Roseby Cu-Au Deposits

PREAMBLE

The Roseby deposits represent a cluster of copper-gold and copper-only mineral resources from twelve separate mineralized zones that occur over an approximate 20km north-south oriented zone in the Dugald River area.

The deposits represent different mineralisation styles located within the broad vicinity of the Mount Roseby Fault Zone. Mining of the deposits has not occurred, with the most recent mining study, produced in 2018, envisaging extraction via open pit mining from five of the mineral resources.

LOCATION

Geological Domain

Mary Kathleen Domain (Figs 17.1, 17.4).

Co-ordinates

Lat: 20° 13' 12" S Long: 140° 08' 24" E

MGA Zone 54: 410,600 E, 7,763,400 N

(the centre of an approximate 20km long north-south zone hosting the deposits)

NATURE OF MINES

Mined Commodities

Mining has not occurred at Roseby, however the published Mineral Resource includes copper and gold.

Mining Method & Depth of Mining

The 2018 Feasibility Study presented for the Roseby deposits (termed the Eva Copper Project by Copper Mountain Mining Corp-CMMC, 2018) envisages open pit extraction of Cu-Au or Cu-only ores from five deposits over an approximate 12-year mine life (including two years of stockpile rehandling). Conventional open pit mining methods would be employed.

The Little Eva pit, which contains 83% of the ore reserve (by tonnage) will extend to approximately 250m below surface (Fig. 17.2) in the Central Domain.

PRODUCTION AND RESOURCES

Mineralised Bodies

The Roseby deposits comprise 12 mineral resources (Table 17.1), individually ranging from 0.7Mt (Charlie Brown) to 132Mt (Little Eva), with a copper grade between 0.36% to 0.66% Cu.

Dimensions and Orientation of Mineralised Bodies

Only the larger deposits, or those for which there is information available in the 2018 Feasibility Study, are discussed here:

Little Eva

Little Eva (Fig 17.2) comprises a set of variably dipping 20-50m thick tabular copper-rich bodies within a broader halo of low grade copper (<0.15% Cu). The bodies increase in grade to the north from >0.15% Cu in the Southern domain to >0.5% Cu in the Central and Northern domains. The dip of the bodies increase from shallowly (20°) west-dipping in the south, to 65 ° west-dipping in the central zone, to 55° east-dipping in the northern zone. The number of lenses decrease (or coalesce) towards the north.

Turkey Creek

The Turkey Creek mineralisation (Fig 17.3) is a 50-70m thick north-south trending steeply east-dipping (50-80°) unit that extends over a strike distance of approximately 1200m, with the northern 200m folded into a southeast plunging synform. The highest grade mineralisation (>0.2% Cu) forms lower and upper zones with a lower grade core between them.

Lady Clayre

The Lady Clayre deposit (Fig 17.5a) is located on the flanks of an outcropping syncline cored by schist and slate. The multiple mineralized bodies dip steeply (70-80°) towards the northwest. The bodies occur over approximately 600m strike length

Ivy Ann

The Ivy Ann deposit (Fig 17.5b) comprises a steeply (80°) east-dipping tabular body of approximately 500m strike length. It is hosted within amphibolite and psammite. The Ivy Ann deposit is located approximately 25 southeast of the Little Eva deposit, and is not located on the base maps in this chapter.

Bedford

The Bedford deposit (Fig 17.5d) is comprised of a north and a south body. They are both approximately 800-1000m long, although the proposed pit outlines from CMMC (2018) only include between 250-500m strike length of

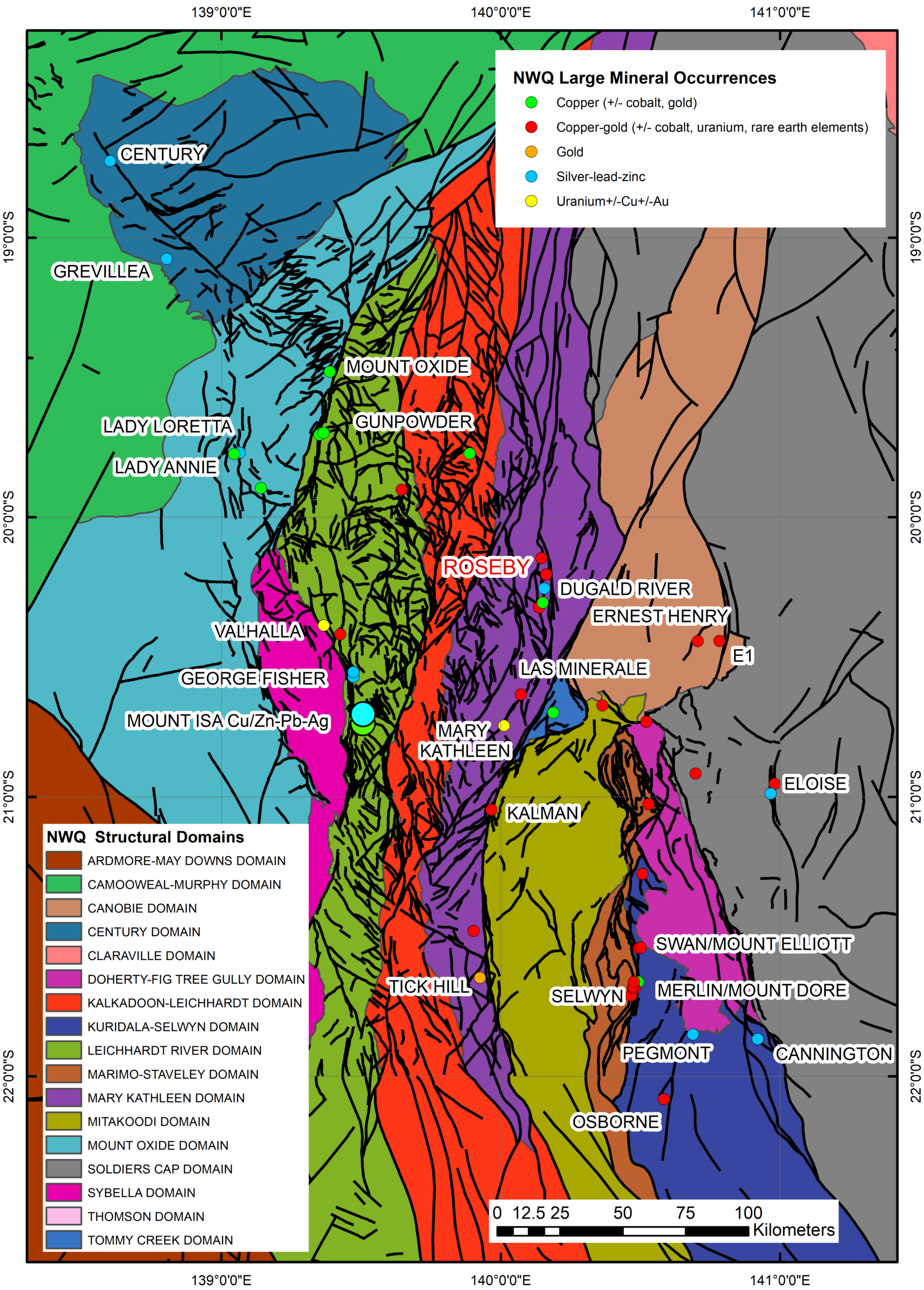


Figure 17.1: Location of the Roseby deposits shown with respect to the Mount Isa Structural Domain Map from the 2010 NWQMEP GIS

each body. The mineralisation plan and cross -sections indicate they are both comprised of several thin (10-25m thick) steeply west-dipping (65-80°) lenses.

Blackard

The Blackard deposit (Fig 17.5c) has a slightly different geometry to the other deposits in the Roseby project in that it comprises a relatively flat-lying shallow blanket (within the “oxidized metasedimentary zone”), which in the western portion of the deposits turns to dip steeply to the west where it becomes the sulfide zone below the weathering profile.

Production

There has been no production from the deposit. The 2018 Feasibility Study (CMMC, 2018) envisages a life-of-mine (LOM) average annual throughput of 9.75 Mtpa, with a total LOM production of 428,000t of copper and 203,000oz of gold over a 12 year project life.

Mineral Resources & Ore Reserves

Mineral Resources and Ore Reserves have been reported at a various times. The Mineral Resources are tabulated in Table 17.1. As a summary, they include:

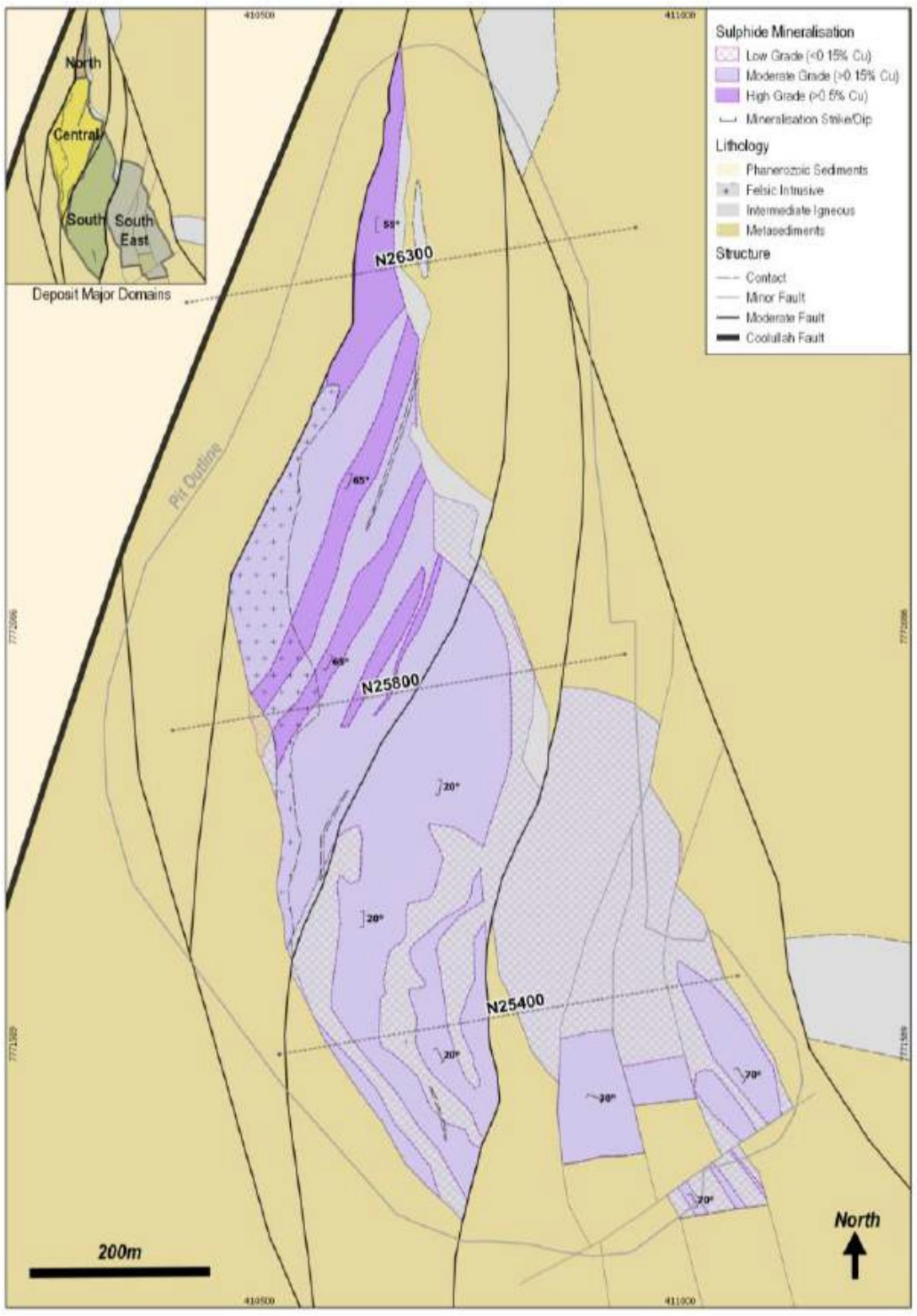
- a copper-gold resource of 173Mt @ 0.37% Cu and 0,07 g/t Au, and
- a copper resource of 157Mt @ 0.54% Cu.

