



MINERAL RESOURCES TASMANIA

DEPARTMENT of INFRASTRUCTURE, ENERGY *and* RESOURCES

Tasmanian Geological Survey Record 2003/10



Ground truthing of Western Tasmanian Regional Mineral Program geophysical data in the Granite Tor area

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Introduction

This report describes the results of four days of fieldwork in the Granite Tor area, between Cradle Mountain and Tullah in western Tasmania in January and early February 2003. The major geological feature in the area is the Granite Tor granite pluton, which is poorly known. Aeromagnetic and radiometric data, obtained as part of the Western Tasmanian Regional Minerals Program, provided new information about the area. The purpose of the work was to investigate the nature of a number of features apparent on the images derived from these data.

The area is strongly dissected, with the topography ranging from about 400 to 1000 metres above sea level. Because of the lack of roads in the area access was by helicopter, with a camp being established on a ridge at 397 420 mE, 5 377 700 mN¹, which provided a base for ground traverses. The camp location was chosen because it was relatively close to one of the features of interest identified on the radiometric coverage. The area is generally covered by low dense vegetation with sparse small areas of hummocky button grass or bare rock. The nature of the vegetation made ground traversing difficult and limited the area that could be reached from the camp during three days of fieldwork. A helicopter was used on a fourth day of fieldwork to reach various other locations where there was bare rock or vegetation sufficiently low to allow the helicopter to land.

Field stations were marked on a 1:20 000 scale topographic map, with the positions confirmed by a GPS instrument. A number of rock samples were collected for later thin section examination. Positions visited were chosen on the basis of features of interest on the radiometric coverage and the availability of a helicopter landing area near the outcrop.

Previous work

Ward (1908) examined the western contact between the Granite Tor granite body and the country rock mica schist and concluded that the granite dipped under the country rocks. He suggested that the exposed granite was part of a much larger granite mass. He also inferred a Devonian age to the body, based mainly on the grounds that the granite was undeformed. This suggestion was later substantiated by K-Ar dating on muscovite and biotite from the granite (McDougall and Leggo, 1965) which gave an average date of 359 ±5 Ma when using the dates recalculated for the decay constant of Steiger and Jäger (1977). A tin deposit on the southwest margin of the body near Bluff River was investigated in 1966 (Noldart and Jennings, 1966). The northern margin of the granite was mapped as part of the Mackintosh 1:63 360 scale map sheet (Barton *et al.*, 1966) and described very briefly in the explanatory report on that sheet (Collins *et al.*, 1981). The granite boundary for the remainder of the body depicted on the Burnie and Queenstown 1:250 000 scale geological map sheets (Williams and Turner, 1973; Corbett and Brown, 1975) was based on aerial photograph interpretation.

Alcoa of Australia Ltd carried out an exploration program in the Granite Tor area between 1978 and 1984 with tin and tungsten as target commodities. The main activities undertaken were stream sediment sampling, rock chip sampling with chemistry and petrological examination of the samples, limited geological mapping, an airborne magnetic survey and a photogeological interpretation of the area.

1 All grid references are in AMG coordinates and use the AGD55 datum.

Aeromagnetic and radiometric coverages and the location of the granite boundary

The known granite areas on the aeromagnetic image of the Granite Tor area (fig. 1) have a very uniform character, which is in contrast to the slightly more variable character shown by known areas of Precambrian country rocks. This contrast has been used to postulate a new location for the boundary between the granite and the country rocks where it was previously based on photogeological interpretation. This boundary was then checked against the combined radiometric image for K, Th and U (fig. 2). On this image known granite areas generally show as lighter colours than known areas of country rocks. This is consistent with the more radioactive character of granite compared to the quartzite and schist of the Precambrian country rocks.

