Gold exploration and the use of magnetic methods in northeast Tasmania

D. E. LEAMAN
Leaman Geophysics, GPO Box 320D, Hobart, Tasmania 7001

ABSTRACT

A review of the physical characteristics of and available data about major gold deposits in northeastern Tasmania suggests that these deposits can be linked to particular granitoid compositions and regional and local trend patterns. Rather subdued ENE elements appear to be crucial, and large deposits occur where regional and local trends of this type are superimposed. The actual details of a mineralised site are governed by local conditions including lithology changes or fold conditions but these are not diagnostic.

Magnetic surveys, in the form of regional and specific area surveys, seem the simplest way of locating target sites in terms of these concepts and conditions, and the use of magnetic data has been critical to definition of the common characters listed. Ground surveys can limit exploration to specific prospects once the target zones are established. These methods, with support from semi-regional gravity surveys, can provide comprehensive structural, genetic and target evaluation, and achieve site discrimination in terms of potentially economic deposits.

The review study indicates that "Golden Gate"-style mineralisation may be recognisable but subtle, and that only some of the plethora of small workings possess similar characteristics. If this is indeed indicative of worthwhile prospectivity then the same techniques could be applied to blind target possibilities.

INTRODUCTION

Much gold has been recovered from many small to large workings in northeast Tasmania. Most occurrences were irregular and often thin vein systems variable in size, continuity, orientation and grade. Many occurred in a single NNW-trending zone about 500 m wide extending from near Mangana to the coast at Lyndhurst. The presence of so many sites along a single axis does not mean, however, that vein systems within or along the axis are controlled by the regional orientation; they appear to be virtually randomly oriented within it. Previous workers have assumed the regional orientation, or structure, to be ascendant but consideration of the spread of occurrences, including the significant Lisle, Lefroy and Beaconsfield workings, suggests that more than one element has controlled mineralisation. The NNW trend may be recognised widely, but never appears specific to mineralised sites.

No consistent geological or geophysical patterns have ever been recorded for Tasmania's gold deposits. Most exploration over the past century has been based on the pan or the trench, or inspection, where possible, of previous workings. The lack of obvious criteria or controls and a monotonous, repetitive host geology of Mathinna Beds has deterred science-based exploration. The rocks, and their complex deformed structures, are not easily understood. The presence of important mineralisation in this environment is simply frustrating.

Geochemical and geophysical methods are recent innovations in exploration programs. The apparent association of gold with sulphides or arsenic has encouraged many trials, but no characteristic responses have yet been proven. Anomalies also tend to be diffuse. There is also no necessary basis to the assumption that arsenic is a gold indicator. Reid (1925) observed that while there is a correlation between gold content and arsenic there is a cut off, and high arsenic/ arsenopyrite levels are usually lacking in gold.

Geophysics has been applied even more sparingly. This reflects the assumption that no useful physical contrasts exist in the relevant materials. Quartz is notoriously difficult to identify and the Mathinna Beds host rocks have also been considered homogeneous. These assumptions have long been known to be invalid but the province has never attracted the innovation required to apply workable exploration technologies. Leaman (1974), in the pioneering geophysical research on these rocks at Lefroy, showed that self potential, thermal and piezoelectric methods can define the quartz systems (but not say whether they are mineralised) and that magnetic methods yielded some curious results only recently explained. Most of these methods are not in the "in general use" category and have not been taken up.

Genetic relationships have also been a long-standing puzzle. Workers such as Klominsky and Groves (1970) have recognised the affinity of the gold with biotite hornblende granodiorite and implied a direct genetic relationship. While this association seems reasonable in some localities it has always been generally rejected, as the important Mathinna, Mangana, Lefroy and Beaconsfield sites appear far removed from granitoids of any type. This is another fallacy. Workers since 1973 have ignored the findings of Leaman *et al.* (1973) who suggested that granodiorite is less than 1.5 km beneath the mineralisation at Lefroy.

Regional mappers in northeast Tasmania have attempted detailed subdivision of the granite and adamellite families of the two major batholiths (Scottsdale and Blue Tier) but have

LEAMAN, D. E. 1992. Gold exploration and the use of magnetic methods in northeast Tasmania. *Bull. geol. Surv. Tasm.* 70:149–160.

placed all granodiorites into a single class. Textural and magnetic property differences suggest that this should not be done (Leaman, 1992*a*). It should not, therefore, be accepted either that granodiorites are not associated with gold because they are nowhere to be seen or because there seems no reliable relationship with them. The latter condition ignores the possibility of a single family member forming the key source and control upon mineralisation.

Vein orientations and local structures in the Mathinna Beds hosts have also be found to be variable where recorded. Local controls appear dominant, even where major regional control would be expected — as along the Mathinna to Alberton zone. Vein patterns do not appear to be systematic or significant. These problems are compounded by poor outcrop generally, deep weathering in some units, and a complex, several-generation vein suite.

Grades and vein extent also remain a crucial problem for any evaluation. A very few mines have provided significant production; most workings have been marginal or limited in development. This usually reflects variation in grade with depth, but may indicate under capitalisation, which was endemic when the region was in full production. Major reductions in grade, often of an order of magnitude, have been noted near the level of regional weathering or water tables. Only some sites maintain grade levels to significant depths (>50 m) and it is these rare sites, such as the Golden Gate at Mathinna or the Tasmania at Beaconsfield, which have produced large quantities of gold. It is clear therefore that some form of discriminator must be found which can separate the golden eggs from the chaff, as all may look the same near the surface. Presuming they outcrop of course...

EXPLORATION NEEDS

A principal aim of any exploration is to assess and define the identifying characteristics of such important sites and determine their presence elsewhere. This approach then allows ranking or discrimination of the many known small workings or new target prospects. In this respect the Mathinna area, and the Golden Gate Mine with its production of 7895 kg, must be used as the prototypical yardstick until a greater understanding is achieved for the entire province. It represents a large vein system in typical host materials. Alluvial deposits, such as Lisle, are excluded from this discussion.

Some indication of the current understanding and knowledge about this important, and once highly productive, gold province can be obtained by considering the magnitude of published descriptions. The topic has rated a half page or less than two pages respectively in the 1962 and 1989 editions of the 'Geology of Tasmania'.