The Ore Reserve, published in the 2018 Feasibility Study (CMMC, 2018) and based only on the copper-gold resource, comprised:

Table 17.1: Tabulated Mineral resource figures for the Roseby deposits.

Deposit	MEASURED			INDICATED			INFERRED			TOTAL		
	Tonnes (Mt)	Cu (%)	Au (g/t)	Tonnes (Mt)	Cu (%)	Au (g/t)	Tonnes (Mt)	Cu (%)	Au (g/t)	Tonnes (Mt)	Cu (%)	Au (g/t)
Mineral Resources as published in 2018 Feasibility Study												
Little Eva	56.7	0.39	0.07	65.2	0.34	0.07	10.3	0.33	0.07	132.1	0.36	0.07
Turkey Creek	6.9	0.47	-	6.9	0.44	-	5.3	0.39	-	19.1	0.44	-
Bedford	-	-	-	3.0	0.54	0.14	0.8	0.42	0.14	3.8	0.51	0.14
Lady Clayre	5.1	0.42	0.17	2.2	0.4	0.18	5.0	0.36	0.15	12.3	0.39	0.16
Ivy Ann	1.1	0.38	0.07	4.0	0.35	0.08	1.0	0.32	0.07	6.1	0.35	0.08
									Sub-total	**173.5**	**0.37**	**0.07**
*Mineral Resources as published in August 2012**												
Blackard	28	0.54	-	49	0.47	-	19.3	0.49	-	96.6	0.49	-
Scanlan	-	-	-	18	0.65	-	3.8	0.6	-	22.2	0.64	-
Longamundi	-	-	-	-	-	-	10.4	0.66	-	10.4	0.66	-
Legend	-	-	-	-	-	-	17.4	0.54	-	17.4	0.54	-
Great Southern	-	-	-	-	-	-	6.0	0.61	-	6.0	0.61	-
Caroline	-	-	-	-	-	-	3.6	0.53	-	3.6	0.53	-
Charlie Brown	-	-	-	-	-	-	0.7	0.4	-	0.7	0.40	-
** Blackard Mineral Resource figures are from update in October 2019*									***Sub-total***	**156.9**	**0.54**	**-**

Little Eva Deposit Geology



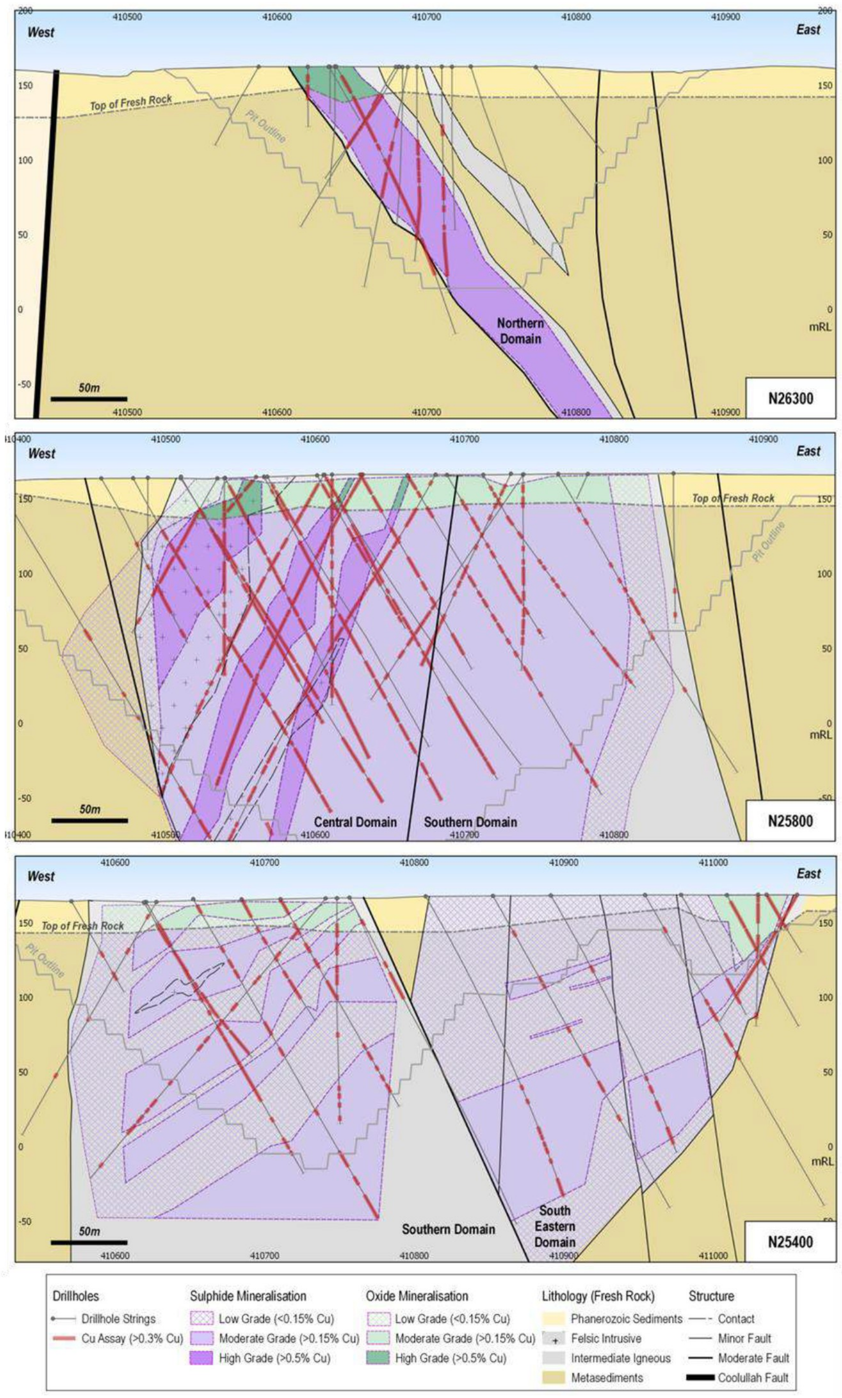


Figure 17.2: Geological plan and set of serial cross-sections from the Little Eva deposit. They demonstrate the narrowing of the orebody to the north, and the generally west-dipping nature of the higher grade zones (darker pink) in the southern and central domains, which change to east-dipping in the northern domain. From CMMC (2018)

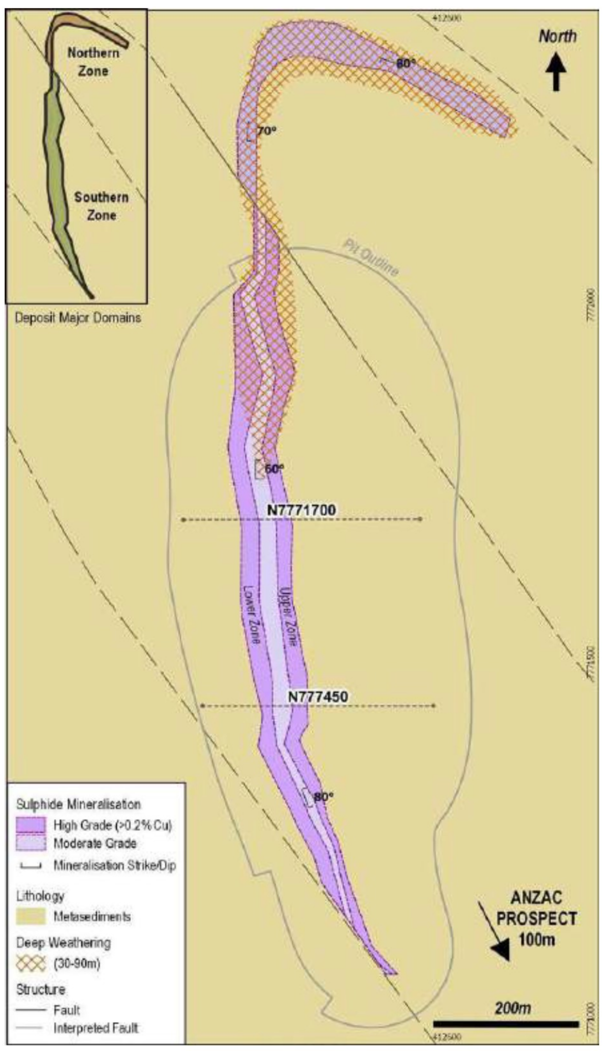
- 117Mt @ 0.40% Cu, 0.07 g/t Au.