In the southern part of the Granite Tor body the darker coloured areas on the radiometric image (fig. 2) generally fall outside the boundary suggested for the granite based on the magnetic image, thus supporting that interpretation. Near the postulated southern boundary there is a darker area between about 596 720 mE, 5 372 770 mN and 598 275 mE, 5 373 854 mN which appears inconsistent with that being an area of granite. This area is thickly vegetated lower ground without bare rock and it seems possible that there may be a thin layer of glacial material or a thicker soil layer masking the usual radioactive character of granite in the area. Alcoa collected two rock chip samples (Speijers, 1979; samples 12221, 12222) from within the area but unfortunately did not provide descriptions of them. Chemical analyses of these two samples, for a range of elements, had similar values to the other samples from definite granite areas so it is concluded that they were of granite.

During this investigation the area was viewed from the air but no outcrop was identified and no ground information obtained on its rock type. A helicopter landing was achieved a short distance south of the boundary postulated on the basis of the aeromagnetic image (at 397 360 mE, 5 372 720 mN) and a sample of quartzite was collected (MGT14), thus placing a limit on the southern extension of the granite in this area. A landing and sampling (MGT12) at 392 560 mE, 5 372 470 mN also confirmed that the area was Precambrian quartzite and beyond the southwest margin of the granite, as predicted from the aeromagnetic and radiometric images (fig. 1, 2).

In the western part of the Granite Tor body, between 393 350 mE, 5 377 260 mN and 394 390 mE, 5 375 690 mN, there are irregularly shaped areas that are darker on the radiometric image (fig. 2), suggesting some variation in the granite or some other rock type. Outcrop was not found within any of the dark areas but two samples were collected from nearby. The samples (MGT7 at 394 530 mE, 5 376 340 mN and MGT10 at 393 830 mE, 5 375 750 mN) are granite of a

similar character to elsewhere in the Granite Tor body. It seems likely that the darker areas are distinguished by having no outcrop and a thicker soil cover, which has masked the radiometric response of the underlying granite.

The Precambrian country rocks adjacent to the northwest boundary of the granite body have a similar light colour on the radiometric image (fig. 2) to that shown by the granite. The boundary of the granite in that area is known from the Mackintosh geological map sheet (Barton *et al.*, 1966). A structural reading in the High Tor area, at about 393 090 mE, 5 378 200 mN, indicates that the area was visited during the mapping and that the boundary there is reliable. Further south the granite boundary has not been mapped. The southward continuation of the light-coloured areas on the radiometric image may be due to the continuation of the same Precambrian country rock or might be caused by granite. The boundary drawn for this report relies on the slight change in character of the magnetic image between the granite and Precambrian country rock areas and may be incorrect. Geological mapping is required to establish the position of the granite boundary in that area with greater certainty.

Near the northern boundary of the Granite Tor body there is a small distinct area (around 396 000 mE, 5 379 000 mN) that is dark on the radiometric image, reflecting low radiometric counts (fig. 2), and which has a similar response to most of the country rocks. It occurs in an area shown as granite on the Mackintosh map sheet (Barton *et al.*, 1966). A ground traverse from the camp site confirmed that the area is quartzite and a sample (MGT1 at 395 930 mE, 5 378 740 mN) was collected. The quartzite is similar to quartzite in the Precambrian country rock of the area and forms slightly higher ground than the granite. On the basis of this ground information and the radiometric image, an area of Precambrian quartzite has been added to the geological map in this area. It may represent a remnant of the roof to the granite body.

Alcoa collected a granite rock chip sample (Speijers, 1979; sample 12202) from within this area, which appears to have been located in or close to the area visited and identified as Precambrian quartzite. It seems possible that the position from which this sample was collected was not precisely identified. A similar problem occurs with the position of one of the granite samples collected for age dating (McDougall and Leggo, 1965; sample GA1140 at 395 840 mE, 5 379 220 mN) which also falls in the suggested Precambrian area, although not close to a spot visited during this investigation. Again it is suggested that the sampling position may not have been precisely identified. Another possibility is that these samples were collected from an incised creek where the granite underlying the Precambrian quartzite is present as a small window not recognised in this study. On a ridge at 395 000 mE, 5 378 600 mN, a short distance to the west of this area, a sample of quartzite was collected

and analysed by R. G. Richardson in 1989 (MRT sample 401392) as part of a geophysical properties survey. The extent of this area of quartzite is not known but it is unlikely to be large because there is not a dark feature on the radiometric image (fig. 2) in that area.