Let us consider what an explorer may need to know or what may be essential to site definition.

Systematic exploration is usually based on some conception of general or genetic setting. In this case an ability to define host structures or units (basic detailed mapping not possible from outcrops) as well as vein location and orientations, coupled with the facility to discriminate mineralised from unmineralised terrain, is required.

Any method able to achieve target focus or discrimination in the apparently bland, poorly exposed, vein-rich terrain of the Mathinna Beds would be rightly considered a sound right arm. If it was applicable at all scales and low cost as well; perhaps a saviour...

Such a method exists.

Magnetic methods are able to provide information in respect of all regional-to-focus requirements. Leaman (1992*a*) has recorded a twenty year research and specification history, initially considering common as well as exotic geophysical methods with structural bias, to support this claim. This paper considers only examples and conclusions based on that research.

A more fundamental issue relates to the worthiness of the region in the first place. The region has been a producer of some note but does it have the potential to be a great producer? Leaman (1992*b*) shows that the basic setting of northeast Tasmania is comparable with other very rich provinces, and that the gold was possibly derived from large Cambrian ultramafic bodies during the Devonian uplift–intrusion cycle. This under-rated region is worth some effort.

DISCUSSION

Mineralised sites at Mathinna, Mangana, Dans Rivulet, Golden Ridge, Alberton, Mt Horror, Warrentinna, Lyndhurst, Gladstone, Burns Creek, Lisle, Golconda, Lefroy, Back Creek, The Glen, Beaconsfield and Little Den (fig. 1) have been assessed for regional context and common denominators.

Few of these sites are well served by any type of data set. Only a few have been covered by any aerial magnetic data and fewer by adequate ground survey. Most are covered by a regional gravity survey but the station density is uneven and generally coarse.

The figures provide an indication of the best data available and of some of the conclusions which may be drawn.

Figures 2 and 8 illustrate how high quality aeromagnetic surveys can define formation scale, continuity and lithological variations, as well as structural offsets, within the almost non-magnetic Mathinna Beds. This is prized information given the difficulties of mapping these rocks. See Leaman (1987*b*, 1990, 1992*a*) and Richardson (1992) for some indication of the specification required.

Figure 3 provides an example of an older survey using poorer specifications. It is still most informative and draws attention to the primary variations in the units of the Lisle region. Structure can be mapped across at least part of the area and it is not wholly consistent with published regional mapping. Many other elements are exposed by such surveys. Several of the surveys cover blocks of granodiorite, and demonstrate that these intrusive rocks present a range of properties and relationships. Some are strongly magnetic. See also Leaman (1992*a*).

These examples prove that the magnetic method can define most of the structural and stratigraphic elements of northeast Tasmania.

Figures 6 and 7 illustrate the nature of magnetic responses due to the presence of granodiorite and the type of inferences which may be drawn. Figure 6 shows that granodiorite lies both east and west of Mathinna — as well as beneath it. This crude model does not discriminate compositions or true thicknesses. Figure 7 suggests that several granodiorite members are present in the Lisle–Golconda area but that only one is associated with the known gold deposits. The properties of this intrusive are almost identical with those inferred in the vicinity of Golden Ridge, Mathinna, Lyndhurst and Gladstone. This correlation, wherever data is available, seems more than coincidence.

Gravity data, or nearby exposure, at other sites indicates that granodiorites are a genetic element in these gold deposits, including Beaconsfield. These intrusives are now remnants of the original plutons because of diapiric intrusion and dilation by later granite-adamellites. The critical composition, marked by its physical properties, appears to be the first intruded on the basis of rock relationships. Any genetic relationship may be in terms of fluid generation, transfer and fracture control, rather than any compositional control.

Thus magnetic methods may have assisted (with gravity methods) creation of a genetic model. Regional exploration may need to consider the location of particular members of the granodiorite family.

Figures 4 and 5 provide examples of the use of medium resolution ground surveys to trace vein system orientation (Gladstone) or define anomalous, possible altered or mineralised, zones (Tower Hill). Veins produce spikes due to oxidation and alteration in the wall rock. Each vein produces a double spike which is usually integrated as a single feature. Background variations with spike responses appear to mark mineralised areas. Very high resolution ground surveys have shown that such areas are very limited and, where previously worked, very productive. Vein alteration trends in such zones always curl asymptotically to sub E-W trends, even though more obvious structures may trend NNE or NNW. This curl of trends would explain the common observation of E-W trends at many sites while veins in the surrounding hosts display scattered orientations. Primary stress controls at the time of emplacement seem to be reflected by these observations but many more sites need to be examined using very detailed surveys.

Figure 8 stresses the need for very high quality data if all the required information is to be recovered. The contour interval is 0.5 nT. The left plot provides a basic compilation of the data while the right plot draws attention to some very subtle ENE trends. Initial analysis (Leaman, 1990) overlooked these, including failure to view appropriately shaded sun images, and they were only recognised after consideration of common factors seen in other data and other sites.

Other factors reviewed included suggestions from gravity data, vein information and drainage patterns. The trend is apparently general at prime sites and must be sought. Its poor representation in this data set is due to a 3:1 line bias in favour of E-W lines even though the line spacing is about 100–150 metres. This line bias must be changed for future surveys.

The examples shown in Figures 2 and 8 demonstrate that magnetic data can also define structures of some subtlety but regional persistence. Mineralised sites (or zones) are positively discriminated.

SUMMATION

The observations noted in the above discussion may be condensed into five factors.

1. A granodiorite association is definite at many sites and can be inferred (within 1.5 km) at others (including perhaps Little Den and Beaconsfield). A genetic link is implied — if only in terms of heat engine, circulation and fracture association with primary plutons.

2. The key granodiorite lithology forms part of a primary intrusion, and possesses low density and susceptibility properties.

3. The quartz veins occupy fracture fills in the roof of this body, and the essential deformations predated or were contemporaneous with the intrusion. Subsequent venation and disruption reflect the disturbance associated with intrusion of the batholith series.

