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# The effective magnetic contrast of the Jurassic dolerites of Tasmania

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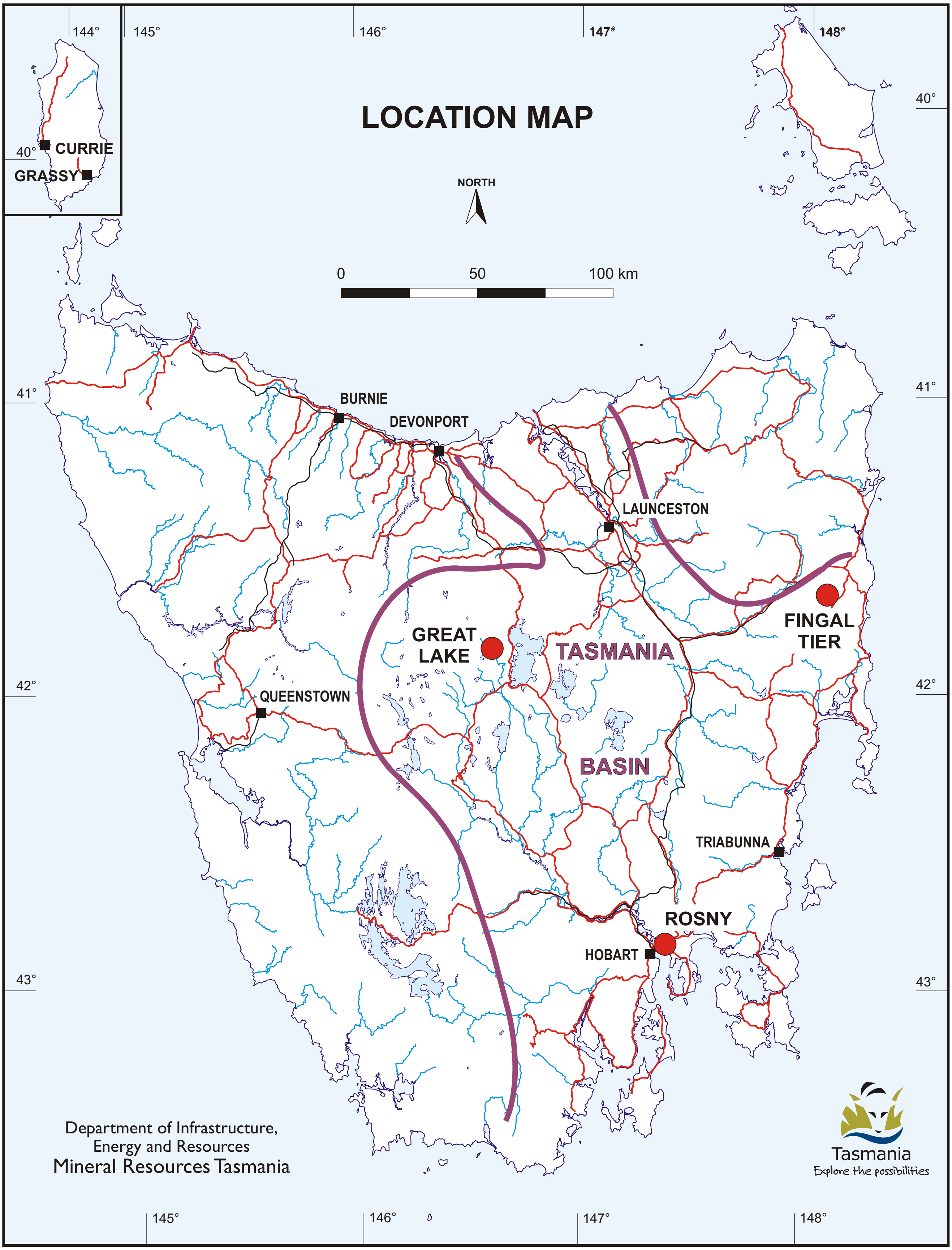


**Figure 1.** *Location of important dolerite intrusions, Tasmania.*

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### Abstract

A review of the magnetic properties and field responses of a Tasmanian dolerite sheet suggests that the magnetic field is controlled by variations in remanent magnetisation. There is general correlation between susceptibility and crystal size and texture through the intrusion but no correlation between susceptibility and the nature of the magnetic field. As the natural remanence and modern field vectors are crudely aligned, the effective contrast of the intrusion is the vector sum which is equivalent to a susceptibility of about 0.07 SI. Intruded rocks are non magnetic. Variations within the intrusion are explained in terms of oxide-rich horizons (up to 0.15 SI) and reversely magnetised sections.

