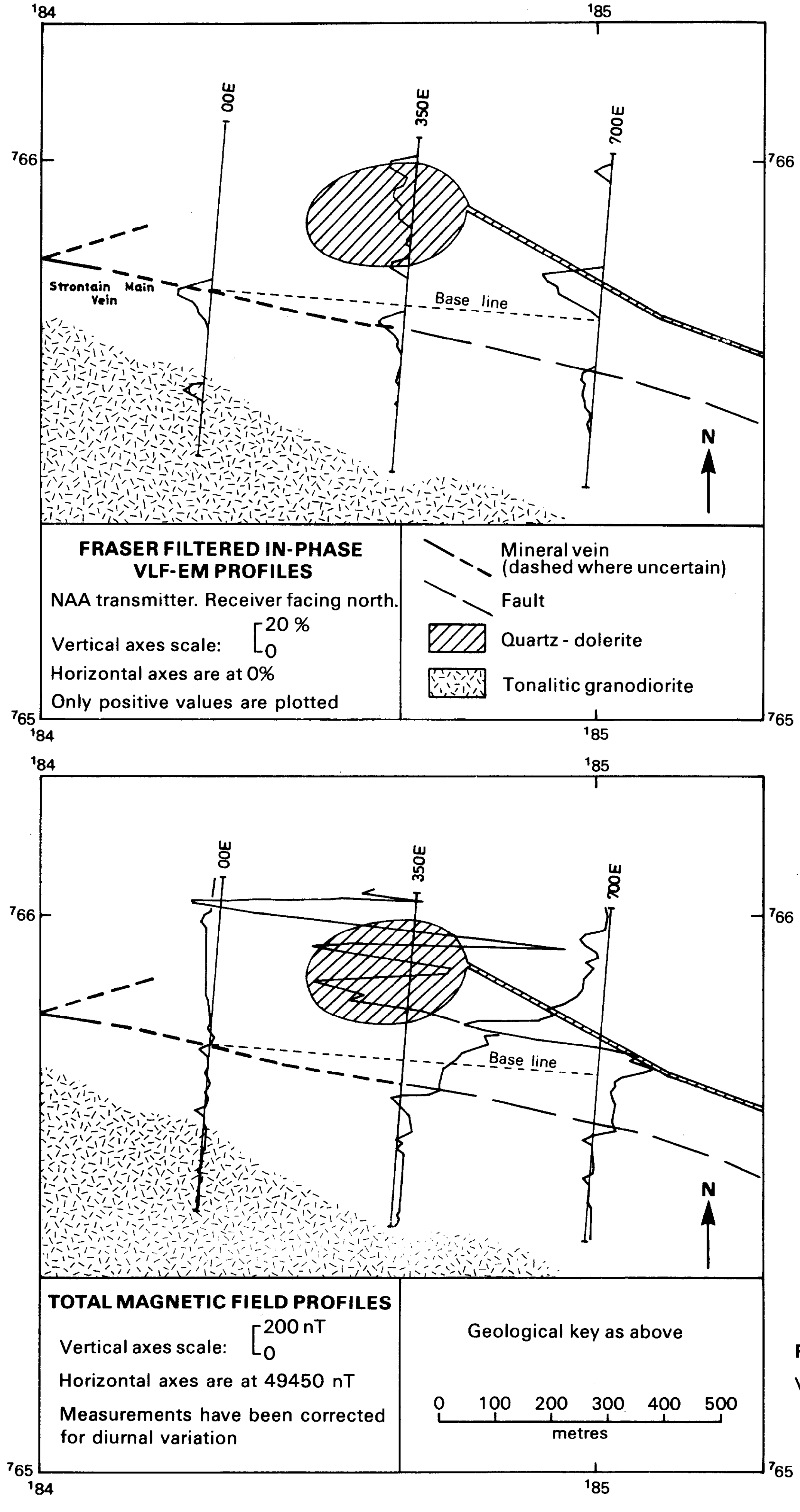


Figure 10 Bellsgrove area: VLF-EM and magnetic results

The features identified by this reconnaissance survey need to be followed up in more detail. Closely spaced VLF-EM and magnetic/gradiometric traverses would facilitate the identification of anomalous trends against background noise. Also, topographic corrections and alternative filters (for example that of Karous and Hjelt (1983)) should be tested on the VLF-EM data. Galvanic resistivity surveys would provide more information on the structures giving rise to the VLF-EM anomalies and the induced polarisation method could be employed if significant concentrations of metallic sulphides are suspected. Seismic refraction and resistivity soundings are suitable methods for estimating drift thickness. A study of the magnetic properties of the basic dykes would be beneficial; for example, palaeomagnetic measurements may allow the discrimination between different intrusive phases. A detailed study of the variation of a dyke-related magnetic anomaly along a crush zone may reveal sites where a decrease in anomaly amplitude can be correlated with alteration of the dyke, perhaps associated with mineralisation.