4. Mineralised sites are complex but mappable units and clear disruptions of the units are not necessary elements in the process controlling venation or mineralisation. While vein systems may be locally controlled by shallow features, the fundamental controls are exercised regionally or from depth. Thus a range of vein orientations is to be expected at mineralised sites. Particular sites may occur in fold limbs, axes or ductility differences in the host sequence. These are random elements.

5. Sites appear to occur at nodes along ENE or E-W trending features and intersections. Large deposits occur where local features of this trend are superimposed on regional elements. These are the non random elements.

Thus magnetic methods, although dismissed because "nothing is magnetic" and no adequate data were acquired until 1987, are able to provide critical targetting or discriminating focus in terms of all exploration needs at all scales.

All companies generating the data used here have never had, or taken, the opportunity to utilise it in the manner suggested because of financial collapse or withdrawal from tenements. It is time that the approach suggested here was properly tested on new targets.

REFERENCES

KLOMINSKY, J.; GROVES, D. I. 1970. The contrast in granitic rock types associated with tin and gold mineralisation in Tasmania. *Proc. australas. Inst. Min. Metall.* 234:71–77.

LEAMAN, D. E. 1974. Geophysics of the Lefroy Goldfield. *Tech. Rep. Dep. Mines Tasm..* 17:79–87.

LEAMAN, D. E. 1987*a*. *Report on trial survey, Portland Mine*. Report for Placeco Australia by Leaman Geophysics [TCR 87-2693].

LEAMAN, D. E. 1987*b*. *Acquisition report, airborne geophysical surveys EL 34/86 Gladstone*. Report for Placeco Australia by Leaman Geophysics [TCR 88-2762A].

LEAMAN, D. E. 1989. *Ground magnetic survey, EL 55/83 Mangana*. Report for Pegasus Gold Australia by Leaman Geophysics [TCR 89-3052A].

LEAMAN, D. E. 1990. *Aeromagnetic survey, EL 55/83 Mangana. Acquisition report (including preliminary interpretation)*. Report for Pegasus Gold Australia by Leaman Geophysics [TCR 90-3197A].

4/12

LEAMAN, D. E. 1992*a*. Mainly magnetics, Mathinna Beds and Gold Mineralisation in NE Tasmania. *Exploration Geophysics* 23 (In press).

LEAMAN, D. E. 1992*b*. Finding Cambrian Keys: an essay in controversy, prospectivity and tectonic implications. (This volume).

LEAMAN, D. E.; SYMONDS, P. A.; SHIRLEY, J. E. 1973. Gravity survey of the Tamar Region, northern Tasmania. *Pap. geol. Surv. Tasm.* 1.

REID, A. M. 1925. The properties of the Ringarooma Gold Mining Company, Alberton, Tasmania. *Unpubl. Rep. Dep. Mines Tasm.* 1925:119–129.

RICHARDSON, R. G. 1989. The Mangana–Alberton aeromagnetic survey — a preliminary interpretation. *Rep. Dep. Mines. Tasm.* 1989/19.

RICHARDSON, R. G. 1992. The optimum specifications for regional aeromagnetic surveys in Northeast Tasmania. *Rep. Dep. Mines Tasm.* 1992/19.