GEOLOGICAL SETTING

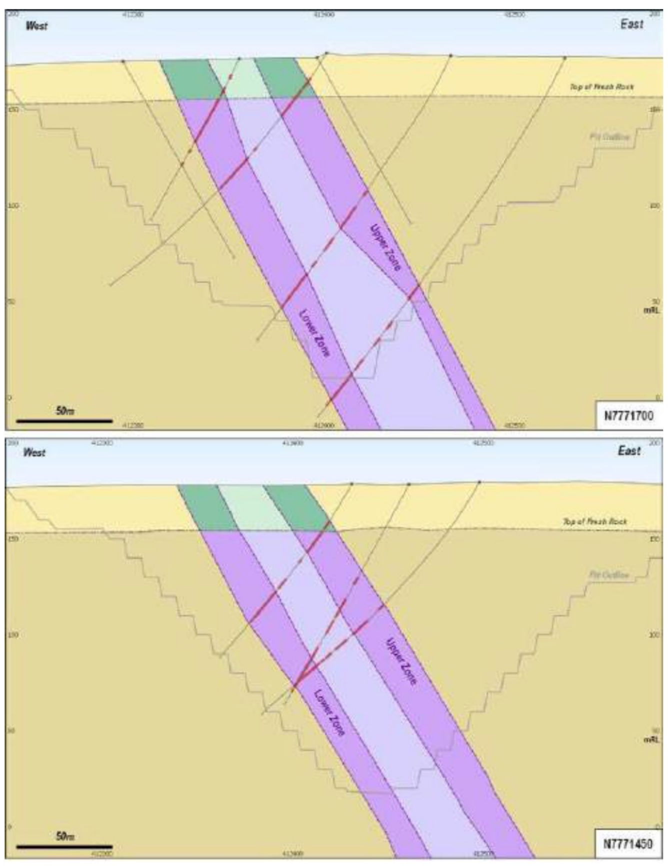
The Roseby deposits lie within the central northern part of the Palaeoproterozoic Mary Kathleen Fold Belt (MKFB—Fig. 17.1). The Mary Kathleen Fold Belt is dominated by the metamorphosed rocks of the Palaeoproterozoic Leichhardt Superbasin, including the Magna Lynn Metabaslt, felsic volcanic rocks of the Argylla Formation, arenites of the Ballara Quartzite and calcsilicate and pelitic rocks of the Corella Formation (Forrestal et al, 1998).

The Roseby deposits are located in the Mt Roseby Corridor, a 3 to 4 km wide, north trending high strain zone which extends for more than 40 km (Robertson, 2003). The Mt Roseby Corridor is dominated by metamorphosed calc-silicate, siliciclastic and intermediate volcanics of the Mesoproterozoic Cover Sequence 2 of the Eastern Succession (Connor et al. 1990) which also hosts the Dugald River Pb-Zn-Ag deposit (Fig 17.1, 17.6).

Figure 17.3: Geological plan and set of cross-sections from the Turkey Creek deposit. The deposit is consistently steeply east-dipping except for the small synform at the northern end of the orebody. From CMMC (2018)



Turkey Creek Deposit Geology



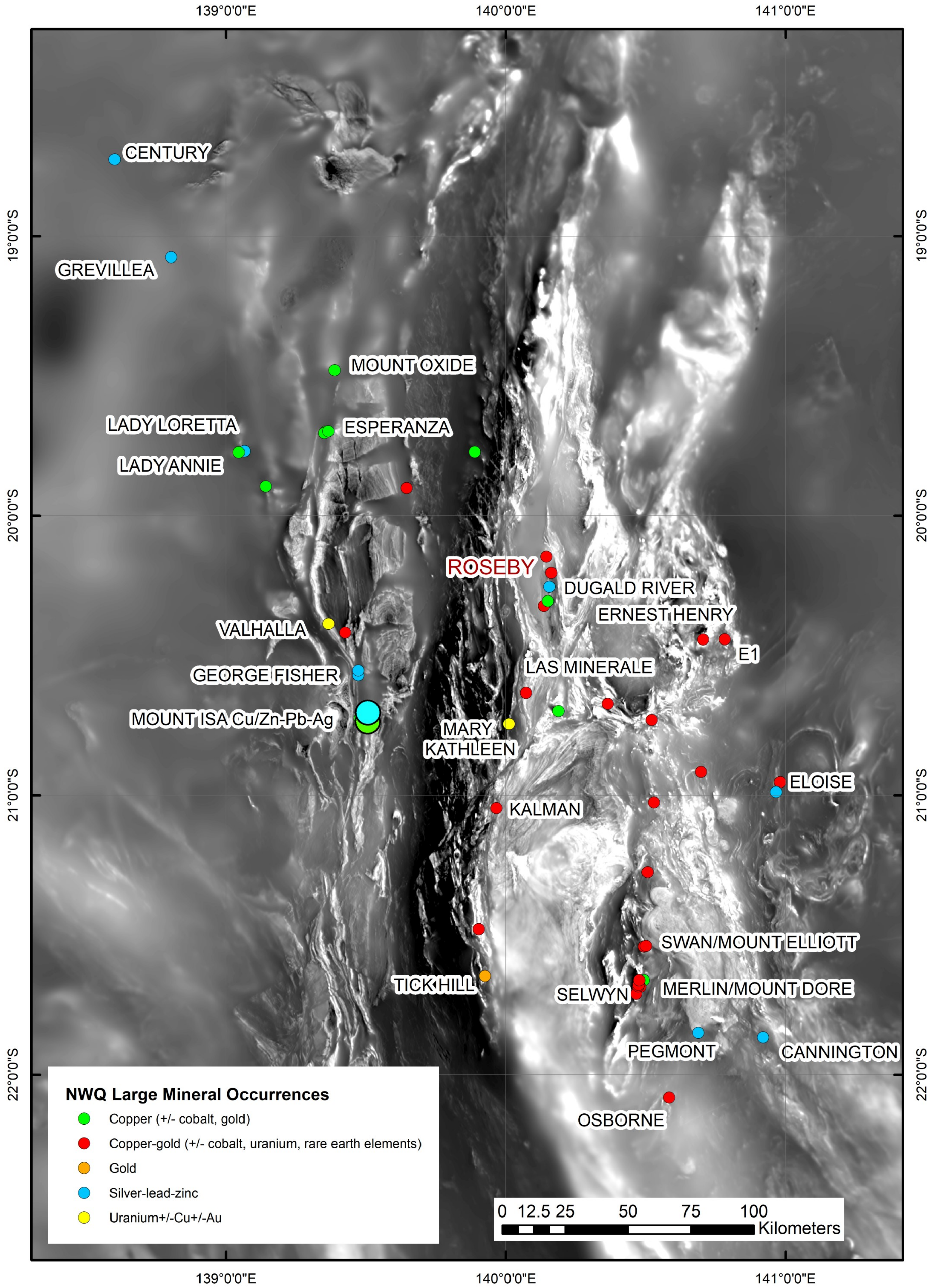


Figure 17.4: Location of the Roseby deposits overlain on an image of total magnetic intensity from the Isa Open Range survey.

HOST ROCKS

Regional Stratigraphy

The Boomarra Metamorphics (maximum age of 1767±4 to 1776±6 Ma) represent the oldest rocks outcropping in the region, lying to the east of the north striking Mt Roseby Fault (Fig. 17.6). These units are metamorphosed to amphibolite facies and comprise medium grained quartzose to feldspathic metasandstone and schist with minor calc-silicate granofels.

Connor et al. (1990) attributed the main intrusive units east of the Mt Roseby Fault to two phases of the Naraku Granite (Williams Suite). These have since been segregated into the Dipvale Granodiorite (Wonga Suite; 1746±7 Ma) and the Mavis Granodiorite (Williams Suite; 1501±9 Ma; Fig. 17.6).

Sheppard and Main (1990) and Porter (1991) originally assigned the then undifferentiated phyllites, black slates and arenite units east of the Mount Rosebee Fault to the Soldiers Cap Group, which stratigraphically underlies the Mary Kathleen Group. The updated stratigraphy (Withnall and Hutton, 2013) now assigns these mapped units to the Corella Formation, part of the Mary Kathleen Group including minor occurrences of the Lime Creek Metabasalt Member, Ballara Quartzite and Overhang Jaspilite.

West of the Mount Roseby Fault, the Mary Kathleen Group, including the Corella Formation and Lime Creek Metabasalt Member, occur as a northwest trending sequence which are disconformably overlain by the Knapdale Quartzite and Mount Roseby Schist of the Mount Albert Group (Fig. 17.6). The Knapdale Quartzite (approx. 2,000 m thick) comprises pink to white feldspathic to quartzose and micaceous metasandstone and metaconglomerate. The Dugald River Shale Member, host to Zn-Pb mineralisation at Dugald River, is now classified as part of the Mount Roseby Schist (cf. previous classification as Corella Fm. e.g., Connor, 1990). The Dugald River Shale Member comprises a grey muscovite, biotite, quartz psammopelitic schist with minor quartzite and carbonaceous metasiltstone. The Coocerina Formation, comprising black shale, scapolitic siltstone and minor limestone, and the Lady Clayre Formation, comprising grey, fine-grained dolomitic sandstone and siltstone are considered to represent stratigraphic equivalents of the Mount Roseby Schist (Broome and Corley, 2017).