Alcoa established a grid on the northwest margin of the granite and carried out geological grid-mapping (Speijers, 1980). They established that the granite dips at a low angle beneath pelitic sedimentary rocks and also noted that the granite margin is chilled and the sedimentary rocks are hornfelsed. Granitic dykes, occasionally with greisenous margins, were reported to penetrate the country rocks and that common small quartz veins may carry sparse patches of wolfram, bismuth and sulphide minerals.

The southeast margin of the granite has been interpreted based on the aeromagnetic (fig.1) and radiometric images (fig. 2), and also with more certainty on geological grid-mapping carried out by Alcoa (Speijers, 1980). The ground traverses indicate that the granite extends further south than shown on the Queenstown 1:250 000 scale geological map sheet (Corbett and Brown, 1975). The shape of the granite boundary in this area suggests that two major NNW-trending faults have down-faulted a block of Precambrian rock into the granite body, forming a graben structure. It is likely that the Precambrian rock in this block is only a shallow southward-dipping wedge overlying granite. In the northern part of the block the granite emerges from beneath the Precambrian rock near 400 809 mE, 5 377 694 mN. A rock chip (sample 13493) collected by Alcoa (Speijers, 1980) in the northern part of the Precambrian block at 401 369 mE, 5 377 437 mN is granite and suggests that there is a small granite window (too small to indicate on the map) there and that the Precambrian rocks form only a thin layer.

A small outlying area of granite has been postulated in Inglis Creek near 404 370 mE, 5 376 600 mN on the basis of a light area on the radiometric image (fig. 2).

Petrological character of the granite

Alcoa collected 43 rock chip samples from locations spread widely throughout the granite body (fig. 1) and provided petrological descriptions Speijers (1979). The rocks were described as ranging from adamellite to granite, with minor variation in texture. They ranged from equigranular to porphyritic and were generally medium-grained to coarse-grained and consisted of quartz, microperthitic K-feldspar, lesser amounts of plagioclase, and minor biotite and muscovite. Variations in the proportions of the feldspars marked the variation between granite and adamellite. Accessory minerals reported were zircon as inclusions in biotite, trace apatite associated with micas and rare garnet (present in only two samples). Tourmaline was reported as an accessory mineral in several samples and abundant in one. Hydrothermal alteration was

considered absent from about 75% of the samples and mostly restricted to sparse sericitisation of plagioclase in the remainder. The range of variation in the character of the granite reported is consistent with there having been a single intrusive phase.

Granite samples were collected from eleven localities as part of this work (fig. 1). Their character was found to be consistent with the description provided by Alcoa. In outcrop there was little variation in the grain size, which was generally coarse grained. Most outcrops were porphyritic, with K-feldspar phenocrysts ranging up to 30 mm, although outcrops often had a grey encrustation and it was difficult to establish the porphyritic character of the rock. In some areas the K-feldspar showed a very pale pink colour and the plagioclase had a pale green tint. Large crystals or patches of quartz crystals with a smoky dark colour were usually evident. Muscovite was present as prominent flakes in addition to biotite. The granite generally had a very uniform appearance with very few minor intrusions or xenoliths. Several small (<100 mm) fine-grained pale grey xenoliths were seen at only one locality (397 230 mE, 5 377 790 mN) and thin (<100 mm) aplitic dykes with pegmatitic patches were seen at 397 120 mE, 5 377 240 mN.

Thin section examination of the samples added little to the information provided by Alcoa. The biotite was generally altered to chlorite but where fresh was a deep red/brown colour. Muscovite was present as large primary flakes and as smaller crystals veining and replacing K-feldspar. Plagioclase crystals generally had cloudy sericitically-altered core regions.

Geochemistry of the granite

Alcoa analysed 35 rock chip samples, collected from widely spread locations (see Figures 1 and 2 for sample locations) over the outcrop area of the granite, for a range of elements in order to characterise the granites chemical composition (Speijers, 1979). Based on the average (see Table 1) of these analyses the granite was considered to be enriched in Sn, W and Li and depleted in Pb, Zr, Ti and Mg compared to two granite averages (exact reference not given).

