7. Cross-Correlation of Magnetics with Potassium-40

Image processing packages often rely on visual comparison of two data sets through the intensifying method, where the comparison is made by controlling the brightness of one data set by the other. Cross-correlation is a statistical method of comparing two data sets and it has the advantage of revealing subtle relationships that are usually lost in the intensifying method

7.1 Hypothesis

Aeromagnetic and radiometric data sets are often used in the early stages of exploration and so cross-correlation of the data can be investigated as a means of identifying exploration targets. The hypothesis for identifying targets assumes that some mineral deposits and in particular porphyry copper deposits: -

- contain magnetite
- have associated potassic alteration zoning

and that:

- even though radiometrics only sense the surface or top few centimetres of soil, the concentration of potassium-40 counts will reflect the structure of deeper sources.
- there will be a correlation between the magnetic data set and the potassium-40 data set at the location of mineralization.

7.2 Porphyry Copper Alteration Zoning Model

The alteration and mineralization model used principally for this hypothesis is the Lowell and Guilbert (1970), model. This genetic model, Figures 7-1 and 7-2, is based on the San Manuel-Kalamazoo copper-molybdenum porphyry deposit. Also discussed are variations from the Lowell and Guilbert (1970) model.

7.2.1 Potassic Zone

The alteration mineral assemblages of the potassic core are typically K-feldspar, sericite and quartz for the inner core and quartz, biotite and K-feldspar, with or without sericite and anhydrite for the potassic zone. For the San Manuel-Kalamazoo deposit, magnetite in the potassic core is rare or absent (Lowell and Guilbert, 1970). Sillitoe, (1979), states that for a number of gold rich copper porphyries (Au > 0.4gm/ton), "gold is normally present in potassium silicate alteration, which commonly carries an unusually high magnetite content". The magnetite content for gold rich porphyries is stated as being between six and ten volume percent. In addition, molybdenum grades and gold grades of copper porphyries showed an inverse relationship, although there are significant exceptions to this, Bajo de la Alumbrera, Argentina and Ok Tedi, PNG (Sillitoe, 1979). Bajo de la Alumbrera has significant grades of copper, gold and molybdenum with ten volume percent magnetite in the potassic core. Ok Tedi also has significant grades of copper, gold and molybdenum but magnetite is scare except in skarn ore peripheral to the stock (Sillitoe, 1979). Therefore magnetite may or may not be present in the potassic zone.

7.2.2 Phyllic Zone

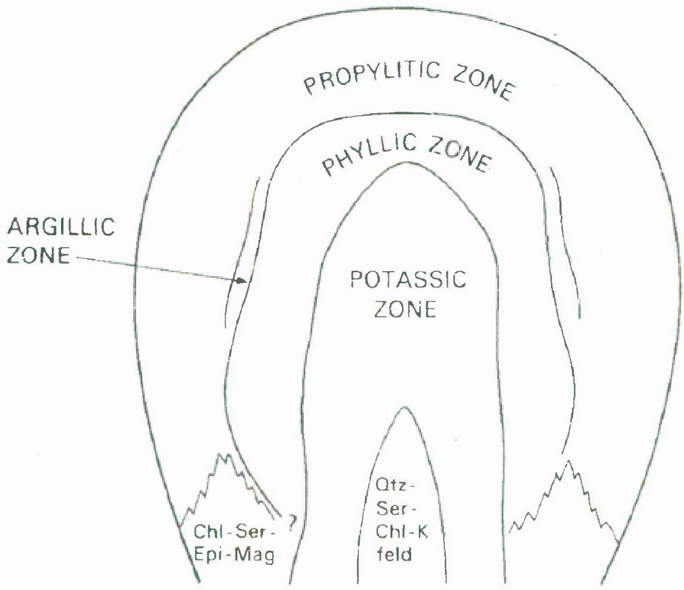
The phyllic zone is characterized by the alteration minerals quartz, sericite, pyrite, hydromica and minor chlorite. As with all alteration boundaries in porphyry systems, the transition from potassic alteration to phyllic alteration is generally gradational over thirty metres or so (Lowell and Guilbert, 1970). The ore shell is situated across the boundary of the potassic zone and the phyllic zone. The ore minerals are typically chalcopyrite, ± bornite and in association with magnetite and quartz (Sillitoe, 1979, Corbett and Leach, 1994). It has to be noted that, Lowell and Guilbert (1970) make no reference of magnetite co-existing with the copper ore and San Manuel-Kalamazoo is a copper-molybdenum porphyry system. Of the twenty-seven porphyry systems compared by Lowell and Guilbert only Sanford, Arizona, has any mention of magnetite and then only in the inner alteration zone.