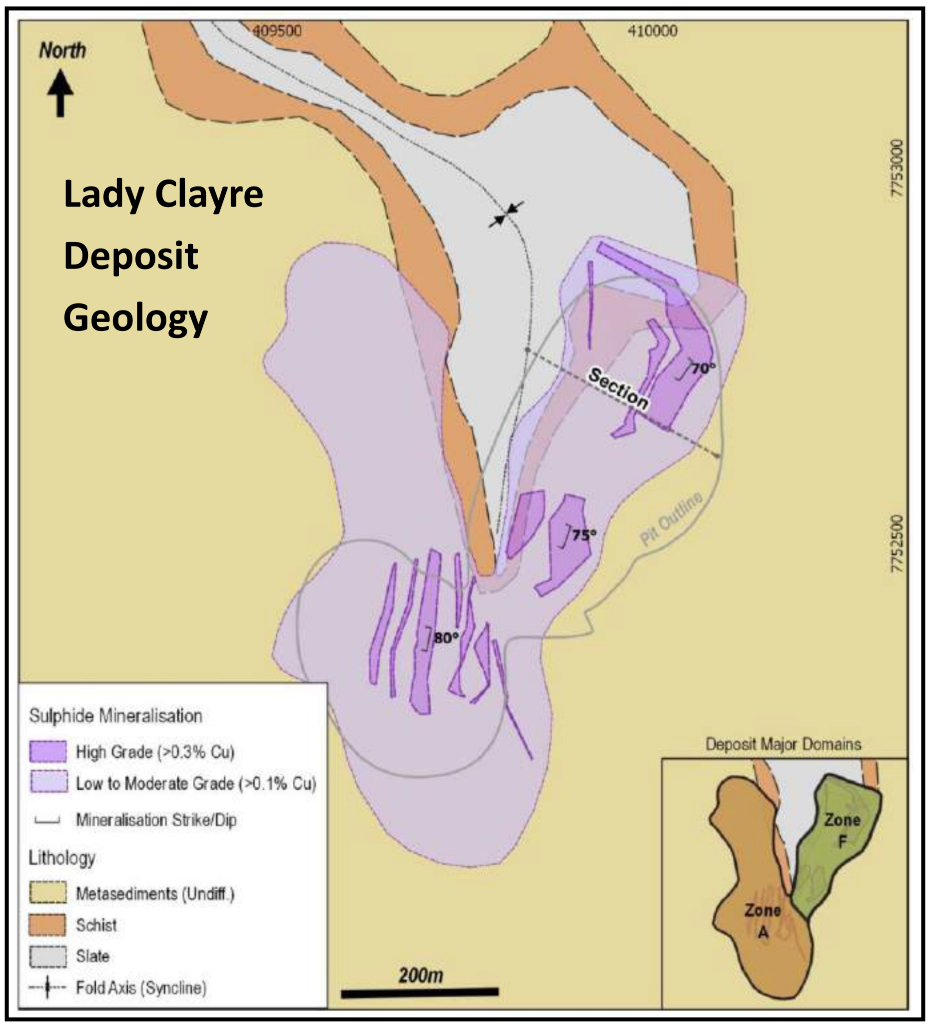
Mine Stratigraphy

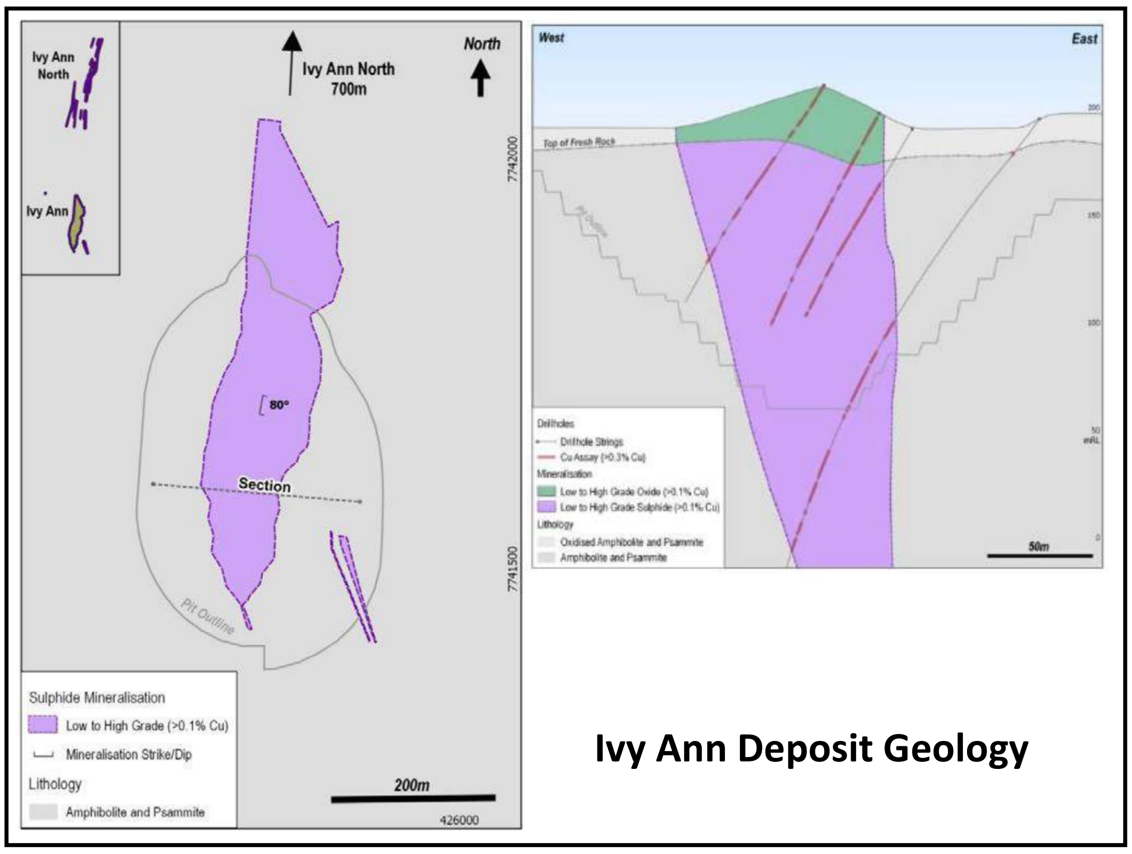
The majority of the Roseby project copper deposits are hosted within the Corella Formation or the Mount Roseby Schist, with the Lady Clayre deposit within the Coocerina Formation.

<u>Little Eva:</u>

The host unit to mineralisation at Little Eva is the Corella Formation, comprising biotite and scapolite-rich schists which have a regional north-south oriented fabric. Volcanic rocks are also mapped in the area, and the the Corella Formation is intruded by a felsic porphyry (CMMC, 2018). In more detail:

- Felsic porphyry – Pink to red, containing plagioclase phenocrysts up to 6 mm in length, K-feldspar and biotite. Forms limited areas of resistant high ground with pervasive malachite staining in outcrop. Unit is locally pervasively altered to ‘red-rock’ assemblage with abundant chlorite and calcite-magnetite veins emplaced along the contact with the Corella Formation schist (Gniel, 2011).
- Mafic to Intermediate volcanic rocks – Mapped by CMMC (2018) as feldspar-phyric to amygdaloidal volcanic units, interpreted to be volcanic flows or sub-volcanic intrusions, dipping east (60 to 70 degrees) and are intruded by feldspar-porphyry. Thomas (1994) identified the presence of mafic igneous rocks at Little Eva.
- Hematite breccia – Light pink to dark red coloured irregular outcrops typically occurring at the margins of the felsic porphyry comprising 10-30 cm diameter subangular to subrounded clasts of highly red-rock altered host rock (unidentifiable protolith) with magnetite-bearing matrix (Gneil, 2011).
- Corella Formation – Grey biotite-scapolite schist containing abundant muscovite and amphibole. Chlorite-rich veins with minor magnetite and biotite are oriented parallel to the regional north-south oriented fabric. Scapolite is common as metamorphic porphyroblasts up to 10 mm in length in addi-





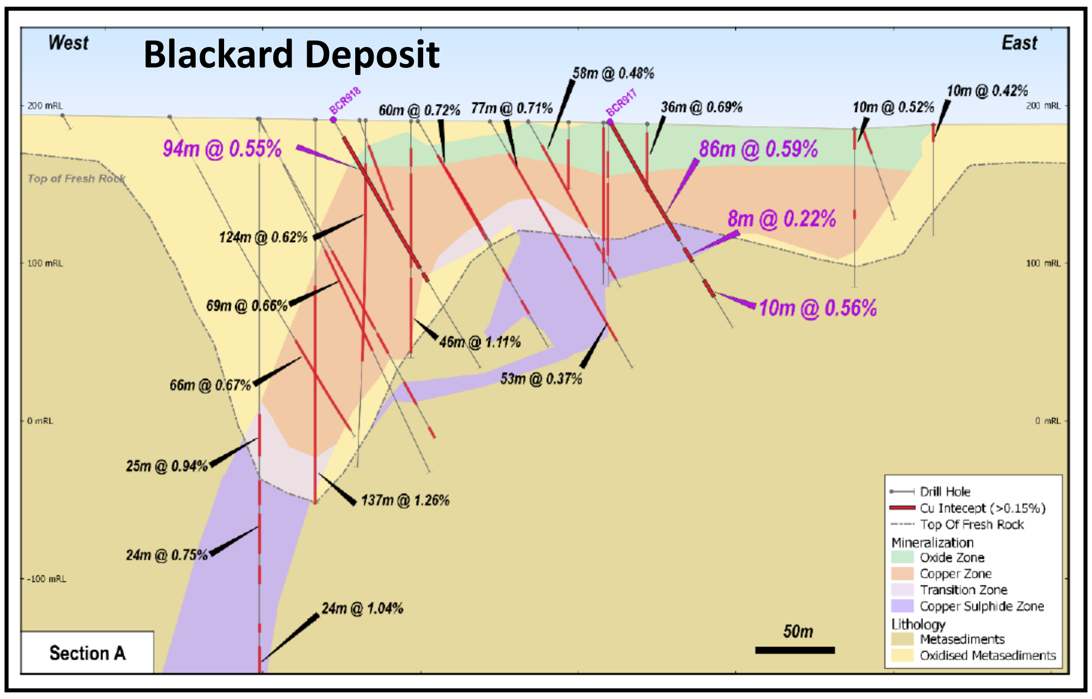


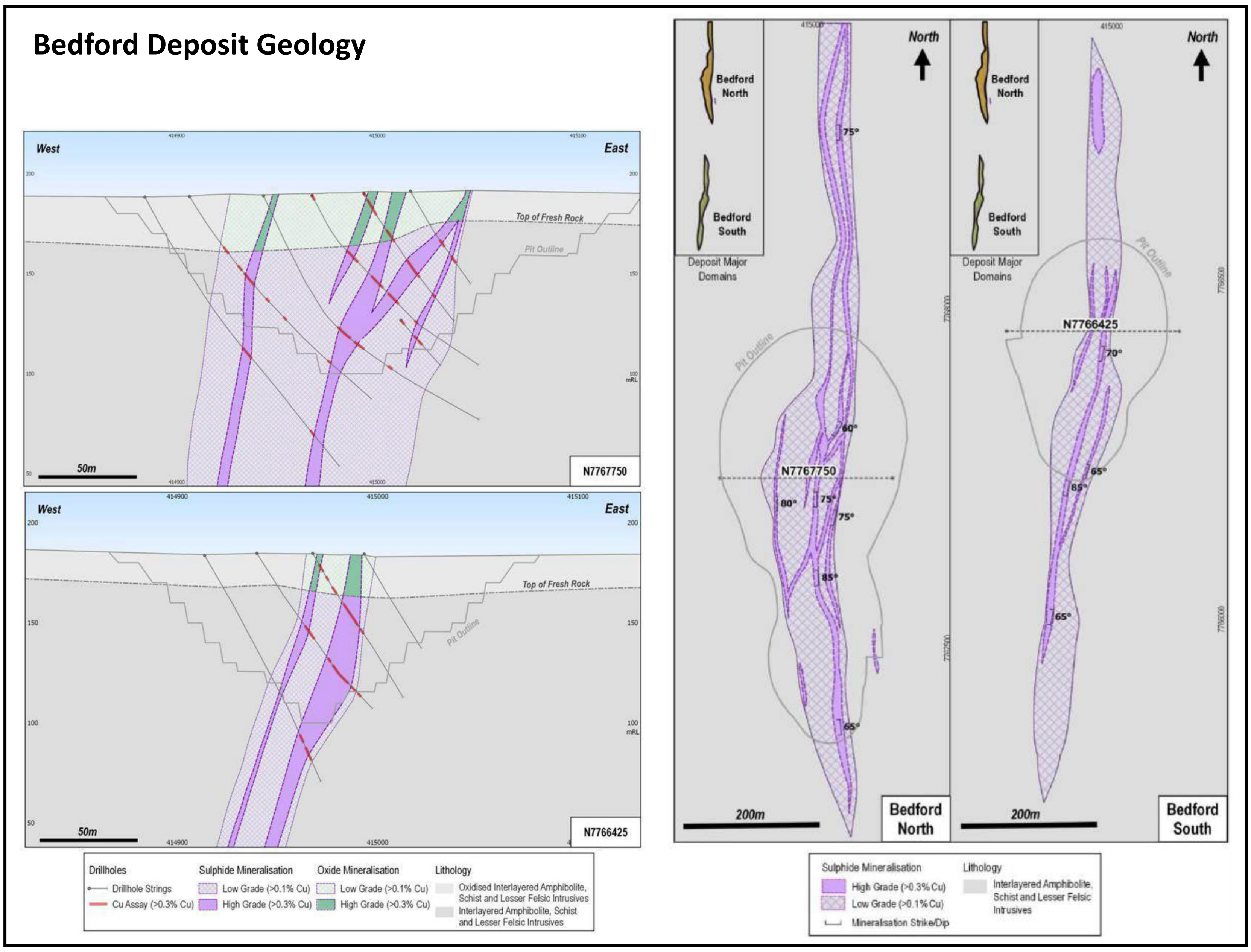
Figure 17.5: Geology plans and sections from selected Roseby deposits (from CMMC, 2018):