Table 1

Average trace element composition (given as ppm) of rock chip samples from the Granite Tor pluton

Cu	6.9	F	1190	Zr	70
Li	125	Pb	5	Sn	23
Ta	<15	Mg	1030	Zn	33
W	11	Ti	490	Ga	21
Mo	<3	Bi	<5	Be	7

Three whole-rock analyses from the northern part of the body (see Figures 1 and 2 for locations), giving a more comprehensive set of major and trace elements, are also available and are reproduced here (Table 2).

The Tasmanian granite plutons can be grouped into suites with distinctive chemical, isotopic and petrographic character (McClenaghan, in prep.). The Granite Tor granite has been included in the Pieman suite, together with the Pieman and white Heemskirk granite bodies. The suites have been characterised as having been derived from partial melting of sedimentary (S-type) or igneous (I-type) source rocks (McClenaghan, in prep.) using the criteria of the restite model (White and Chappell, 1977; Chappell *et al.*, 1987; Chappell and White, 1992; Chappell, 1999). One of the criteria used to assign granite suites to the I-type or S-type grouping is their mineralogical composition. Al-rich minerals such as muscovite and garnet (very minor), that occur in the Granite Tor body, characterise it as an S-type granite. The moderately peraluminous character (aluminium saturation index (ASI) 1.152–1.216) of the analyses of the Granite Tor body also support the view that it is an S-type granite.

The Granite Tor granite, as for the other granites in the Pieman suite, is felsic and can be distinguished as crystal fractionated on the basis of its major and trace element composition. Chappell (1999) has suggested that crystal fractionated granites can be distinguished from unfractionated granites by having less than 50 ppm Sr. On this basis the Granite Tor body is strongly crystal fractionated, as the highest Sr value is only 15 ppm (Table 2). The high Rb and low Ba values (Rb >453 ppm and Ba <74 for this body; Table 2) support this view as significant feldspar fractionation is indicated by Rb concentrations above 250 ppm and Ba below 200 ppm (Blevin and Chappell, 1992). The relatively low Y, Ce and Th values for the granite body (Table 2) are also consistent with fractionated S-type granite (Chappell, 1999).

Economic potential of the granite

The Granite Tor granite body has a high mineralisation potential as strongly crystal fractionated granites can be considerably enriched in incompatible trace elements (Blevin and Chappell, 1992).

The type of ore-elements associated with a granite suite can be related to its oxidation state (Blevin and Chappell, 1992). Concentration of Sn in the melt by fractional crystallisation would be favoured for less oxidised granite suites. S-type granite suites are ilmenite bearing and not strongly oxidised, which suggests that the strongly fractionated S-type Granite Tor body could be enriched in Sn. This is supported by Alcoa, which considered the body to be enriched in Sn compared to various granite averages based on the average of the rock chip analyses (Table 1). A tin deposit on the southwest margin of the body near Bluff River (Noldart and Jennings, 1966) confirms the potential of the body for this commodity. Cassiterite is described as occurring sporadically in a series of small quartz tourmaline veins and narrow greisen veins, which strike in a northerly direction. They are contained within weathered medium-grained

Table 2

Whole-rock analyses of samples from the Granite Tor Granite pluton. Samples WT71, WT72 from Chappell (pers. comm., 2001), sample 401393 Mineral Resources Tasmania.