7.2.3 Argillic Zone

The argillic zone is not always present, but when present clay minerals are prominent (Evans, 1993).

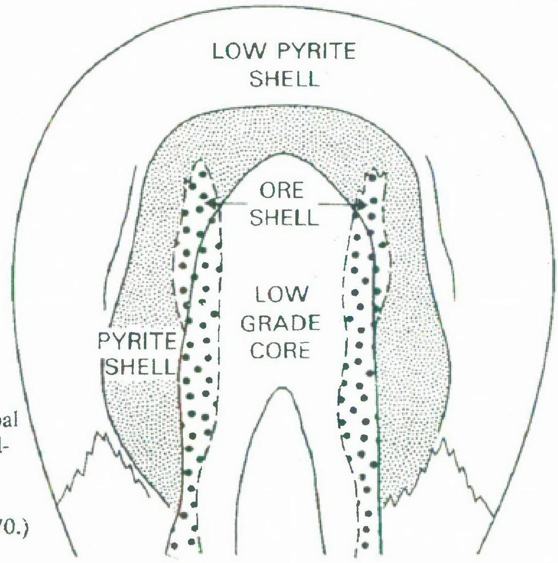
7.2.4 Propylitic Zone

This zone is always present. The mineral assemblage is chlorite, pyrite, calcite, epidote (Evans, 1993). Lowell and Guilbert (1970) state that chalcopyrite is rare and pyrite constitutes one to three volume percent of the rock and that, magnetite substitutes for pyrite near the base of the ore body. This outermost zone grades into the country rock.



Hydrothermal alteration zoning pattern in the Lowell-Guilbert model of porphyry copper deposits. (After Lowell & Guilbert 1970.)

Figure 7—1: Alteration Zoning in the Lowell and Guilbert model of porphyry copper deposits.



Schematic diagram of the principal areas of sulphide mineralization in the Lowell-Guilbert model of porphyry copper deposits. Solid lines represent the boundaries of the alteration zones (After Lowell & Guilbert 1970.)

Figure 7—2: Principal areas of sulphide mineralization in the Lowell and Guilbert porphyry copper model.

7.3 Summary

Corbett and Leach (1994), summarizes the alteration and mineralization of the Lowell and Guilbert model as:

- Quartz core quartz sericite, chlorite, K-feldspar
- Potassic Zone quartz, K-feldspar, biotite, ± sericite, ± anhydrite.
- Phyllic Zone quartz, sericite, pyrite.
- Propylitic Zone chlorite, epidote, carbonate, adularia, albite.

And the sulphide zoning within the shell-like alteration as:

- Ore zone pyrite, chalcopyrite, magnetite on the periphery of the potassic alteration in contact with the phyllic alteration.
- Low-grade core central lower grade equivalent to the ore shell.
- Pyrite zone pyrite>>chalcopyrite which rims the ore shell within the phyllic alteration.

- Low pyrite shell outermost.

This hypothesis and the processing associated with it may not be applicable to all styles of copper, gold and base metal mineralization and may also return a positive response where unassociated magnetic anomalies and potassium-40 anomalies of similar wavelength co-exist. In addition, if the potassic alteration is buried there may not be a potassium anomaly recorded.

The advantage of this processing is that the resultant data set is easily interpreted as it contains only areas that correlate, anti-correlate and have no correlation.