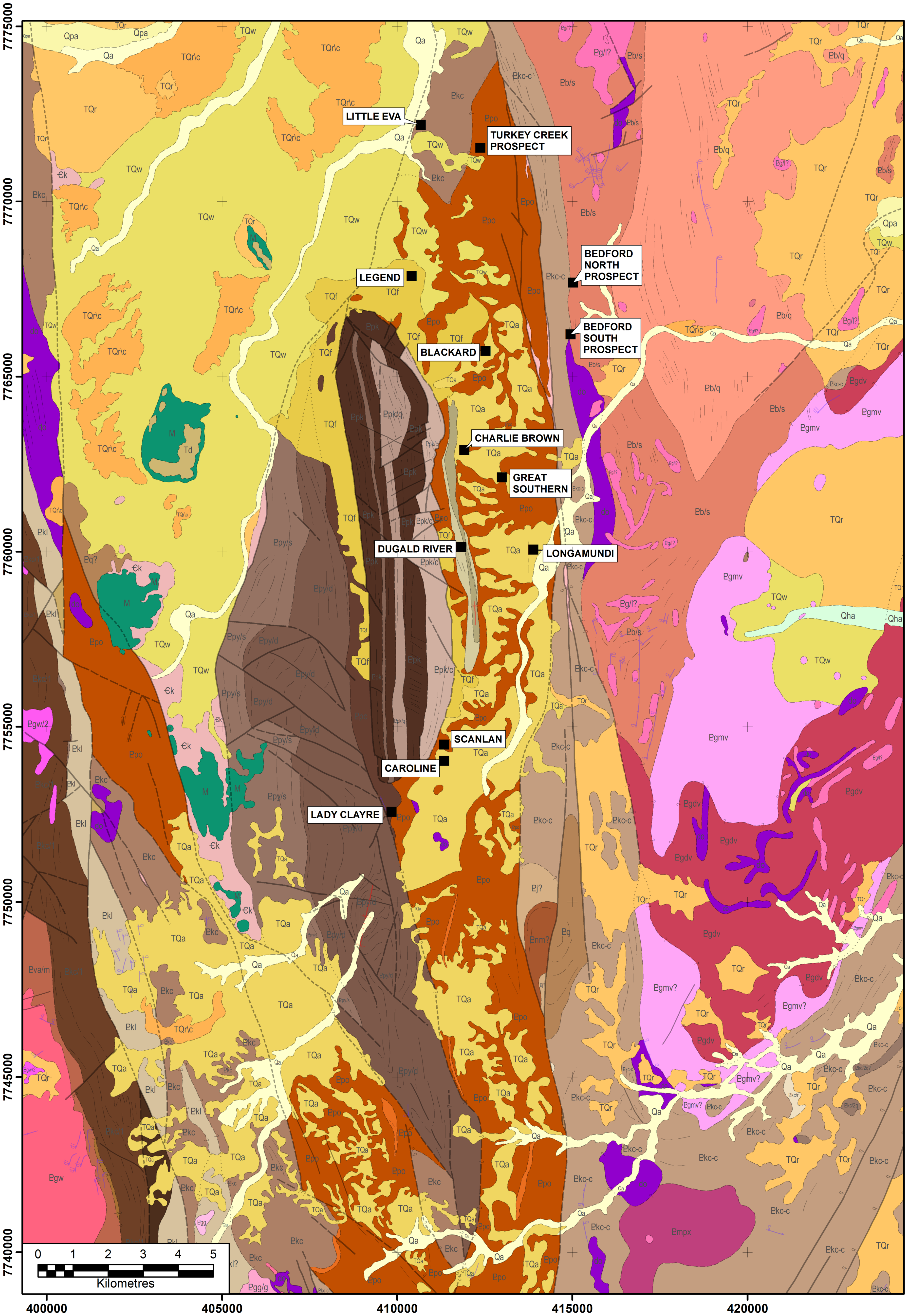
a) (above) the Lady Clayre deposit

b) (top right) the Ivy Ann deposit

c) (right) the Blackard deposit

d) (bottom right) the Bedford deposit (north and southern bodies)




LITTLE EVA
TURKEY CREEK PROSPECT
BEDFORD NORTH PROSPECT
LEGEND
BEDFORD SOUTH PROSPECT
BLACKARD
CHARLIE BROWN
GREAT SOUTHERN
DUGALD RIVER
LONGAMUNDI
SCANLAN
CAROLINE
LADY CLAYRE
7775000
7770000
7765000
7760000
7755000
7750000
7745000
7740000
400000
405000
410000
415000
420000
0 1 2 3 4 5
Kilometres

Quaternary Alluvium

Qa — Qa-QLD
Clay, silt, sand and gravel; flood-plain alluvium

Qha — Qha-QLD
Sand, gravel, silt and clay; active stream channels and low terraces

Qpa — Qpa-QLD
Clay, silt, sand and gravel; flood-plain alluvium on high terraces

Late Tertiary to Quaternary Alluvium

TQa — TQa-QLD
Locally red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high-level alluvial deposits (generally related to present stream valleys but commonly dissected)

TQf — TQf-QLD
Consolidated to non-consolidated, locally mottled clayey to sandy gravel, sand and clay; alluvial fan and slope-wash deposits forming dissected, steep to gently sloping surfaces

TQr — TQr-QLD
Clay, silt, sand, gravel and soil; colluvial and residual deposits (generally on older land surfaces)

TQr/c — TQr\c-QLD
Clay and black soil; pediment slope wash, colluvial and residual deposits

Td — Td-QLD
Duricrusted palaeosols at the top of deep weathering profiles, including ferricrete and silcrete; duricrusted old land surfaces

TQw — Wondoola beds
Red and grey clay, silt and sand

Jurassic - Cretaceous

M — Mesozoic Sedimentary rocks
Ferruginous sandstone, conglomerate, siltstone and claystone

Cambrian

Ek — Kajabbi Formation
Calcareous siltstone, limestone, quartzose to lithofeldspathic sandstone and chert

Williams Supersuite (1500 - 1540 Ma)

Lgmv — Mavis Granodiorite
Medium-grained, hornblende-biotite granodiorite; locally strongly deformed

Burstall Suite Intrusions (1740 - 1730 Ma)

Lgg — Mount Godkin Granite
Pink, fine to medium-grained hornblende syenogranite to monzogranite, commonly with granophyric textures; local biotite syenogranite

Lgg/g — Mount Godkin Granite/g
Altered endoskarn-bearing metagranite

Lmpx — Mount Philp-type breccia
Intrusive breccia containing abundant clasts or xenoliths of mafic rocks (and some calc-silicate rocks) in a grey to pink matrix consisting of albite laths and phenocrysts of amphibole, clinopyroxene and magnetite (highly altered hornblende diorite?)

Wonga Suite Intrusions (1778 - 1738 Ma)

Lgw — Wonga Granite
Strongly foliated to gneissic porphyritic biotite granite and biotite-amphibole metagranite

Lgw/2 — Wonga Granite/2
Foliated biotite granite, leucogranite, pegmatite, aplite

Lgdv — Dipvale Granodiorite
Medium-grained, hornblende-biotite granodiorite to monzogranite; pervasively foliated

Leucogranite, pegmatite, aplite and quartz veins

Lg/I? — Lg/I-MI
Leucogranite, pegmatite and aplite

q-MI — q-MI
Quartz-filled fault zones and quartz veins

Metadolerite

do — Metadolerite (do-MI)
Metadolerite and metagabbro of various ages passing into amphibolite and local biotite or chlorite schist; rare pyroxene-bearing dolerite

Palaeoproterozoic

Lq — Quamby Conglomerate
Polymictic pebble to cobble conglomerate and pebbly, medium to very coarse-grained lithofeldspathicsandstone

Mount Albert Group

Lpy/d — Lady Clayre Formation/d
Dolomitic, locally pyrrhotitic siltstone and silty to sandy dolostone

Lpy/s — Lady Clayre Formation/s
Grey, fine-grained, variably dolomitic sandstone and siltstone

Lpc — Coocerina Formation
Black shale, scapolitic siltstone and minor limestone

Lpk — Knapdale Quartzite
Pink, fine-grained, feldspathic to quartzose, locally micaceous sandstone

Lpk/c — Knapdale Quartzite/c
Calcareous feldspathic medium-grained sandstone, pink quartzite and siltstone

Lpk/q — Knapdale Quartzite/q
White, fine-grained, quartzose sandstone

Lpk/t — Knapdale Quartzite/t
Pink, feldspathic and micaceous siltstone and minor pebble conglomerate

Lpo — Mount Roseby Schist
Grey muscovite-biotite-quartz schist (psammopelite) and minor quartzite, calc-silicate granofels and limestone; commonly thin-bedded with abundant poikiloblastic scapolite porphyroblasts, particularly in the north

Lpo/q — Mount Roseby Schist/q
Grey to pink, fine-grained, thick to very thick-bedded, massive feldspathic to quartzose sandstone

Lpod — Dugald River Shale Member
Dark grey, carbonaceous shale and siltstone and grey mica schist

Lpod/l — Dugald River Shale Member/l
Dark grey silty, dolomitic limestone and siltstone

Mary Kathleen Group

Lkc — Corella Formation
Calcareous siltstone, sandstone and minor limestone, passing into calc-silicate granofels, commonly scapolitic, and marble; local quartzose sandstone passing into quartzite; local breccia

Lkc-c — Corella Formation-c
Laminated calc-silicate granofels, some mica schist; moderate to high magnetic response, moderate potassium response and low in other radiometric channels

Lkc/1 — Corella Formation/1
Laminated calcareous metasiltstone and fine-grained feldspathic sandstone, limestone and siltstone; pass into calcareous scapolitic granofels, calc-silicate (hornblende-diopside) granofels and quartzo-feldspathic gneiss

Lkl — Lime Creek Metabasalt Member
Metabasalt (locally pillowed) and amphibolite

Lkb — Ballara Quartzite
Quartzite, locally micaceous; minor conglomerate

Lj — Overhang Jaspilite?
Predominantly grey siltstone with local jaspilitic layers and common limestone (locally stromatolitic and silicified with jaspilitic layers); local ironstone, banded in places

Lnm? — Mitakoodi Quartzite?
Quartzose to feldspathic sandstone, siltstone, basalt and mica schist; minor limestone

Lb/q — Boomarra Metamorphics/q
White to pink fine to medium-grained quartzose to feldspathic metasandstone and minor psammitic schist and calc-silicate granofels; common massive to banded amphibolite

Lb/s — Boomarra Metamorphics/s
Grey, biotite-quartz-feldspar (psammitic) schist and minor calc-silicate granofels; common massive to banded amphibolite

Lva/m — Argylla Formation/m
Sheared felsic and mafic metavolcanics with abundant aplite and pegmatite veins

Figure 17.6: Geological map (previous page) and stratigraphic legend (right) from the 1:100,000 mapping from the Geological Survey of Queensland of the Roseby area.