Field No.	401393	WT71	WT72
AMG mE	397600	397100	396200
AMG mN	5377900	5377800	5378100
SiO ₂	76.59	75.56	75.07
TiO ₂	0.09	0.08	0.05
Al ₂ O ₃	12.89	13.07	13.55
Fe ₂ O ₃	0.35	0.41	0.38
FeO	1.15	0.90	0.60
MnO	0.04	0.04	0.04
MgO	0.12	0.11	0.07
CaO	0.37	0.31	0.33
Na ₂ O	3.06	3.08	3.48
K ₂ O	5.07	4.73	4.56
P ₂ O ₅	0.11	0.16	0.18
H ₂ O ⁺	0.55	0.88	0.76
H ₂ O ⁻		0.25	0.22
CO ₂	0.21	0.43	0.25
SO ₃ total	0.03		
S		<0.02	<0.02
LOI	0.64		
Total	100.63	100.01	99.54
ASI	1.152	1.216	1.204
Ag	<5		
As	7		
Ba	73	36	18
Ce	41	23	13
Co	<5		
Cr		<1	<1
Cu	16	5	
Ga	13	20.4	22.6
La	14	8	4
Mo	6		
Nb	11	12.5	15.5
Nd	12		
Ni	7	<1	<1
Pb	19	28	20
Rb	460	454	491
Sc	<5		
Sn	10		
Sr	14	15	8
Th	10	11.6	8.8
U	11	5	23
V	<5	3	<1
Y	23	30	21
Zn	14	40	24
Zr	50	66	43

muscovite granite, which is probably a marginal phase of the Granite Tor body.

The strongly fractionated nature of the granite also points to potential for W mineralisation, which is mostly enhanced by crystal fractionation even though it shows little dependence on the oxidation state of the granite magma (Blevin and Chappell, 1992). This is

supported the by the finding of Alcoa that W was enriched in the body compared to various granite averages, based on the average of the rock chip analyses (Table 1).

Alcoa targeted three types of tin deposit (Speijers, 1978):

- The first target was quartz vein and greisen-type mineral occurrences within the main Granite Tor body and any associated cupola-like bodies in the country rocks up to a kilometre from the granite boundary.
- The second target was replacement bodies in rock types capable of neutralising highly acid mineralising solutions emanating from the Granite Tor body, such as carbonates. Such bodies could be at some distance from the granite but connected to it by mineralising fractures. The common association of the magnetic minerals pyrrhotite and magnetite was considered to provide good magnetic target features for this type of deposit.
- The third target was skarn-type mineralisation where the Granite Tor body intruded carbonate rocks. Significant quantities of magnetite and the occurrence of garnet and fluorite would be expected with this type of mineralisation.

The potential of the granite for Sn mineralisation was confirmed by the detection of a number of catchment areas anomalous in Sn within the granite body (Speijers, 1979). Calc-silicate horizons interbedded with quartzite and pelite were identified in the graben structure on the southeast margin of the granite near the Bluff River (Speijers, 1980), suggesting that there might be potential for skarn or replacement-type tin deposits in that area. Alcoa also identified twenty-four magnetic anomalies in country rocks near the margin of the granite (Speijers, 1978) which indicate potential for skarn deposits but these were only partially investigated.

Conclusion

The Granite Tor pluton is a coarse-grained, porphyritic, biotite-muscovite granite. The uniformity of texture and composition suggests that it intruded in a single event. Small areas of country rocks overlying the granite in several areas suggest that the current outcrops are close to the roof of the intrusion. The granite is a strongly fractionated S-type granite and has a high potential for tin and tungsten mineralisation. The locations of the margins of the granite are poorly known, particularly to the west and southwest. The composition of the country rocks is poorly known although some calc-silicate horizons interbedded with quartzite and pelite were identified in one area. Major NNW-trending faults in the eastern part of the granite body have produced a graben structure.

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[29 May 2003]