8 Goonaloom Creek: Case Study

The examples shown below are for the total magnetic intensity (TMI) cross-correlated with potassium-40 and the first vertical derivative of the total magnetic intensity cross-correlated with potassium-40.

Verification of the results is by borehole result of the North Ltd., drilling program on the Goonaloom Creek prospect and the position of previous or current mining activity as shown on the Maryborough 1:250000 geological map sheets.

8.1 Goonaloom Creek Survey

8.1.1 Total Magnetic Intensity Cross-Correlated with Potassium-40

The Perry Fault is a regional fault system that trends northwest through the area covered by data set. Features A, B and C are on a trend that intersects the Perry Fault. Interpreted from the first vertical derivative of the total magnetic intensity data are a number of faults with trends parallel to the Perry Fault and anti-parallel to it. Intersecting lineations or regional structures are conducive to the formation of intrusives that could lead to the development of porphyry systems during times of subduction at continental margins.

Feature A of Figure 8-1, is an annular correlation with its central correlation low at 4019000mE, 7133200mN. The central low correlation can be interpreted as the potassic core of a porphyry system using the Lowell and Guilbert (1970) model of hydrothermal alteration zoning patterns for porphyry style mineralization where magnetite and silica flooding has not occurred. Although the potassium-40 counts will be high in this region, the lack of magnetite will lead to a low correlation.

The annular correlation high around the central zone can be interpreted as the phyllic/propylitic zone containing magnetite, at depth and potassic alteration (Evans, 1983), leading to a strong correlation.

Drill holes S23, S24 and S25 are in the approximate position to encounter the ore shell using the Lowell and Guilbert model. Drill hole S25 would be at the approximate inner limit of the ore shell and drill holes S23 and S24 are at or about the outer limit.

The annular anomaly is astride the inferred geological boundary (Maryborough SG56-6, 1992) between the Triassic Rtn_s and Rtn_v lithostratographic units with, Rtn: andesite, sandstone, siltstone, shales, Rtn_v andesite flows, pyroclastics and Rtn_s volcanoclastic sandstone, siltstone and shales.

The andesite flows, pyroclastics and volcanic sandstones would indicate that erosion has been minimal since the intermediate volcanics ceased. As the typical depth of emplacement is typically two to five kilometres, it can be inferred that the porphyry system has not been unroofed and could be still at some depth.

Feature B appears to be the lower half of an anomaly similar to feature A. The correlation minimum at 405000mE, 7139000mN, is an outcrop of a microdiorite, microgranodiorite unit, Jki. Geological mapping does not suggest this to be the potassic core of a porphyry system.

Feature C is only partly revealed on this survey and appears to be structurally connected to Features A and B. This area could warrant further investigation.

Feature D is at the location of the abandoned Boubijan copper-gold prospect. Drill holes S21, S4 intersect this anomaly of weak mineralization.