## Introduction

Jurassic dolerite is the most common rock in eastern and central Tasmania. It dominates the terrain and its complex intrusive forms and associated faulting have disrupted the Permo-Triassic sequence of glaciomarine and terrestrial deposits of the Tasmania Basin. Interpretation of the dolerite's complex forms has been important for various types of exploration, including power development access tunnel routes, estimation of coal resources and, more recently, petroleum potential of the basin rocks and concealed basement rocks. Problems with data coverage and assessment of its properties have limited magnetic evaluations.

The magnetic character of the dolerite has long been appreciated but reliable interpretations have not been achieved until recently and then only with the control of other methods (mainly gravity), better geological mapping, and drilling. The problem has been: what is the effective magnetic contrast of this strongly magnetised rock?

Remanent magnetisation was recognised in the 1950s and was clearly important to any assignment of properties and interpretation but the data available were never integrated with petrographic and susceptibility information. The need to acquire an integrated set of magnetic data in one intrusion in order to test the relationships between induced and remanent magnetisation, and the observed magnetic field, was recognised in the early 1970s. The observations were completed in 1975–1976 by staff of Tasmania Department of Mines but were never analysed due to other priorities, and the data was then lost.

The field notes, observations and rock descriptions were found in 1999. This paper presents the results and implications of the survey of the Rosny intrusion.

## About dolerite

Much is known about the chemistry, mineralogy, differentiation, form and mechanism of intrusion based on pioneering work more than a generation ago (e.g. Edwards, 1942; McDougall, 1962; Leaman, 1972*a*, 1975). The intrusions are large (320–550 m thick), often multiply injected and layered, differentiated chemically and several may appear in a given rock sequence. Their scale is such that no complete sequence is ever exposed. The intrusions are mid Jurassic in age and dilated about 2.5 km of Permian and Triassic glaciomarine and terrestrial sedimentation (Tasmania Basin, fig. 1). No simple intrusive patterns exist (e.g. Leaman, 1972*a*) and the rock is neither monolithic nor simple in its presentation. The lithology may variously be described as glass, basalt, dolerite, gabbro, pegmatite or granophyre and only field relationships — as sheets and dykes, regardless of scale — determine the use of the name dolerite.

Several studies have been reported which describe the magnetic properties of the Tasmanian dolerites and their origin (e.g. Jaeger and Joplin, 1955; Jaeger, 1957; Jaeger and Green, 1958 — from Great Lake, fig. 1) but these were directed at petrographic relationships and microsurveys (e.g. Wiebenga, 1958). These projects have examined the state and nature of iron oxides and correlations between susceptibility and oxide mineralogy or crystal size and composition. Irving (1956) described the magnetisation of the dolerites and suggested the location of the Jurassic pole but did not relate remanence to either mineralogy or texture.

This information was summarised by Leaman (1973) but there was little quantitative application of magnetic methods to dolerite problems after about 1960 (e.g. McDougall and Stott, 1961). There were two reasons for this; the dolerite was not associated with any major infrastructure or exploration problems of the time and early interpretations of dolerite form and structure were unreliable (e.g. Leaman, 1972*a*). Gravity methods were used instead.

Jurassic pole data were reviewed and intrusions re-sampled (Schmidt, 1976) to show that the early data indicated a more complex arrangement of poles or intrusion characters than previously thought and this debate has not yet been resolved (Schmidt and McDougall, 1977; Leaman, 1978). The review provided additional magnetisation data. The scattered NRM data indicated that the Koenigsberger ratio generally exceeded unity by a substantial margin.