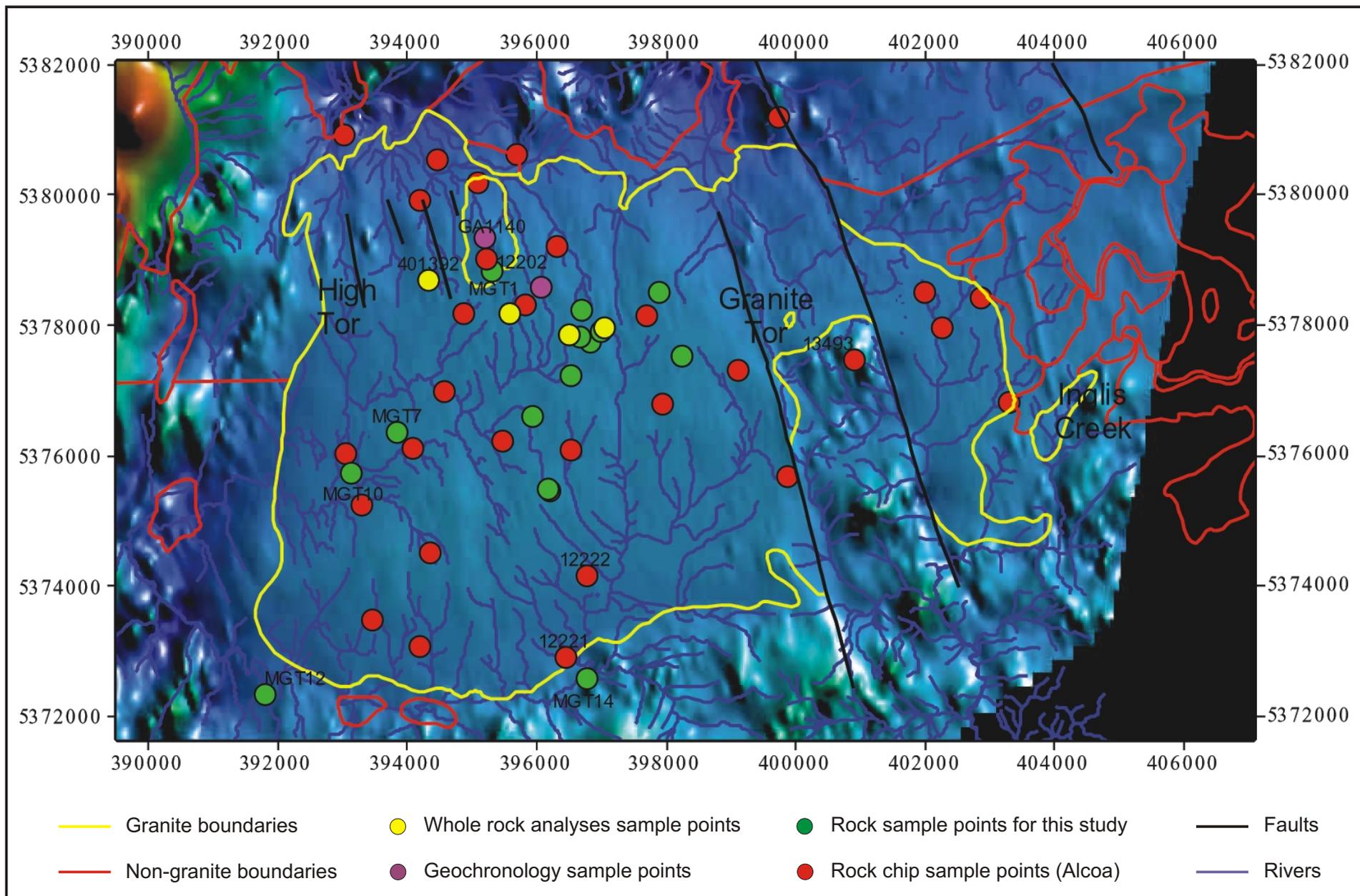


Figure 1. Total magnetic intensity image of the Granite Tor area

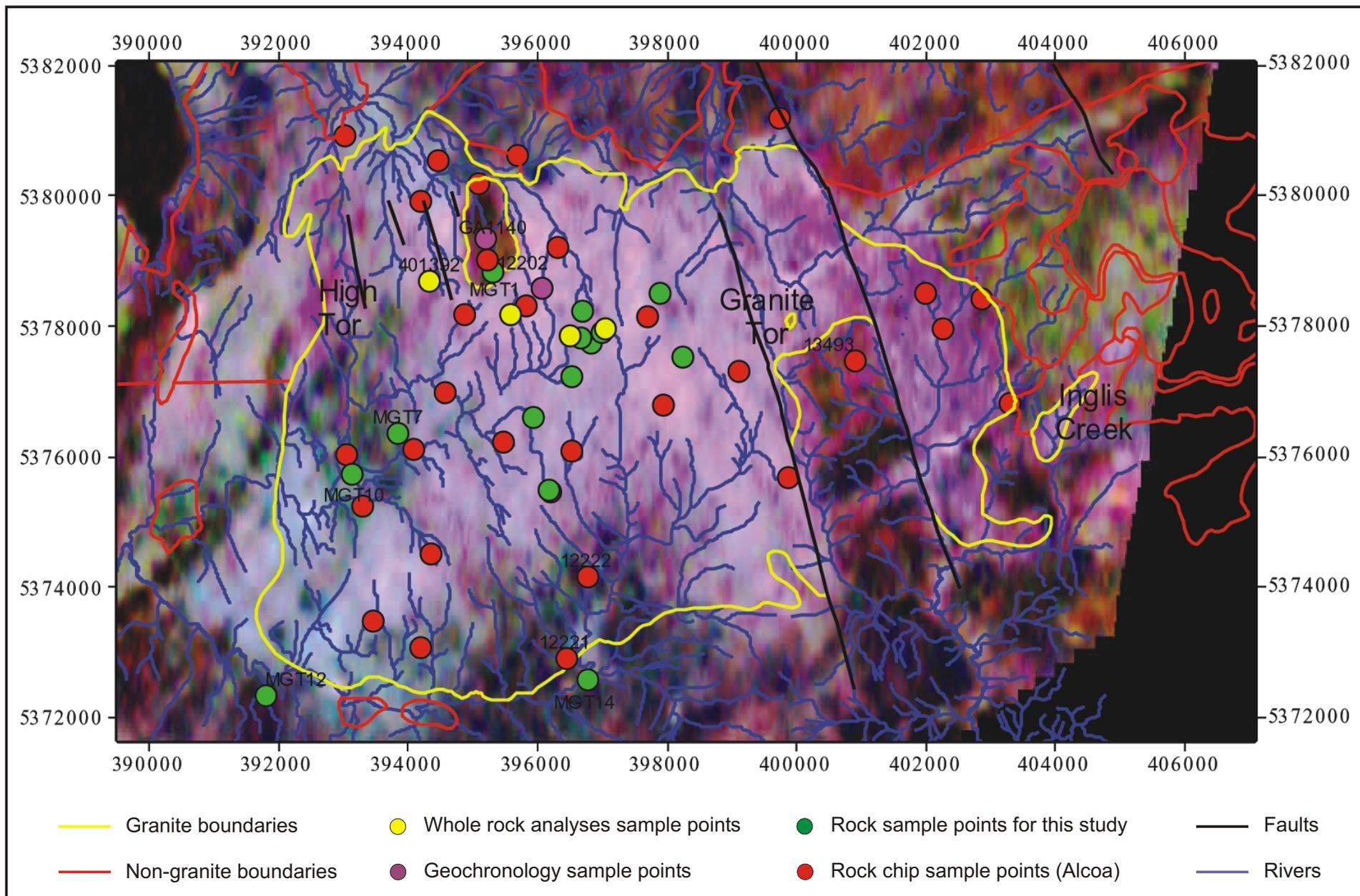


Figure 2. Radiometric image K (red), Th (green) and U (blue) for the Granite Tor area.

Appendix 1

Locations of samples collected during this project

<i>Field number</i>	<i>Registered number</i>	<i>mE</i>	<i>mN</i>
MGT1	R00665	395927	5378736
MGT2	R00666	397119	5377197
MGT3	R00667	397409	5377684
MGT4	R00668	397234	5377779
MGT5	R00669	397276	5378155
MGT6	R00670	397552	5377857
MGT7	R00671	394527	5376340
MGT8	R00672	394527	5376340
MGT9	R00673	394527	5376340
MGT10	R00674	393828	5375745
MGT11	R00675	396765	5375508
MGT12	R00676	392557	5372466
MGT13	R00677	396533	5376578
MGT14	R00678	397358	5372717
MGT15	R00679	398769	5377478
MGT16	R00680	398425	5378418