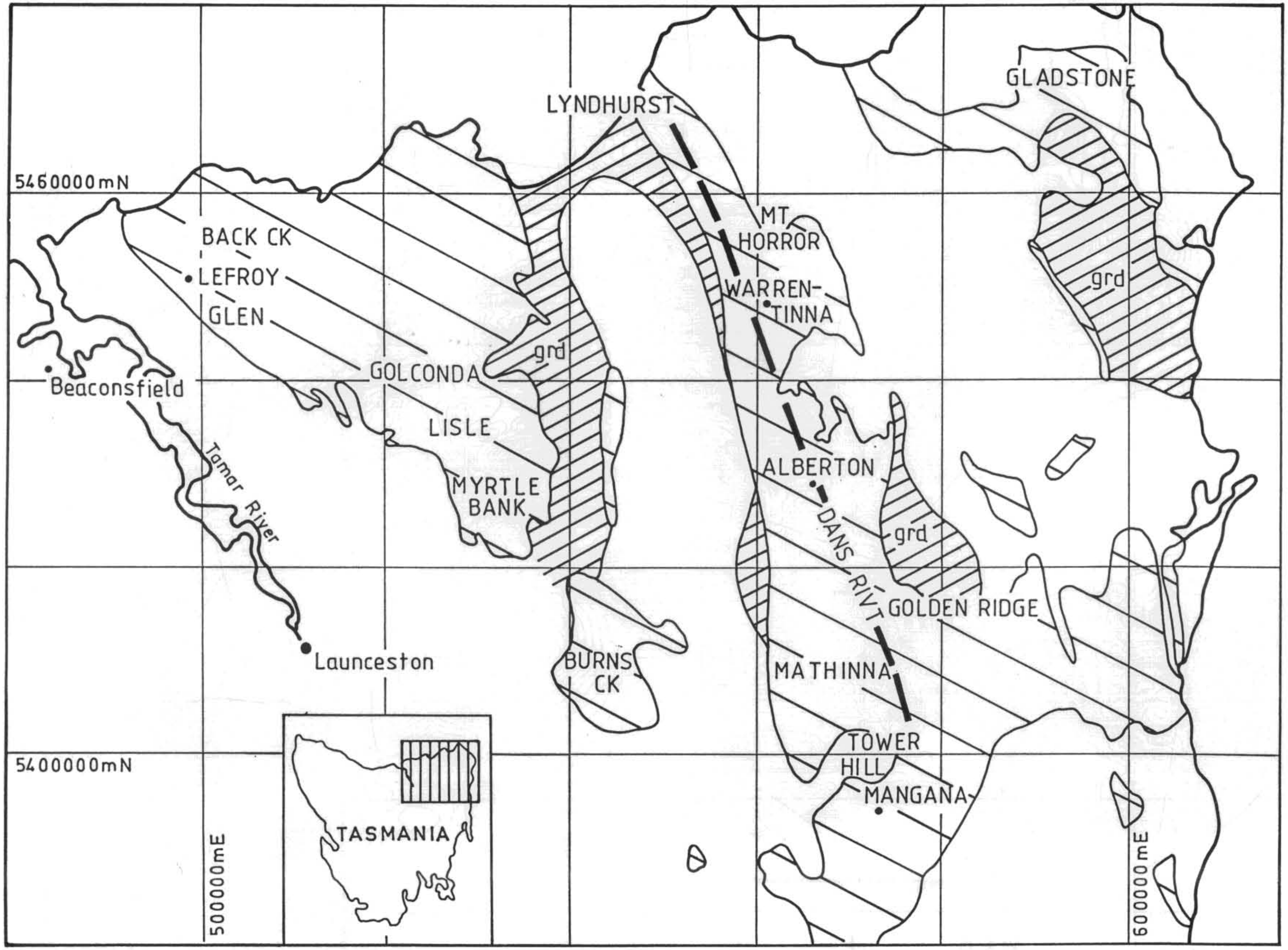

Figure 1. Locality map showing principal goldfields. Mathinna Beds are shown by open diagonal pattern and generic granodiorite in dense pattern.

5 cm

5/12

6/12

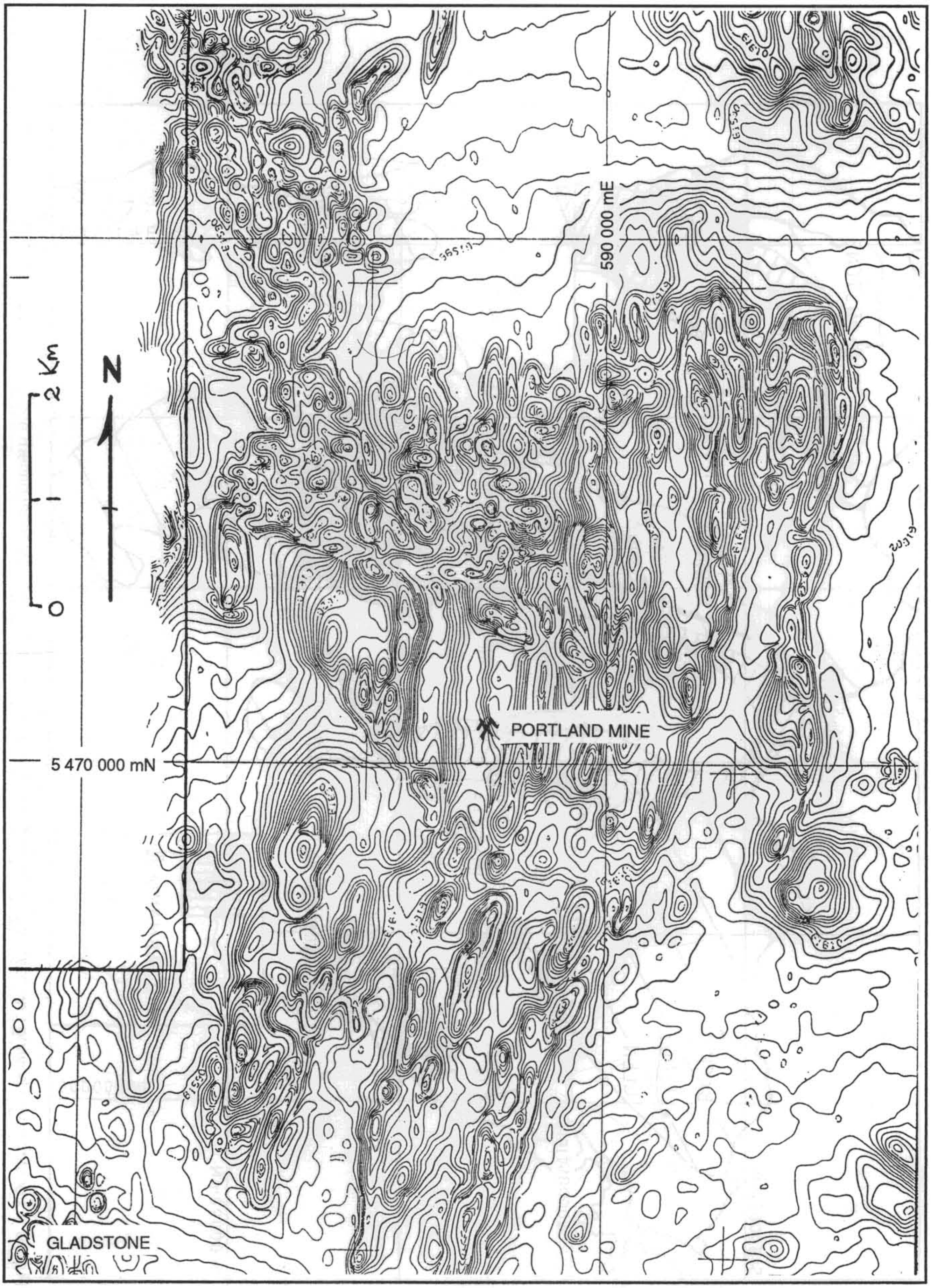

Figure 2

Part of the aeromagnetic survey of the Gladstone area (Leaman, 1987*b*). Note the texture within the block of Mathinna Beds about the mine. Very subtle and poorly defined sub E-W trends can be recognised in the data.