Evaluation of the coal resources of eastern Tasmania (Fingal Tier, fig. 1) employed magnetic methods in regional support of gravity surveys for complete definition of structures and feeding centres (Leaman and Richardson, 1980, 1981) and susceptibility and magnetic field character data were obtained. Few samples were collected for magnetisation studies because of budget constraints. Interpretation of these first high quality aeromagnetic surveys flown over dolerite sheets suggested that the effective contrast of the intrusions was at least 0.05 SI. Intruded Permian and Triassic rocks are non magnetic for all practical purposes.

Further work (Leaman, 1987*a*, *b*, 1990) suggested that the contrast might be as high as 0.065 SI; these results were based on sites where structural, drilling or gravity control was adequate. It had been clear from the earliest surveys in 1955 that remanent magnetisation was significant but its role was never defined nor integrated with susceptibility data which implied a bulk contrast for a typical sheet of no more than 0.02 SI.

All magnetic property assessments have suggested a range in susceptibility of 0.001 to 0.05 SI with typical values less than 0.02 SI for large segments of an intrusion. High values are associated with iron-enriched granophyres which are only found near large dykes or feeders. Early workers (such as Jaeger and Joplin, 1955) established that the crystal size of pyroxenes and plagioclase is a good indicator of both state of differentiation and oxide content, and hence magnetisation.

Information about remanence was much more sketchy and indicated magnetisations of 0.1 to 7 amps per metre with Koenigsberger ratios between 0 and 25. No systematic relationships were known as most sampling was restricted to contact zones (see Irving, 1956; Schmidt, 1976 and discussion by Leaman, 1978). Data from Fingal Tier were too limited to constrain any relationships (Leaman and Richardson, 1980). The Jurassic pole position was found to be complex, with declinations of 304° or 63° and dip of 80° (Schmidt and McDougall, 1977) which may reflect either a record of a partial reversal, or quite distinct intrusions. The modern field, orientated to 14° with a dip of 72°, lies near the mean of the palaeopoles.

## Rosny intrusion

The Rosny intrusion is exposed at sea level along the eastern shore of the River Derwent in the centre of Hobart (fig. 1, 2). Shore platforms with virtually continuous outcrop extend along about five kilometres of irregular coastline and sample the entire intrusion from its top (in the north at Rose Bay) to the base near Bellerive. The dip of the intrusion provides a sea level cross section but the body is faulted near Bellerive, to repeat the roof south of Kangaroo Bay. The irregular form of the coastline presents several aspects of the variations within the intrusion. The only previous magnetic work in the area examined the effects of lightning strikes on bare rock slabs exposed near the hill top (Watt, 1971) and boundaries in Kangaroo Bay (Leaman, 1972*b*).

The intrusion was traversed at high tide mark from base points beyond its roof contacts at Bellerive Bluff and Rose Bay (fig. 2). Measurements included vertical and total magnetic field, susceptibility, rock texture, crystal size, and state of weathering every metre. Each susceptibility value assigned was the average of eight measurements in an area with a radius of 200 mm. These measurements were supported each ten metres by magnetometer-based determinations of remanent magnetisation using the methods of Doell and Cox (1967) and Breiner (1973).

The magnetometers were held at about one metre above the rock surface (precession precision of <2 nT; fluxgate of <15 nT). The proton magnetometer was often destabilised by very strong local gradients and many observation sites could not be occupied. A complete record (over 5000 stations) was obtained with the fluxgate instrument. The field property determinations were compared with direct susceptibility measurements and the confidence established in NRM determinations was about 10% with an orientation precision of about 10 degrees. The method employed provided statistically significant numbers of samples, far in excess of normal sampling for laboratory determinations, although each result is of lower overall precision than laboratory data. Patterns and trends along the profile are well established by the detailed sampling and examples are presented in figures 4 and 5. The Bellerive to Bellerive Bluff profile was included in Leaman (1999).

The magnetic field observed was extremely spiky but with two noticeable characteristics: a general increase in field intensity across the intrusion and a cyclic response with wavelength of about 350 m — which is close to the estimated thickness of the intrusion (fig. 3). Excursions in the field exceeded 10 000 nT but most features had amplitudes of 500 to 1000 nT. These excursions are rapidly smoothed by elevation although tests of sensor clearances were restricted to two and three metres. Only the long wavelength character is evident at continuations of 50 m or more. The field base level (residual zero) was established by correction of base records against the International Geomagnetic Reference Field (IGRF) indication and examination of anomaly responses at contacts.