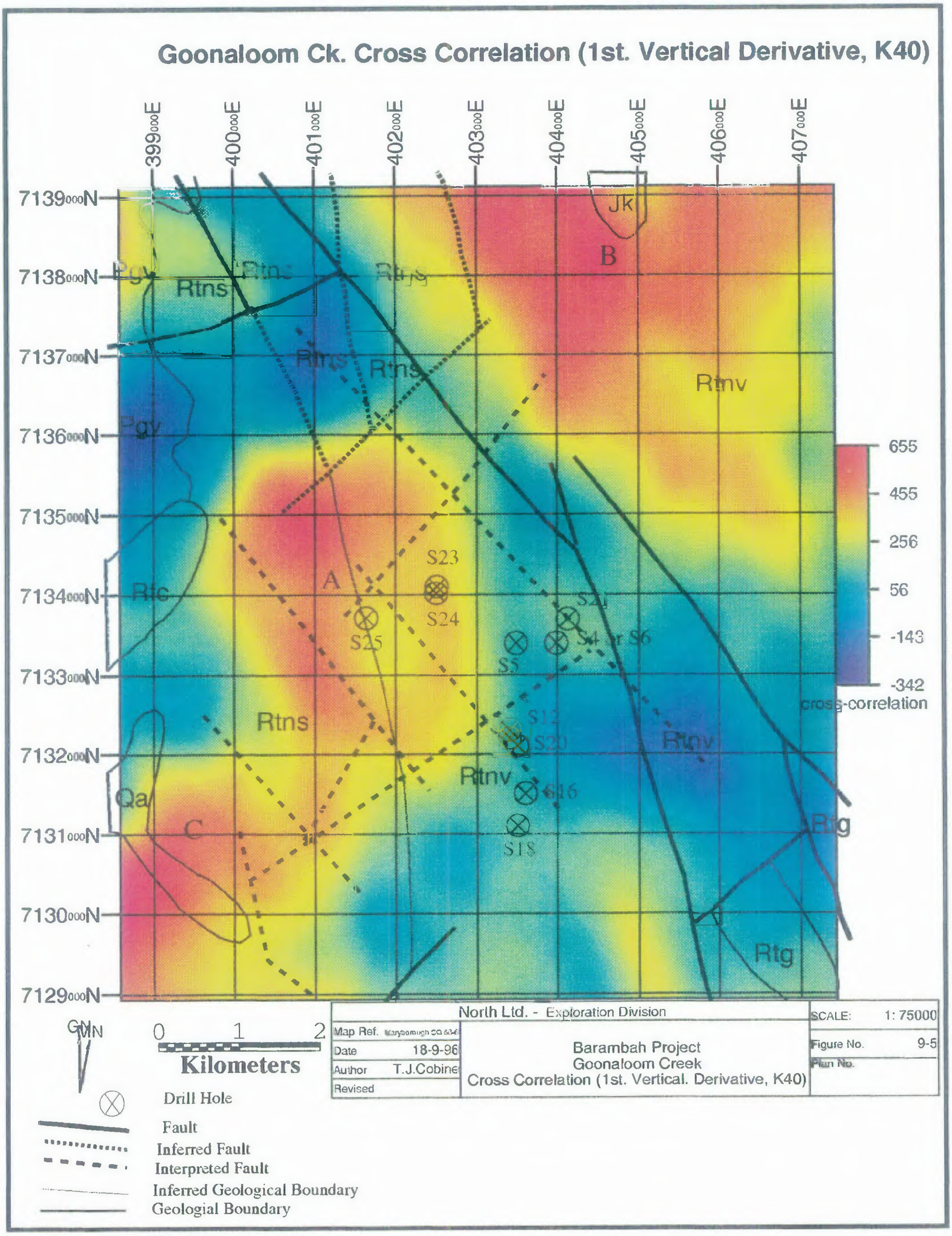


Figure 8—1: Goonaloom Creek; cross-correlation of TMI and potassium-40 counts; faults are inferred from first vertical derivative of the TMI.