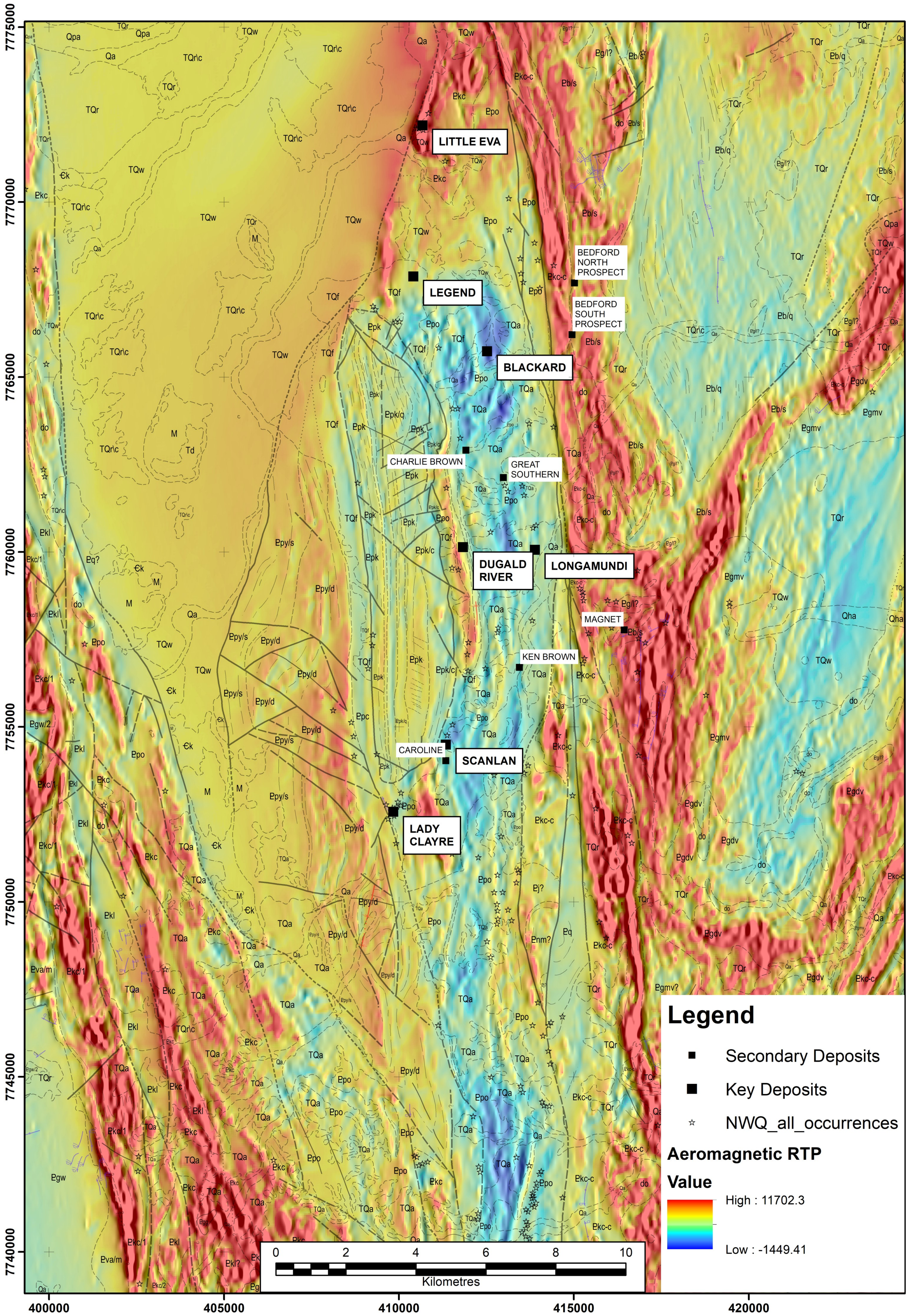


Figure 17.7: Reduced-to-pole aeromagnetic image with 1st vertical derivative sharpening (dataset sourced from QDEX Data https://qdexdata.dnrme.qld.gov.au/GDP/Search).

tion to epidote and K-feldspar (Thomas, 1994).

- Marble – Common in the biotite-scapolite schist and hematitic-breccia units, forming pods or lenses up to 10 m in length. The marble ranges from white to pink in colour and comprises calcite with scapolite, dolomite and ilmenite. Early quartz veins in the marble are cross-cut by barren calcite veins up to 50 mm in diameter (Thomas, 1994; Gneil, 2011).

Blackard

The Blackard deposit is hosted by the Mount Roseby Schist, which comprises calc-silicate and shaley horizons which have been extensively deformed into tight, sub-vertical to overturned isoclinal folds with north-south to northwest-southeast trending axes (CMMC, 2019).

Bedford

The Bedford deposit is hosted by scapolite-bearing quartz-biotite-hornblende-magnetite schists, ortho- and para-amphibolite of the Corella Formation, close to the regional contact with the Boomarra Metamorphics (Fig. 17.6) east of the Mount Roseby Fault.

Scanlan

Scanlan is hosted by the Mount Roseby Schist and is characteristic of Cu-only strata-bound metasediment hosted mineralisation at Roseby.

Lady Clayre

The host rocks in the Lady Clayre deposit comprise the following (summarised from Habermann, 1999 and Gniel, 2011):

- Biotite-quartz-feldspar schist: Dark grey to black, comprises feldspar, quartz, biotite and carbonate with distinct graphitic and chloritic zones. Fine grained with weak schistosity but well developed foliation and crenulation.
- Calcareous feldspathic metasiltstone: Poorly exposed, highly weathered in outcrop and partially obscured by Quaternary cover, comprises largely massive, light grey dolomite, calcite, feldspar, quartz and biotite with strong albitisation.
- Pelitic schist: Extensive outcrops of politic schist at Lady Clayre, forming reddish-brown fine grained exposures comprising quartz, muscovite, biotite and feldspar with localised albitisation and silicification.
- Graphitic black shale: Only intercepted in drill core, comprises black to grey, fine-grained, weakly foliated unit.
- Dolomite: Massive outcrops as pods or lenses comprising dark grey to black, fine to coarse grained dolomite units up to 20 cm thick, interbedded with thinner (1-3 cm) more siliceous beds.
- Lady Clayre Dolomite: Outcrops in the SW of the Lady Clayre prospect, comprises blue-grey medium to thick bedded (5 to 50 cm thick beds) fine grained dolomitic siltstone interbedded with thinner quartz-feldspar beds. Scapolite porphyroblasts and coarse pyrrhotite are common.
- Dolerite: Porphyritic, altered dolerite (pyrrhotite and amphibole alteration) has been intercepted in drill core (5 m long section) at Lady Clayre. Unaltered dolerite outcrops 1 km east of Lady Clayre and comprises plagioclase, augite, olivine and accessory phases.

Structural History of the Mount Roseby Corridor

Deformation Stage	Macroscopic Structure	Mesoscopic Structure	Metamorphic Grade
D1	Regionally extensive detachment faults and ramp faults	Discrete shallow dipping mylonite zones	Lower Greenschist?
D2	Isoclinal folds strongly overturned to the east	Discrete anastomosing shears + pervasive domainal schistosity	Upper greenschist - lower amphibolite
D3	Upright to overturned tight to isoclinal folds overturned to the east	Regionally pervasive schistosity + reactivation of pre-existing fabrics	Middle amphibolite
D4	Localized folds with steep NW - oriented axial planes	Strong, E-W, flat lying crenulations	Greenschist?
D5	Transtensional and transpressional events resulting in down-faulting	Two phases of kink bands and fracture cleavage	Greenschist?

Table 17.2: Structural history of the Mount Roseby Corridor. From Thomas (1994 (adapted from Newbery, 1993)

INTRUSIVE ROCKS

Granitoids

Major intrusions occur east of the Mt Roseby Corridor, to the east of the Mt Rosebee Fault and include the Dipvale Granodiorite, part of the Wonga Suite (1778-1738 Ma), which intrude the Boomarra Metamorphics (Fig. 17.6). The Wonga Suite intrusions, previously assigned to the Naraku Batholith (Xu, 1996; Habermann, 1999) are intruded by the Mavis Granodiorite, part of the Williams Suite (1500 – 1540 Ma).

Closer to the deposits, the Corella Formation at Little Eva is reported as intruded by a felsic porphyry which is interpreted as spatially and temporally related to brecciation and mineralisation (Gniel, 2011). Additionally, CMMC (2018) report that mineralisation at Little Eva is closely associated with hypabyssal intrusions.

Mafic Intrusives

Numerous metadolerite and metagabbro intrusions occur east of the Mt Roseby Fault, with several intrusive units cropping out <1.5 km from the Lady Clayre deposit (Habermann, 1999; Fig. 17.6)

METAMORPHISM

East of the Mount Roseby Fault, the regional metamorphic grade is amphibolite facies, affecting the Boomarra Metamorphics and the Corella Formation (Fig. 17.6). West of the Mount Roseby Fault, the metamorphic grade decreases to greenschist facies. Xu (1996; 1998) attributed the main metamorphic episode at the Dugald River deposit to regional D2 deformation related to NNW-SSE oriented shortening. This developed the principal slaty cleavage and mineral elongation lineations in the Dugald River Shale Member and schistose fabric in the hanging wall schists (Xu, 1996). Peak metamorphic conditions were estimated to be 450°C based on syn-tectonic crack seal veins in the Lady Clayre dolomite (Xu, 1997).

Whittle (1998) estimated peak metamorphic conditions based on the quartz-biotite-muscovite-sillimanite-almandine assemblage in hanging wall metapsammites at Dugald River to have been achieved during D2 (approx. 540-680°C; upper greenschist to lower amphibolite), consistent with Conner et al. (1990). Whittle (1998) suggests at least three main metamorphic events occurred at the Dugald River deposit with peak middle-amphibolite facies occurring during D2 and upper greenschist to lower amphibolite during D3.