The results showed no correlation between susceptibility and field intensity, and other correlations between susceptibility and mineralogy or texture were uncertain, except in regional terms. In the lower part of the intrusion (fig. 4) there was an inverse relationship between susceptibility and texture type, and crystal size, but in the upper part of the intrusion (fig. 5) the relationship was more direct. This reflects the increase in iron oxide content in the more differentiated part of the intrusion. Although weathering effects modify the observed field there was no clear correlation between depth and nature of weathering and either susceptibility or texture type. It may be concluded that in this coastal zone, weathering is skin deep.

The magnetic field correlates very closely with variations in remanent magnetisation, but there is no such correlation with the Koenigsberger ratio which often shows a negative correlation with both the field and susceptibility. When the induction and NRM vectors are combined as effective susceptibility, there is an excellent correlation between observed field and resultant magnetisation.

Results revealed that much of the lower portion of the intrusion was reversely magnetised (also found by Jaeger and Green, 1958 at Great Lake) and that the most intense magnetisations were associated with the pegmatitic and granophyric phases of the upper third of the intrusion. The reversely magnetised portion of the intrusion was associated with the smoothest field character. Some parts of the upper zone were also reversely magnetised but the effects were very localised (fig. 5).

The intrusion can be described in several ways. Susceptibilities range from 0.0 to 0.05 but when integrated across the entire intrusion the average value is less than 0.02 SI, consistent with all previous experience. Most of the intrusion has values less than 0.015 SI. The Koenigsberger ratio ranges between 0 and 40 but typical values exceed 3 throughout the intrusion. NRM ranges from -1.5 amps/metre to about 2 amps/metre in the lower parts of the intrusion and -5 to 15 amps/metre in the upper parts. In the lower part of the intrusion the magnetisation is relatively uniform near the limiting values (fig. 4) with a strong gradient between normal and reverse magnetised rock. NRM magnetisation is much more erratic in the upper part of the intrusion but typically exceeds 5 amps/metre.