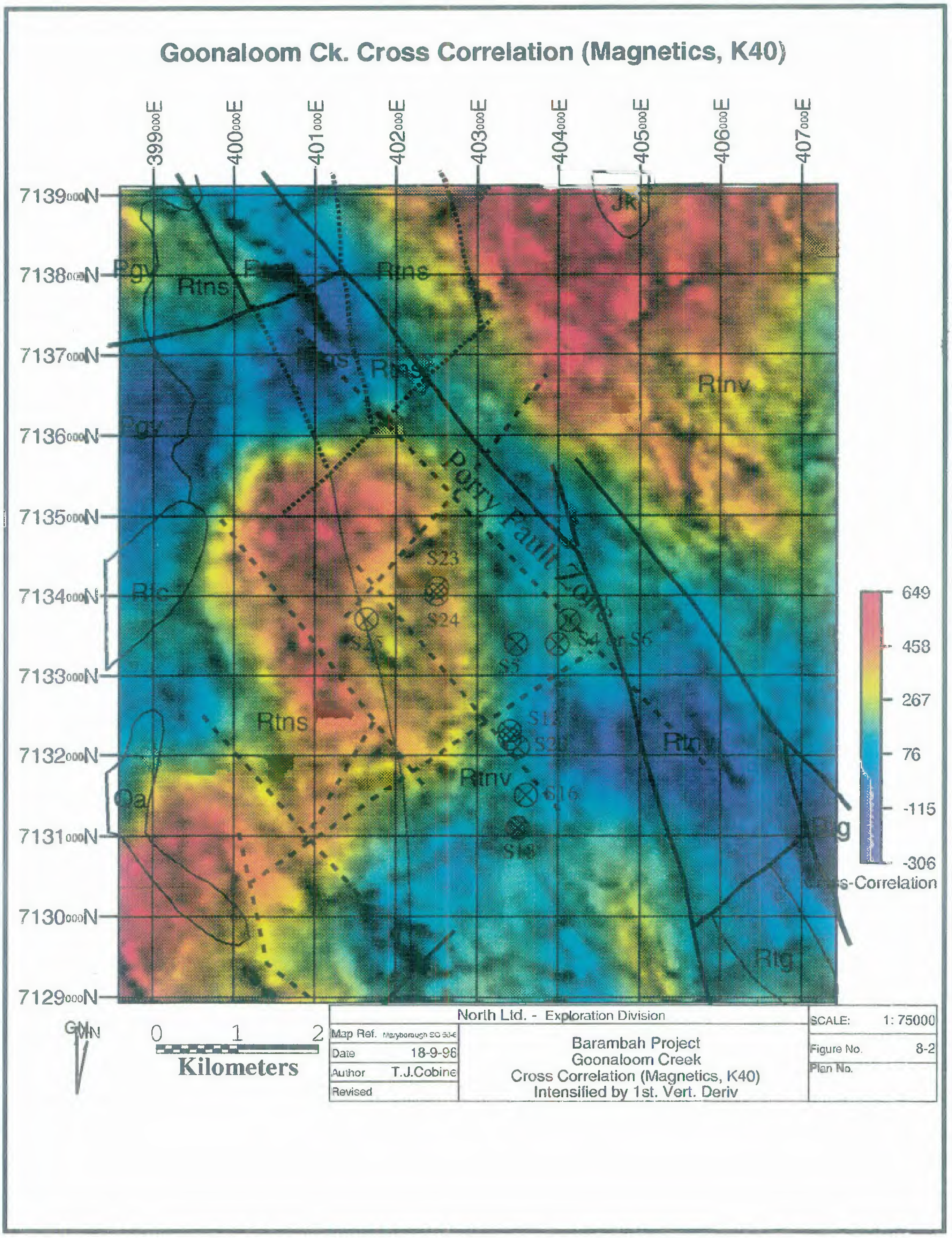


Figure 8—2: Goonaloom Creek; cross-correlation of the TMI with potassium-40 counts; intensified by the first vertical derivative of the TMI; faults inferred from the first vertical derivative data.

8.1.2 First Vertical Derivative Cross-Correlated with Potassium-40

The first vertical derivative of the total magnetic intensity enhances the near surface features or short wavelength information in the magnetic data set and attenuates the deep features or long wavelength information. Cross-correlation of the first vertical derivative of the total magnetic intensity and potassiun-40 will indicate the areas close to the surface that may be mineralized.

Features A, B, C and D are segments of the annular Feature A in the cross-correlation of the TMI with potassium-40. These areas would warrant further investigation.

Feature E is the Boubijan copper-gold prospect.

Feature F is an anomaly related to a weak correlation in the data for the cross-correlation of the TMI and potassium-40 data.

Features G and H are located on intersecting faults. Feature H could be the result of mineralized fluids moving along the fault from the annular Feature A in Figure 8—3. As features B and H appear linked, this could be the result of fluid movement along the fault system. Feature G is related to different structures then Feature E and may not have been part of the mineralizing event but instead related to other events that have occurred in the area.

North Ltd. drilling to date has only intersected minor mineralization (T. Hoschke pers. comm., 1996).