5 cm

7/12

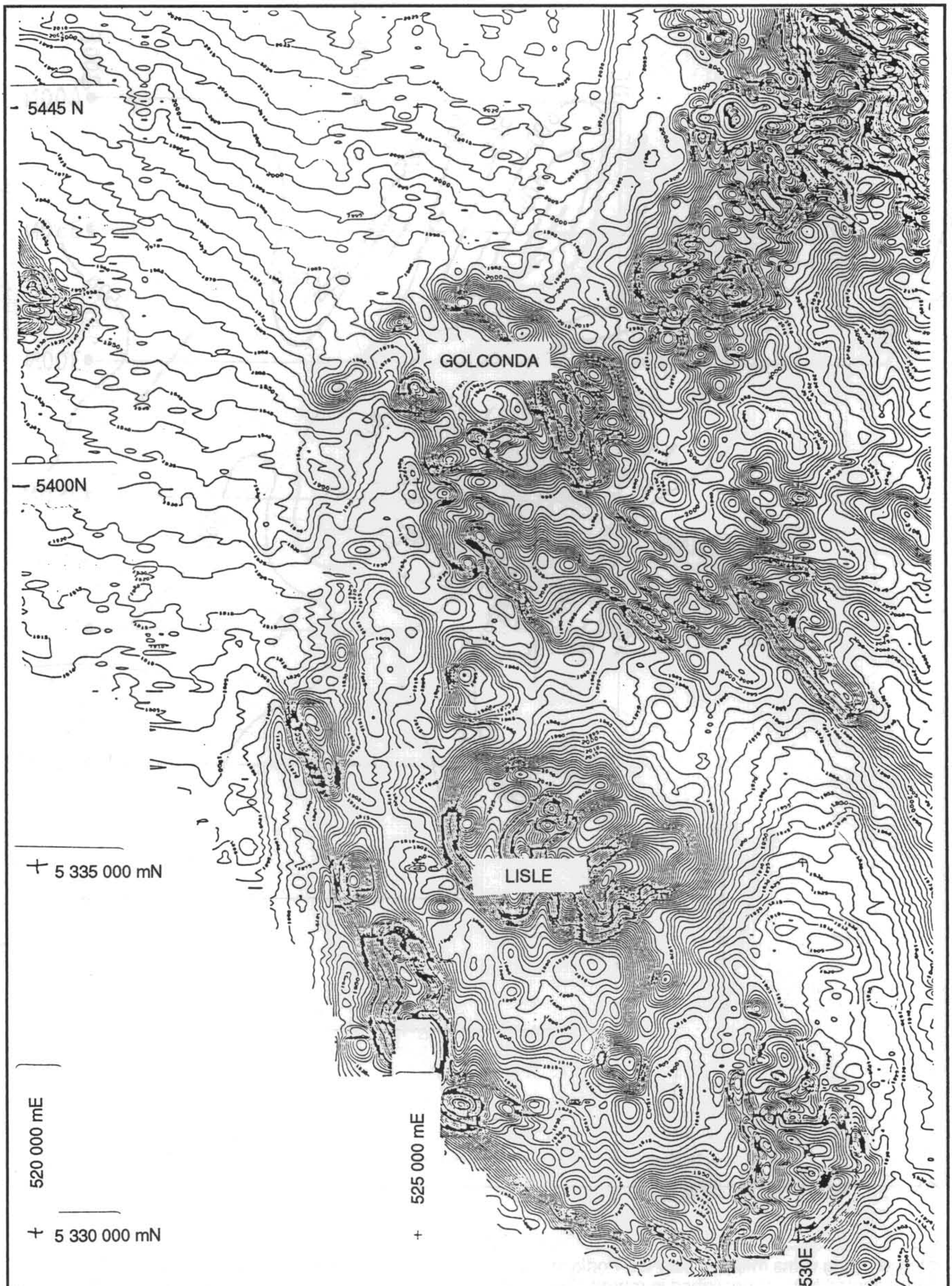

Figure 3

Most of an older aeromagnetic survey in the Lisle–Golconda area. Mathinna Beds responses and the effect of granodiorite and thermal haloes produces an array of patterns. An interpretation of this data is shown in Figure 7.