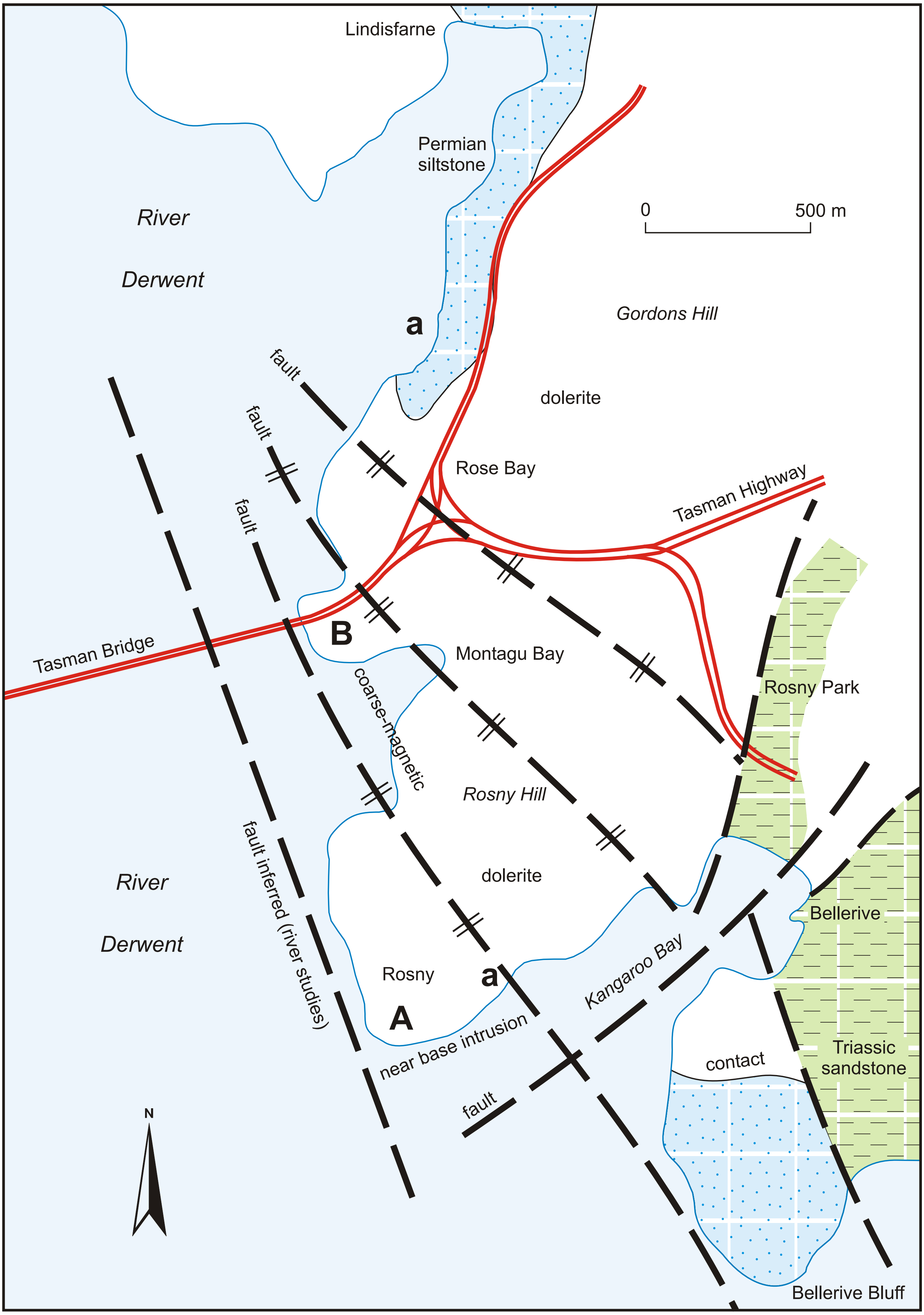


**Figure 2**

*Locality map for Rosny region, eastern Hobart. The entire coastline was surveyed. Section a-a is shown in Figure 3 and the detailed segments shown in Figures 4 and 5 are marked A, B. Faults shown with tick marks were mapped as a result of this analysis.*