STRUCTURAL CHARACTERISTICS

Structural Setting

The Roseby deposits are located in the Mt Roseby corridor, a 3-4 km wide, north-trending, high strain zone which extends for about 40 km.

The major north-south-trending Mount Roseby Fault traverses the area (Fig, 17.6), with most deposits to the west of the fault. However, the Bedford deposit is located approximately 1km east of the fault.

The western margin of the area is truncated by the Cooloolah Fault, to the west of which a thick Cambrian to Tertiary sequence is present. This is evident in the aeromagnetic data, with a notable flat and textureless "magnetically quiet" zone west of the fault.

Structural History

The structural history of the Roseby Corridor is provided in Table 17.2, and summarized by Thomas, 1994 (based on the work of Newbery, 1993) as follows:

- An early detachment phase (D1) responsible for the superposition of stratigraphy,
- Two ductile fold phases D2 and D3 which developed coaxially north-south and produced two pervasive schistosities (S2 and S3)
- Two phases of brittle deformation (D4 and D5).

The Roseby deposits appear to have a strong structural control. This control, particularly localization within shear zones, is reflected in the deposit geometries, which are commonly thin and steeply dipping (refer to the cross-sections shown in Figs.17.2, 17.3 and 17.5).

Finch (2011) suggests the competency contrast between the marble and the quartz-biotite-scapolite schist played a major role in increasing fracture-related permeability and localizing mineralisation.

Breccias are present at Little Eva, and in fact Thomas (1994) terms the deposit a "hematite -rich breccia". Thomas (1994) notes that the hematite alteration appears to have a spatial relationship with the felsic porphyry which outcrops near the middle of the deposit, with the pervasive hematite alteration gradually decreasing away fro the porphyry. The highly altered zone of brecciation at Little Eva is hosted within the Corella Formation, which in this area is composed predominantly of biotite and scapolite-rich schists.

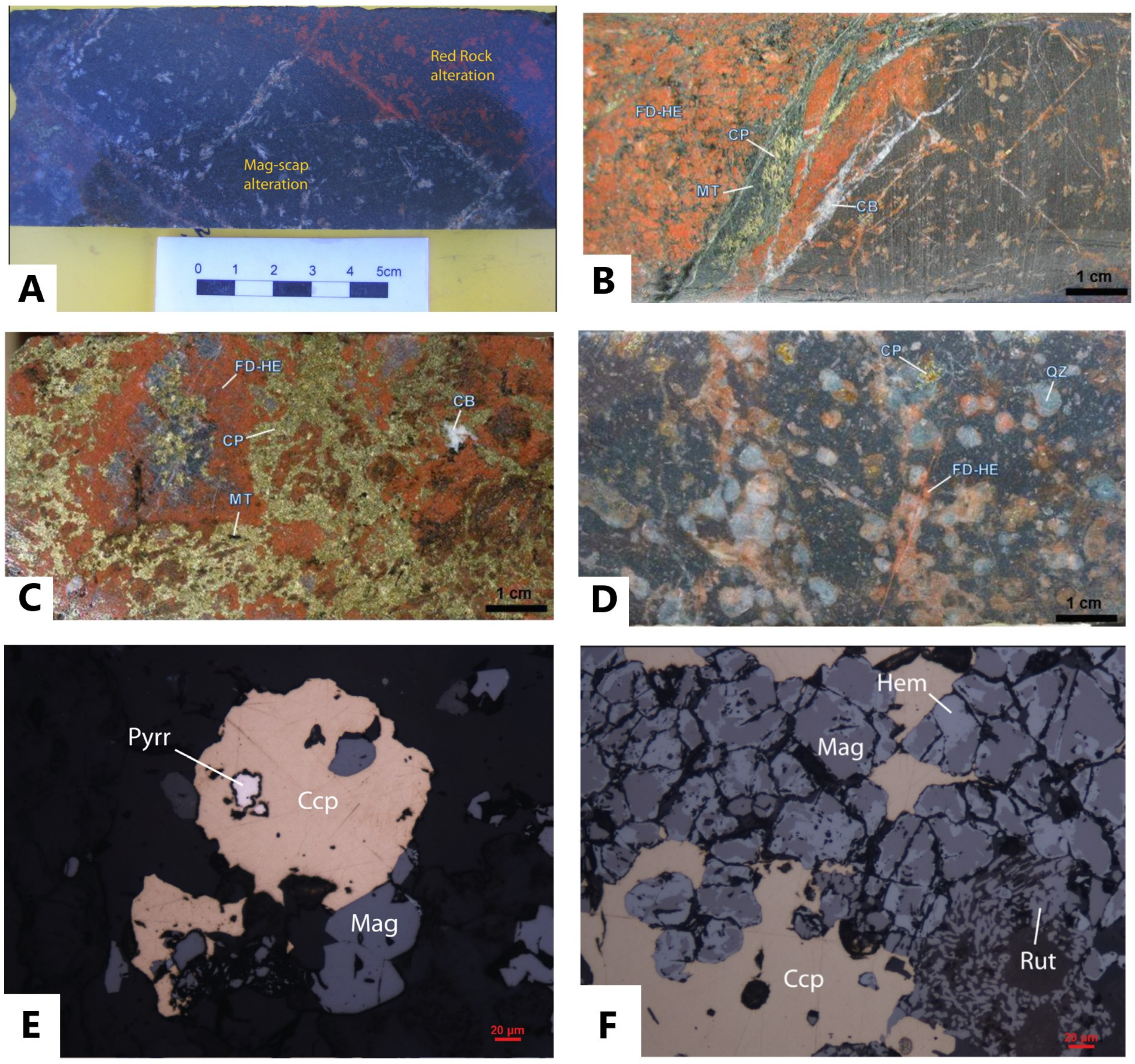


Figure 17.8: Examples of alteration and mineralisation from the Little Eva deposit.

A) Hematite – K-feldspar alteration (red rock) alteration and magnetite-scapolite alteration at Little Eva. Drillhole LED495-85.4 m (from Gniel, 2011).

B) High-grade hydrothermal breccia, with variably altered intermediate igneous clasts in a feldspar (FD), hematite (HE), chalcopyrite (CP), magnetite (MT), and carbonate (CB) matrix (4.8% Cu, 0.2 ppm Au).

C) Feldspar phyric intermediate igneous rock (dark domain, right) overprinted by texturally destructive feldspar-hematite (FDHE) alteration (red domain, left) host to a chalcopyrite (CP), magnetite (MT), and carbonate (CB) filled veinlet network (0.5% Cu, 0.05 ppm Au).

D) C) Feldspar-phyric intermediate igneous rock with quartz (QZ) filled amygdales, patchy weak feldspar-hematite (FD-HE) alteration, and low-grade disseminated chalcopyrite (CP) mineralization (0.2% Cu, 0.02 ppm Au).

E) E) Photomicrographs of early chalcopyrite with pyrrhotite and magnetite. From Gniel (2011).

F) F) Photomicrographs of late chalcopyrite associated with oxidation of magnetite to hematite. From Gniel (2011).

MINERALISATION

General Characteristics

Little Eva

Hypogene features (Fig 17.8)

Recent drilling and modelling by Copper Mountain (2018) indicates that Cu-Au mineralisation is hosted with the north-striking, east dipping subvolcanic intrusive and intermediate volcanic rocks and associated breccias. Thomas (1994) documented mineralisation associated with late-stage calcite veins and breccias which are concentrated in K-feldspar-hematite altered rocks. The mineralisation and alteration paragenesis for the Little Eva deposits is shown in Figure 17.11. Two copper mineralisation styles were documented by Gniel (2011);

- an early event, largely restricted to quartz-albite and red rock altered units, is characterised by intergrown magnetite and chalcopyrite (Fig. 17.x4a) which is closely associated with chlorite, pyrite and pyrrhotite.
- A second mineralisation style, with