5 cm

8/12

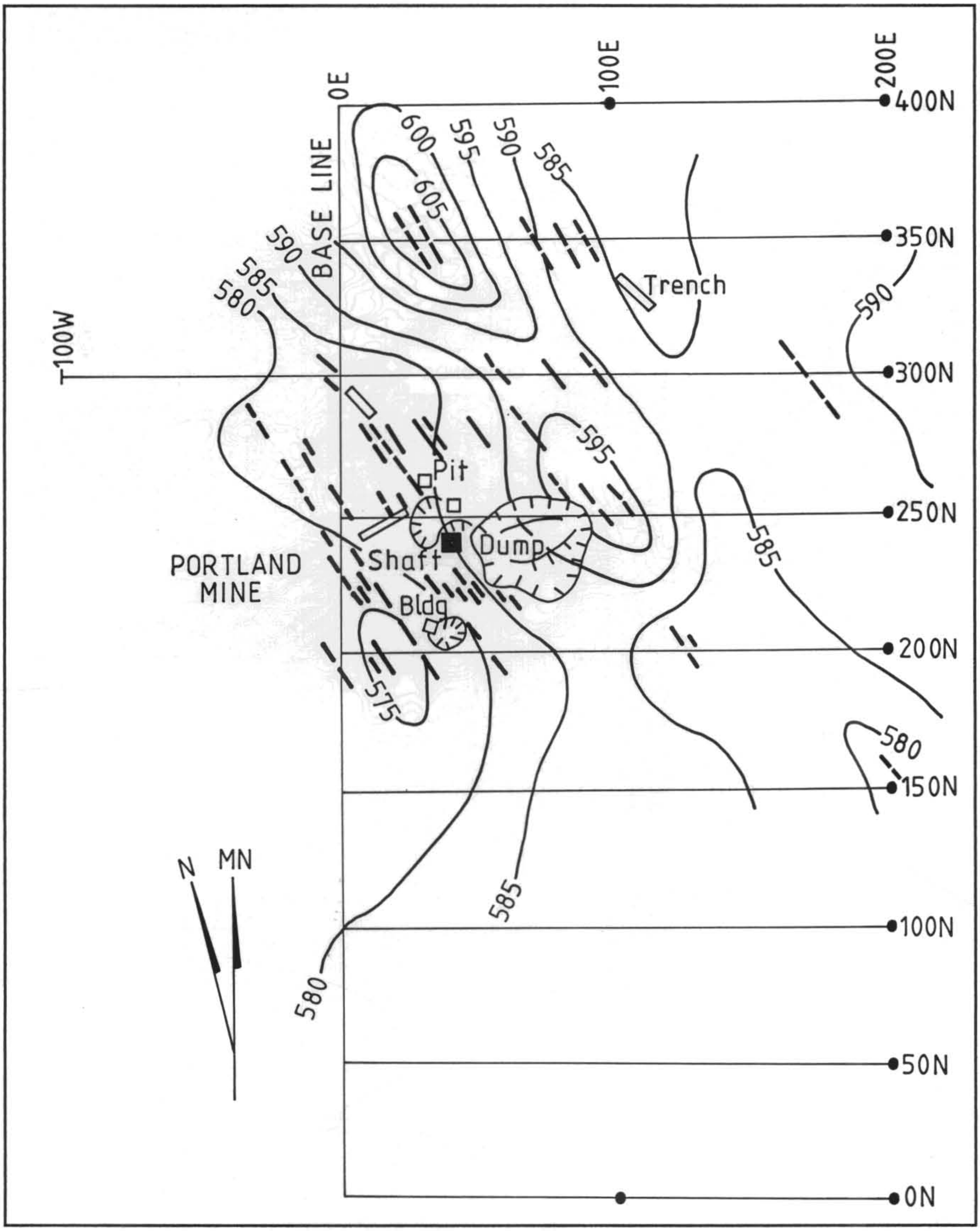

Figure 4

Plan showing veins mapped near the Portland Mine by ground magnetics (Leaman, 1987*a*). Although the veins are oriented NW, as described in reports during mining, all occur in or near a 200 m corridor oriented ENE as defined by the magnetic field more regionally. Gross lithological effects are also oriented NW-NNW.

5 cm

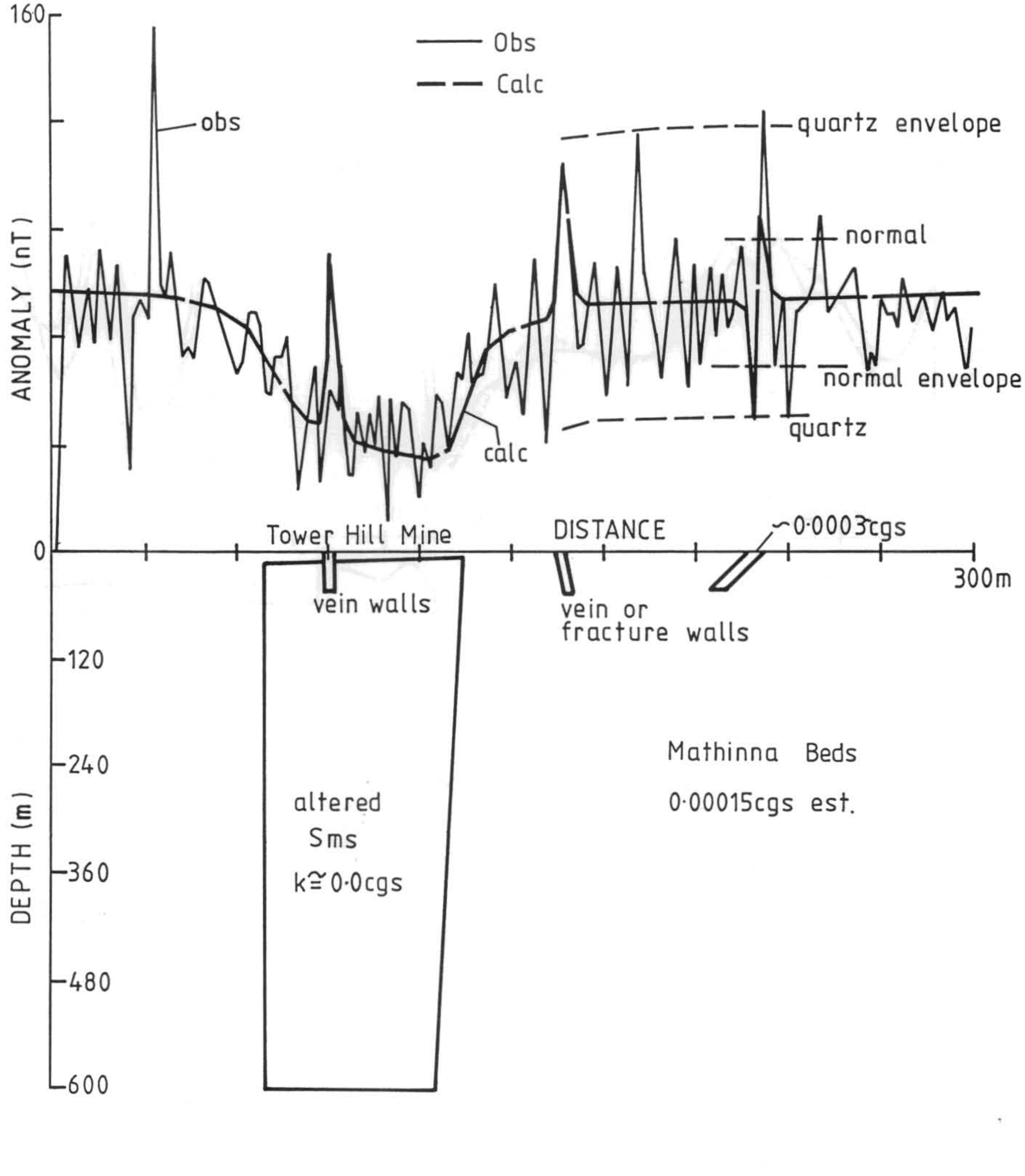

Figure 5

Example of results of ground survey near the Tower Hill Mine (Leaman, 1989). Spikes reflect shallow veins while the broad dip in field intensity reflects local host changes about the mine. Spikes are due to property changes of up to three orders of magnitude in the vein walls. Spikes can be mapped by detailed survey.