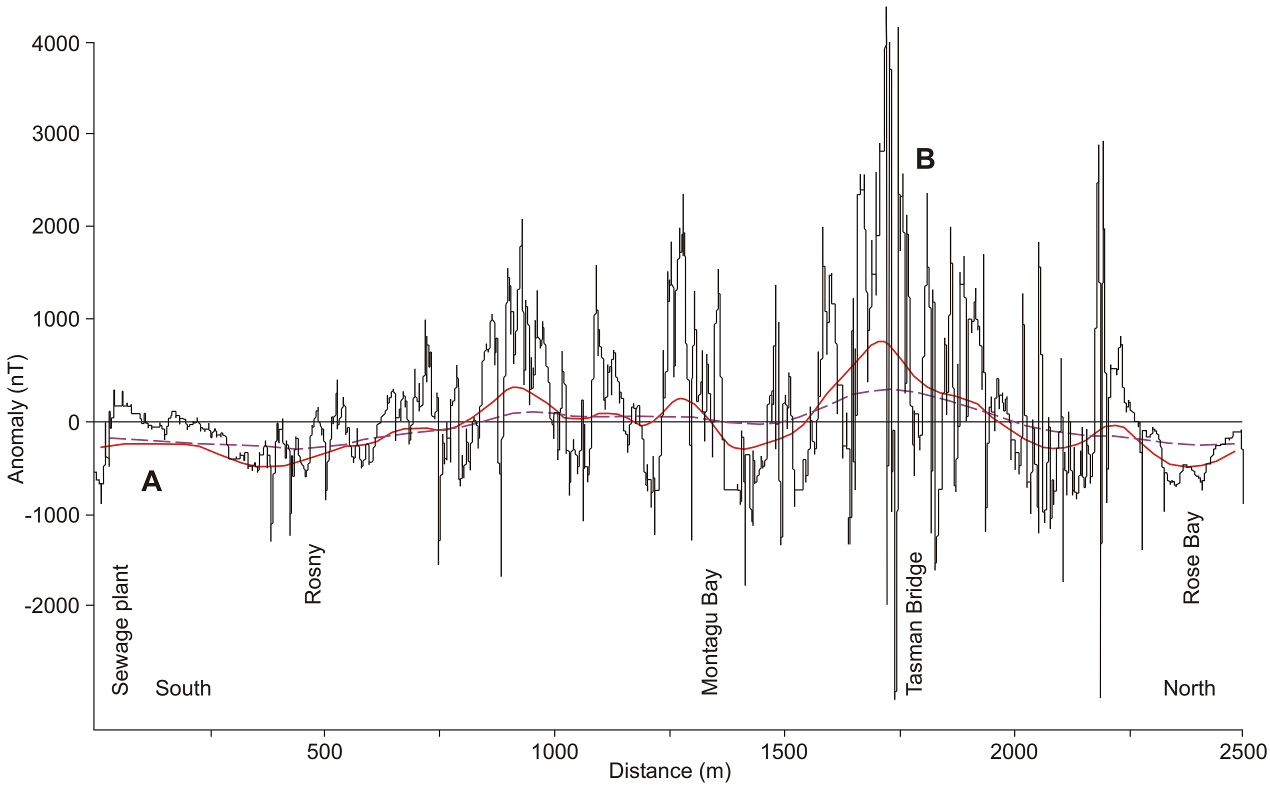


**Figure 3**

*Vertical component of magnetic field between Kangaroo Bay and Rose Bay (a–a in Figure 2). Zones labelled A, B refer to data in Figures 4 and 5. Note the oscillating character of the field which is due partly to the irregular coastline sampling of the intrusion and minor faulting. Continuations for elevations of 50 and 150 m are superimposed.*

If the induction and NRM vectors are combined the following equivalent susceptibilities may be obtained.

- Lower zone: 0.03 SI or, where NRM reversed locally, -0.015 SI.
- Upper zone: 0.15 SI, or -0.05 SI where there are rare reversals.
- Altered zones: 0.1 and 0.3 SI (especially pegmatitic very coarse dolerite).

If all character is integrated across the intrusion then the minimum bulk contrast is 0.04 SI and about 0.07 SI if reversals above the lowest zone are not significant. This value of 0.07 SI is consistent with the inferences based on whole intrusion interpretations controlled by other methods which have suggested effective values of 0.05 to 0.065 SI.

The indicated value of 0.07 SI was tested for the Rosny intrusion by modelling its structure using continuations of the field to 50 and 150 m (see fig. 3) which is the typical flight clearance range for modern surveys in Tasmania. This value, and the more detailed zoning values, led to satisfactory results about the form of the intrusion based on detailed mapping and gravity data. The analysis did allow extraction of information about faulting only suspected previously. This encouraging result fully justifies the use of the method and demonstrates its ability to add to other knowledge, or to be used independently once realistic contrasts are employed. The current understanding of faults in the area is shown in Figure 2.

## Conclusions

Although the Rosny intrusion cannot be considered representative of every dolerite intrusion in Tasmania it is typical in its petrographic and magnetic range. It may also be typical in its component of reversely magnetised dolerite, previously described only by Jaeger and Green (1958) and Leaman (1978). The bulk of the intrusion is normally and very intensely magnetised.

The study of this intrusion was not affected by deep weathering or recent alteration effects due to the fine coastal exposure and it is possible that such effects could influence results elsewhere. The results support the gross relationships previously noted between crystal size and susceptibility and NRM magnitude but the correlation is not systematic between exposures which may show considerable differences in adjacent outcrops. Actual composition-differentiation changes clearly control the iron oxides and resultant magnetisation and it is these, in association with textural changes, which are observed in regional terms.

The magnetic properties of a dolerite intrusion are extremely variable but may be integrated into an effective contrast of about 0.07 SI due to the virtual alignment of the NRM and modern field vectors. Values of this order should be used for structural interpretation of dolerite intrusions until equivalent studies are undertaken more widely or varied for particular projects. Intrusions which carry no reversely magnetised part might well have an effective bulk contrast in excess of 0.1 SI and no contrast estimate should be based on susceptibility determinations alone.