Using the geophysical methods outlined above; it should be possible to identify sites which show potential for mineralisation; however, it is unlikely that mineral occurrences will be positively identified using such methods. Geochemical sampling may provide useful indicators, but the efficiency of this method is limited because of the glacial stripping which has occurred throughout the area (M J Gallagher, personal communication). Detailed geological investigations, including trenching, will be necessary in the areas of interest, followed by drilling.

In addition to further study within the present survey area, there is clearly scope for extending the coverage to trace anomalies beyond the present boundaries. Similar geophysical surveys would be useful in other areas known to have this type of mineralisation, for example around the Lurga Mine (grid reference NM 732 553) and around the vein at NM 917 619 on the east side of Garbh Bheinn (Gallagher, 1958).

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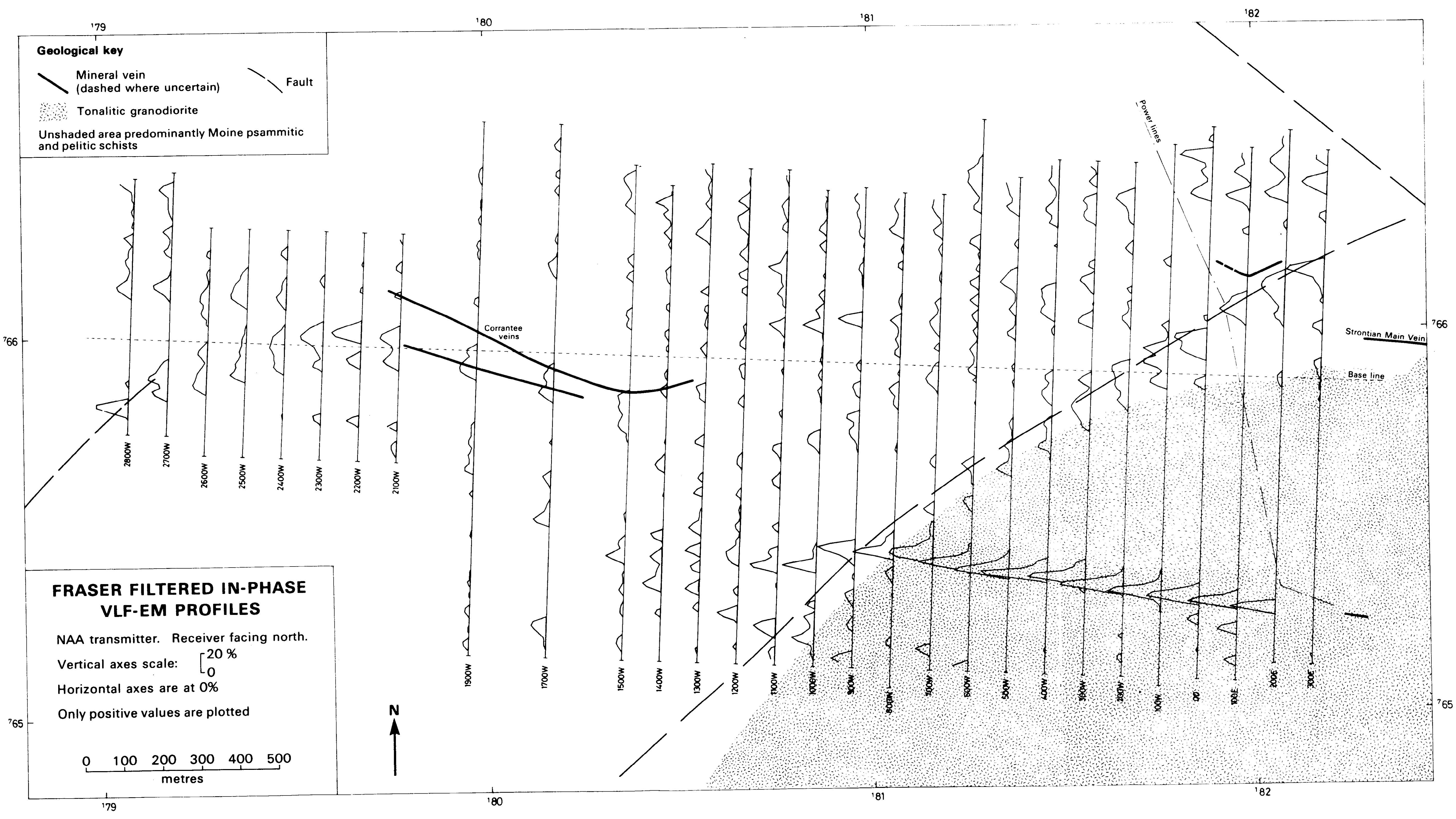
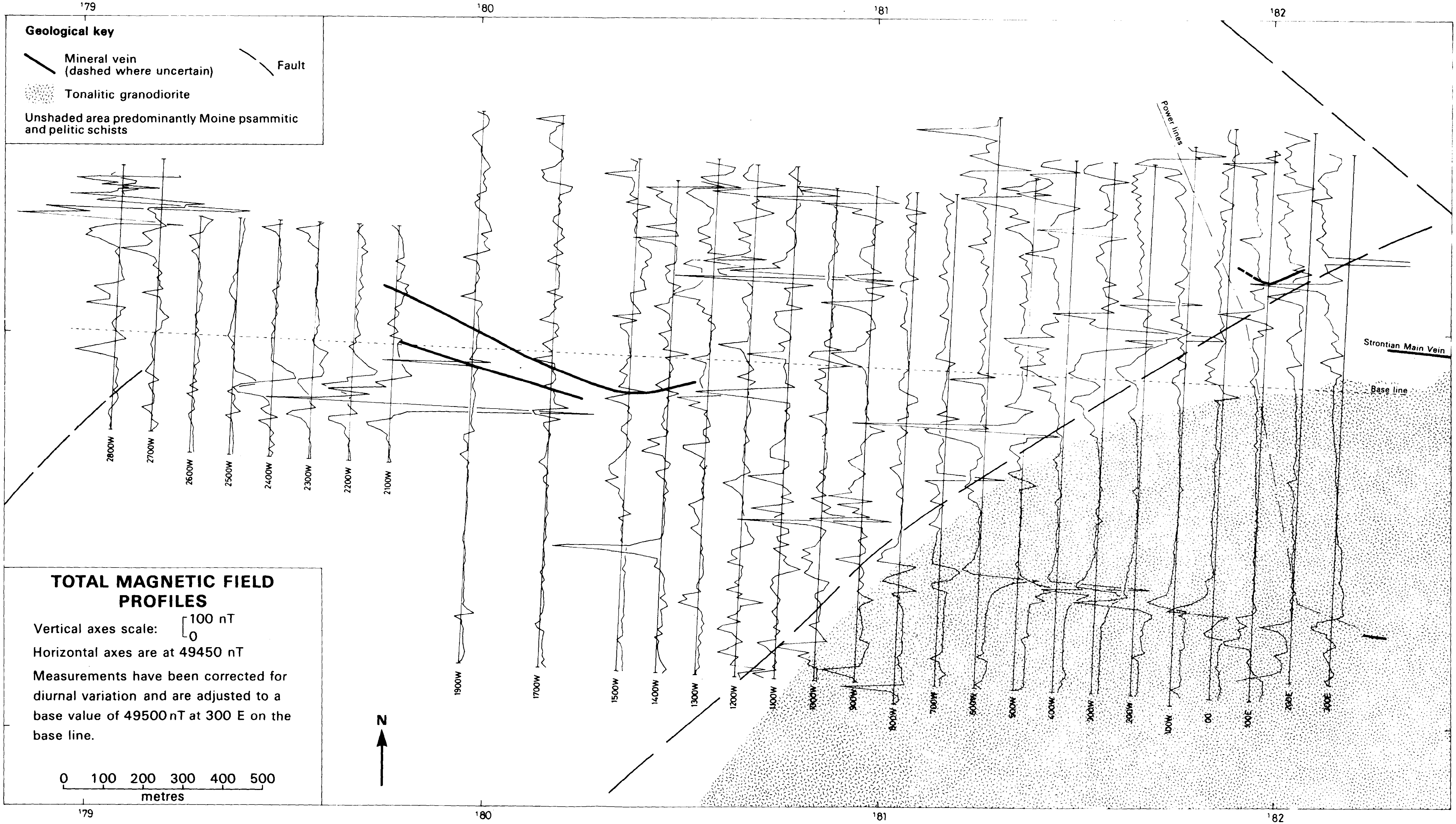


Figure 3 Corrantee-Whitesmith: Fraser filtered in-phase VLF-EM profiles



TOTAL MAGNETIC FIELD PROFILES

Vertical axes scale: 100 nT – 0

Horizontal axes are at 49450 nT

Measurements have been corrected for diurnal variation and are adjusted to a base value of 49500 nT at 300 E on the base line.

Figure 4 Corrantee-Whitesmith area: total magnetic field profiles