5 cm

10/12

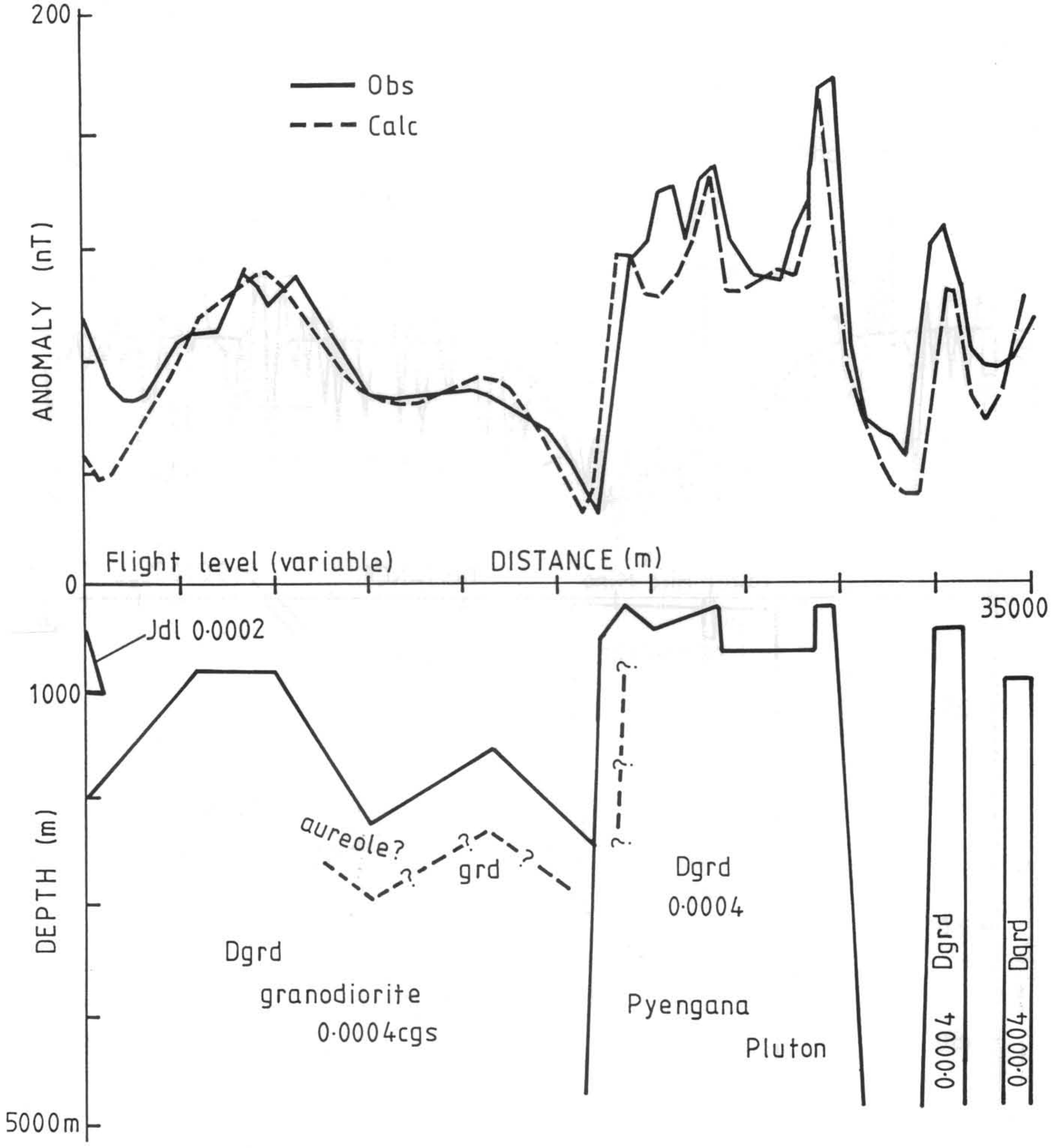

Figure 6

Section across the South Esk Valley near Mathinna showing continuity of granodiorite between exposures to the west and east (Richardson, 1989). This early interpretation makes no allowance for possible variations in granodiorite properties or limited volumes of material after subsequent granite intrusion deep in the section. The implication is general, however, much as inferred by Leaman *et al.* (1973).