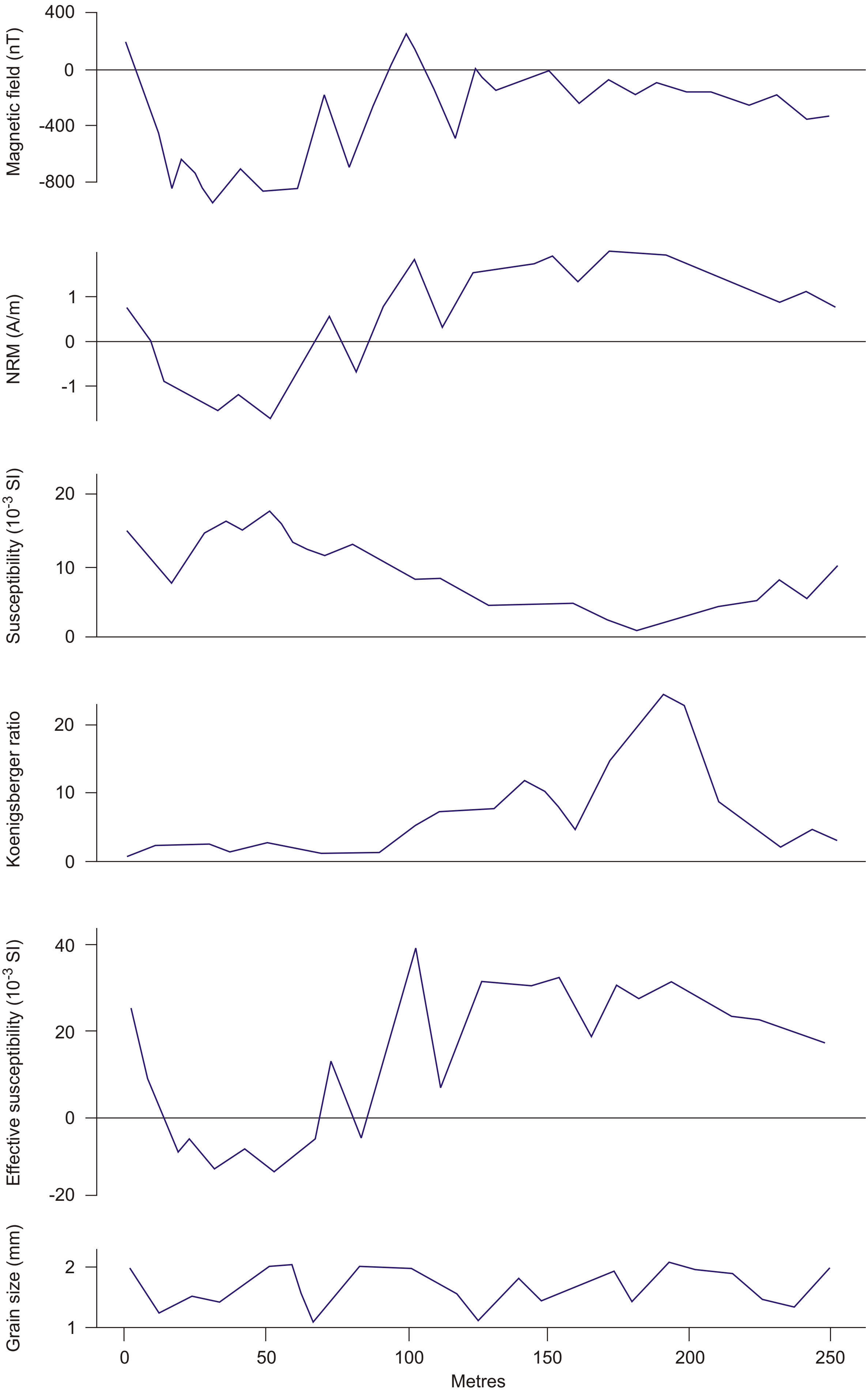


**Figure 4**

*Character of magnetic and rock properties near the base of the Rosny intrusion, zone A (Figure 2).*