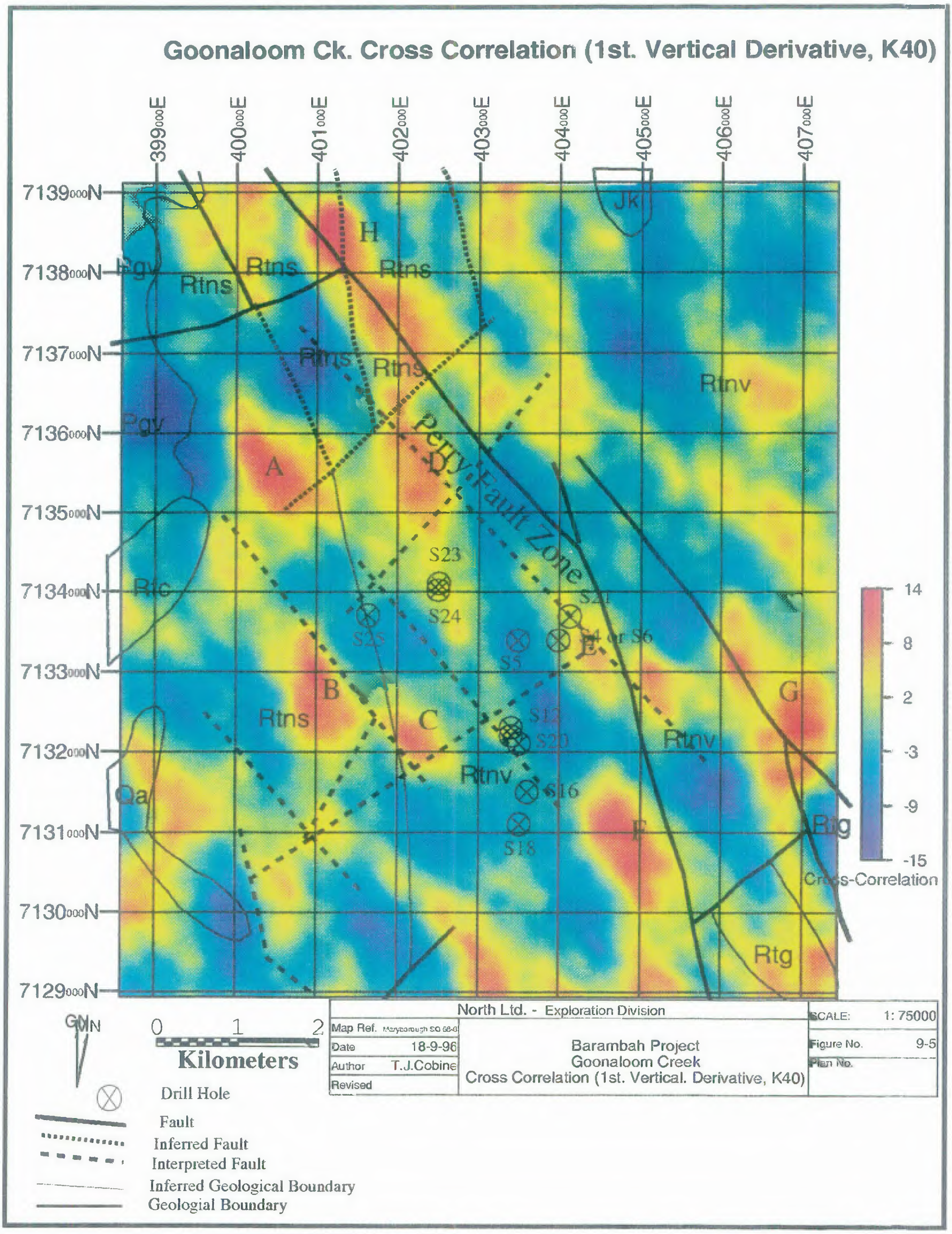


Figure 8—3: Goonaloom Creek; Cross-correlation of the first vertical derivative of the TMI with potassium- 40