5 cm

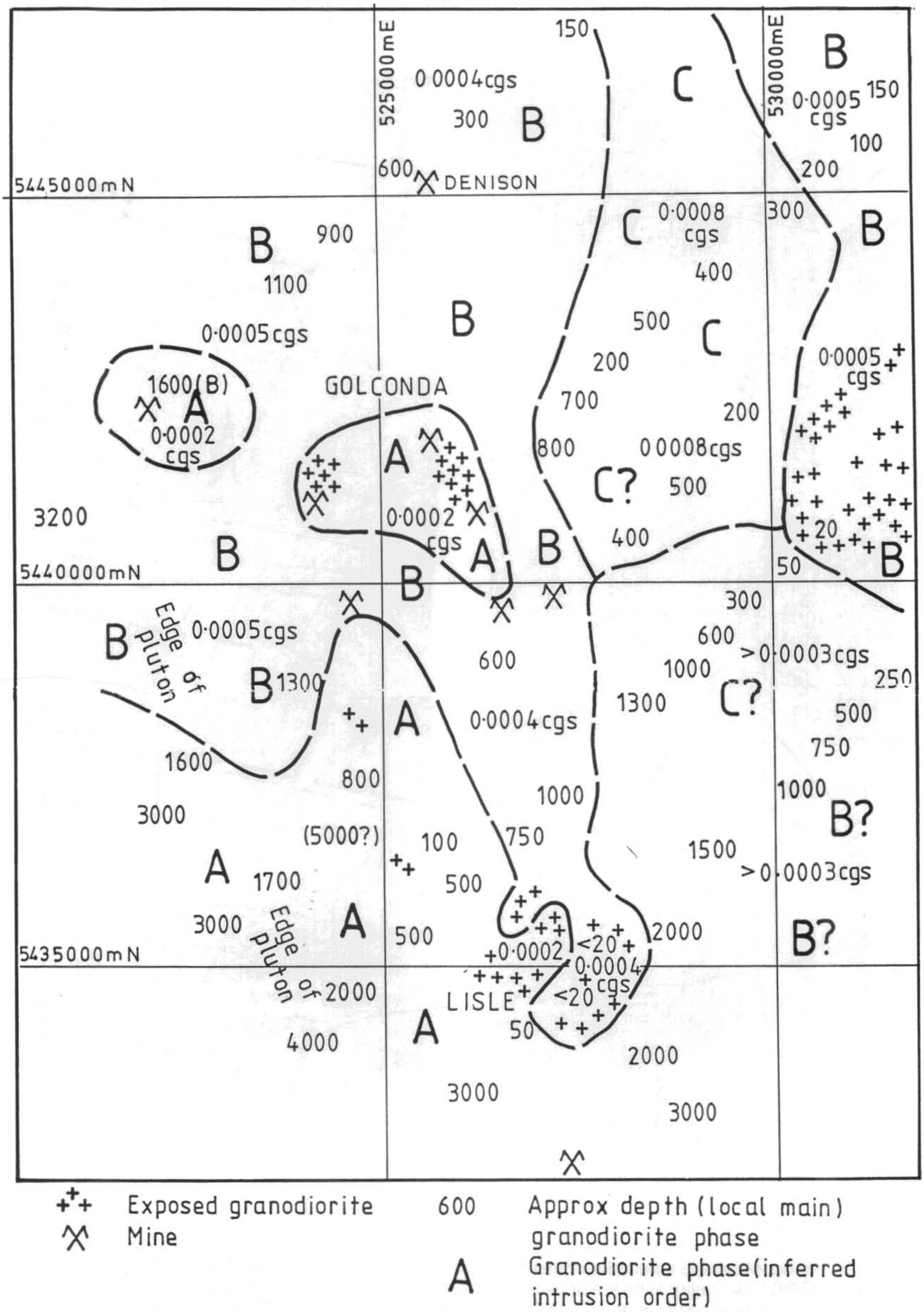

Figure 7

An interpretation of the possible distribution of granodiorite types in the Lisle–Golconda area. These plutons intrude each other in the inferred order and have largely escaped subsequent dilation and intrusion by later granitoids of the Scottsdale Batholith. The alluvial gold at Lisle is concentrated in a valley trap where erosion has worked the roof of body A and its metamorphic halo in the country rocks.

5 cm

12/12

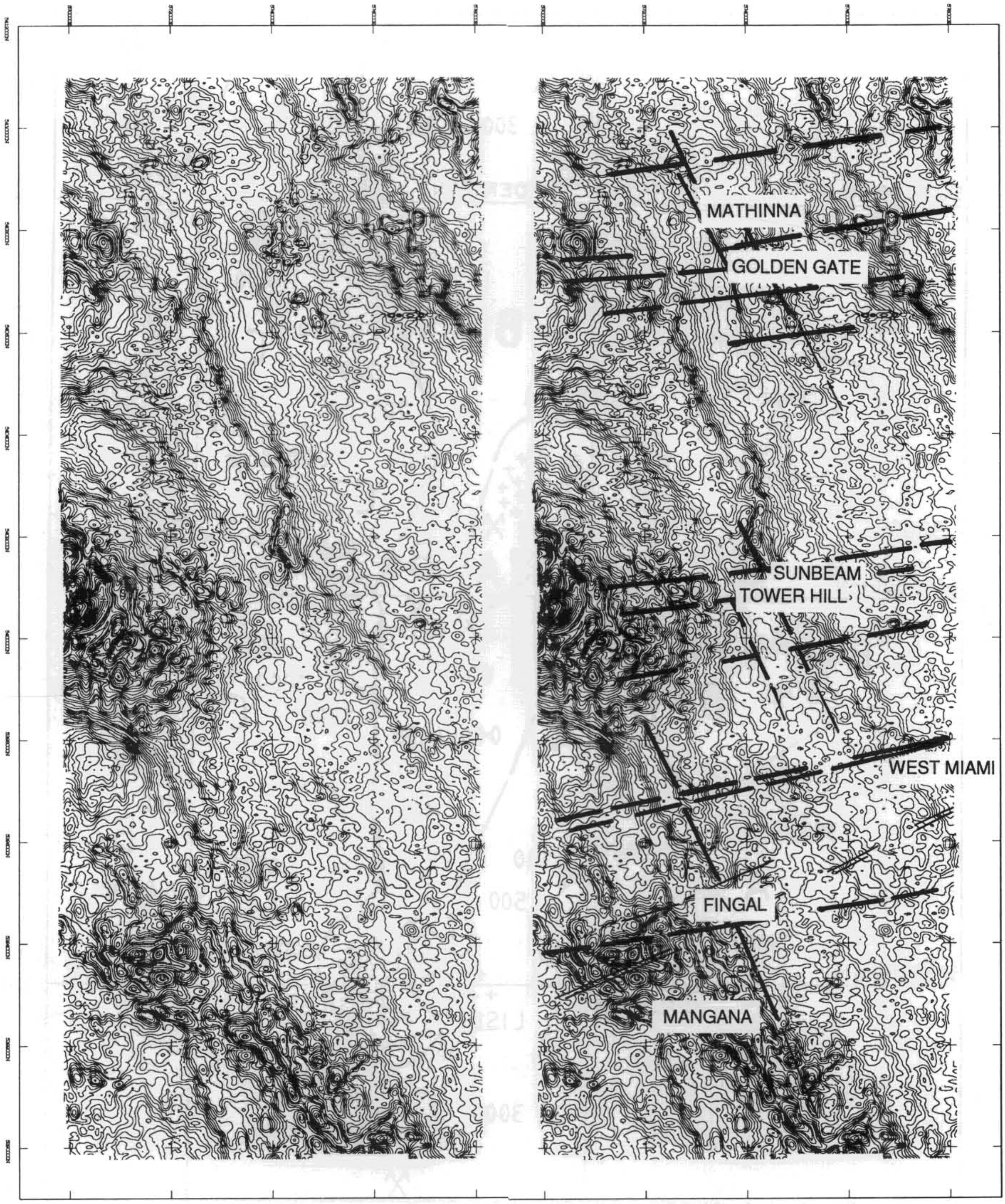

Figure 8

The Mathinna–Mangana detailed aeromagnetic survey with contour interval of 0.5 nT (Leaman, 1990; Richardson, 1992). Two major sites are shown and attention is drawn to some of the more subtle trends in this data. These trends have been rendered poorly because of an unfortunate E-W line bias. More obvious trends are related to lithological changes in the Mathinna Beds.