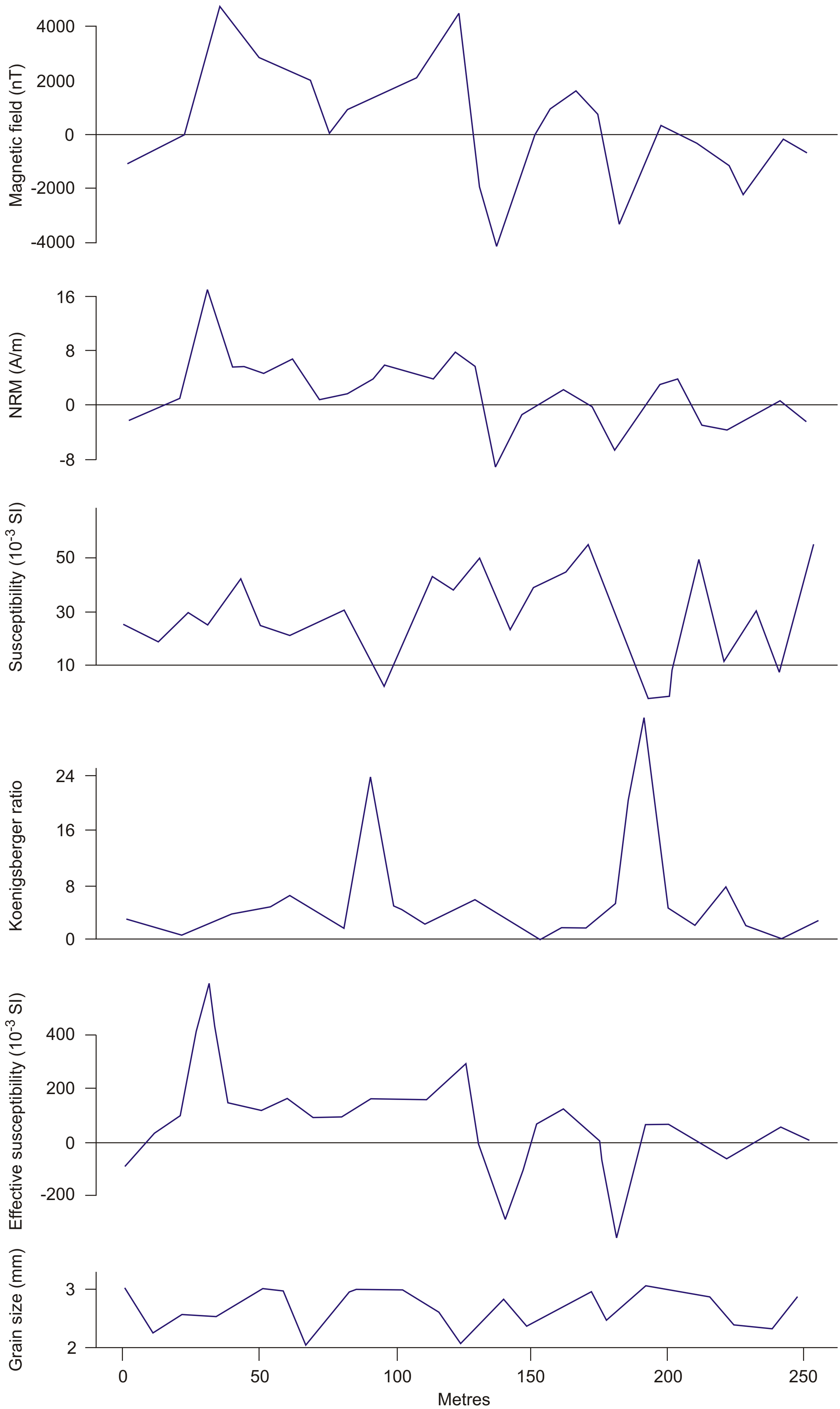


**Figure 5**

*Character of magnetic and rock properties in the upper zone of the Rosny intrusion, zone B (Figure 2).*

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