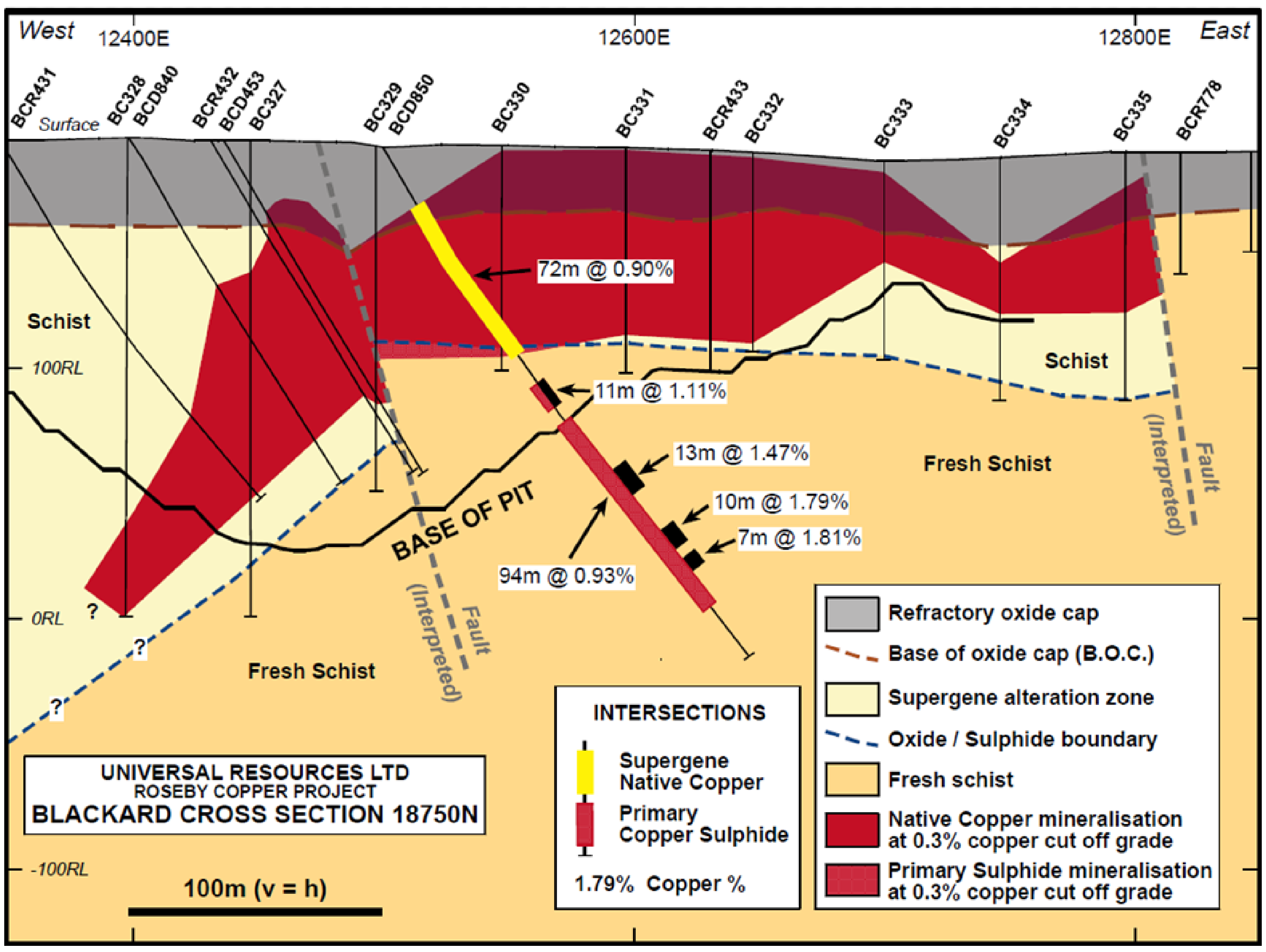
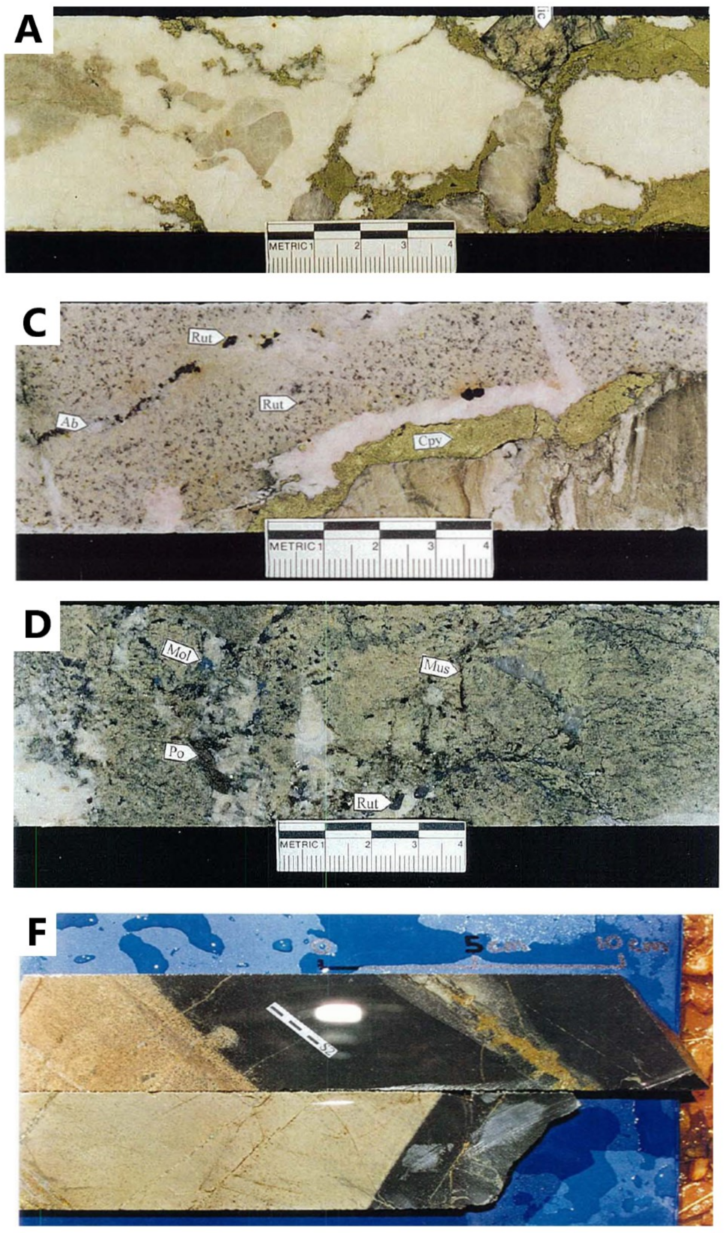


Figure17.9: Section 18750N from the Blackard deposit, illustrating the geometry of the native copper mineralisation as a flat-lying think tabular body. From Universal Resources (2008).



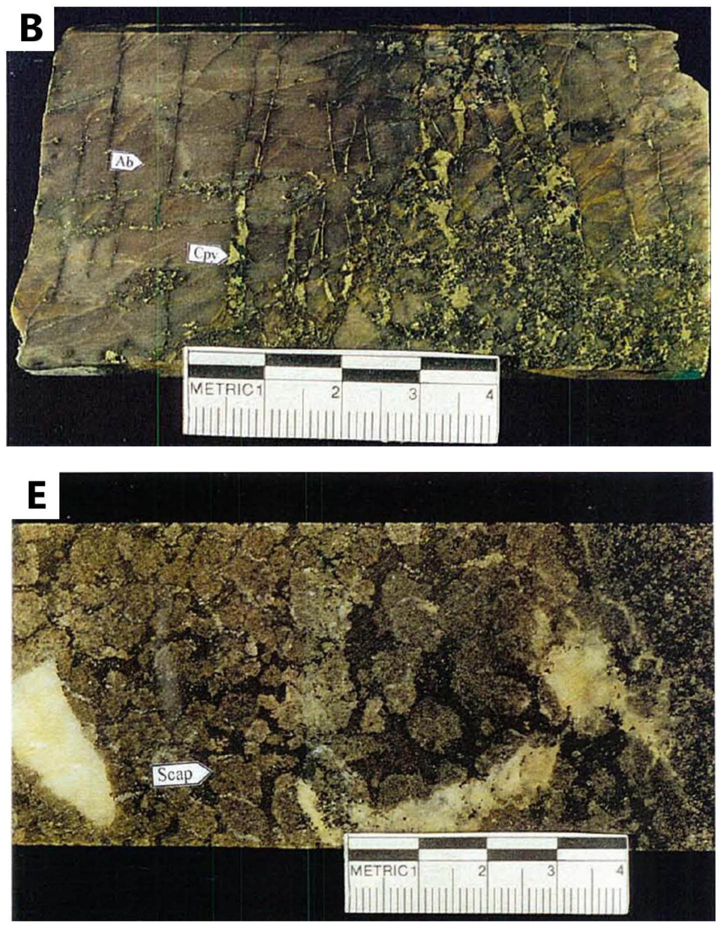


Figure 17.10 (right): Examples of alteration and mineralisation from the Lady Clayre deposit.

A) Stage 5 coarse carbonate-quartz-microcline vein-breccia infill with later chalcopyrite infill/replacement (Habermann, 1999).

B) Stage 5 high-grade mineralisation (3.3 % Cu and 19.7 g/t Au) infilling fine fractures in albite altered unit from Habermann (1999).

C) Lady Clayre Metadolerite and metasiltstone contact with late-stage chalcopyrite infill. From Habermann (1999)

D) Stage 5 strong carbonate-muscovite-chlorite alteration overprinting earlier K-feldspar alteration. Late stage molybdenite is associated with U-bearing minerals including davidite and coffinite (From Habermann, 1999).

E) Lady Clayre strong biotite-scapolite-carbonate alteration of metadolorite. From Habermann (1999)

F) Lady Clayre albite alteration overprinting main cleavage (S2) with a sharp contacts between albite alteration (pale colour) and unaltered schist. From Habermann (1999)

higher proportions of chalcopyrite is associated with hematisation of magnetite, a feature also observed by Thomas (1994); Fig. 17.8f. This mineralisation style is typically associated with breccia matrix infill cements and includes chlorite, prehnite and laumontite (Thomas, 1994; Gneil, 2011).

Surface oxidation features

An 15 to 30m thick oxidation profile has been documented at Little Eva (Robertson, 2003; CMMC, 2018) comprising goethite, hematite, malachite, chrysocolla, covellite, azurite and cuprite and rare occurrences of native copper.

<u>Blackard</u>

At Blackard the mineralisation is subparallel to the fabric and occurs in trough-like structures oriented parallel to the anticlinal axes (CMMC, 2019).

Four zones are documented at Blackard by Universal Resources (2009; 2011) and Copper Mountain (2019). See Fig 17.9.

1. Oxide – completely weathered oxide zone (20-30 m thick) with malachite, azurite, cuprite, hydrobiotite and Fe-Cu complexes
2. Copper – partially oxidised copper zone (up to 120 m thick) comprises native copper with lesser cuprite, hydrobiotite and chalcocite
3. Transition – Narrow (1 – 15 m thick) with transitional composition between the oxidised and hypogene sulphide zones
4. Copper sulphide – Unweathered bedrock with copper sulphide including hypogene chalcocite, bornite and chalcopyrite as disseminations and clots associated with pervasive and veinlet carbonate alteration.

<u>Bedford</u>

At Bedford copper occurs as primary sulphides in fresh rock and as secondary oxide minerals within the weathered zone.

An irregular 20-m to 30-m-thick zone of weathering with oxide mineralization blankets the deposit. Although the base of oxidation is well defined, variability of copper mineral species within the weathering profile is not well understood.

In the sulfide zone the dominant ore mineral is coarse grained chalcopyrite (with minor magnetite, pyrite, pyrrhotite, and gold), which occurs within quartz veins, breccia fill, and disseminations within the host shear zone (CMMC, 2018).

<u>Scanlan</u>

Mineralisation at Scanlan comprises stratabound metasediment hosted finely disseminated copper sulphides and coarse grained vein hosted copper sulphides in the hypogene zone, overlain by an oxidised weathered zone up to 60 m thick dominated by native copper. The different styles of mineralisation at Scanlan (disseminated and vein hosted) infer both hydrothermal replacement and structurally controlled mineralisation (Altona, 2015).

<u>Lady Clayre (Fig 17.10)</u>

Cu-Au mineralisation at Lady Clayre is associated with late-stage brittle deformation with mineralisation occurring as infill and associated alteration (Stage 5; Fig. 17.13) localised in fractured host rocks (Habermann, 1999). Early alteration and mineralisation was dominated by quartz-carbonate veining followed by chalcopyrite-pyrrhotite mineralisation which infills space and replaces carbonate (Fig. 17.10a,b. This was followed by a later muscovite-pyrite overprint.

ALTERATION HALO

General Characteristics

<u>Little Eva</u>

Little Eva is characterised by highly fractured, magnetite-rich alteration that has been overprinted by hematite-rich alteration assemblages (Thomas, 1994). Hematite occurs with K-feldspar alteration domains and is associated with higher grade Cu-Au mineralisation which is locally related to quartz-calcite veining. In proximity to mineralisation, the Corella Formation is highly brecciated with no preservation of pre-mineralisation deformational fabrics, suggesting alteration and mineralisation post-dates D3 regional deformation events.

A summary of the alteration at Little Eva is provided by Thomas (1994) and Gniel (2011). The metasomatic alteration paragenesis is shown in Fig. 17.11 from Gniel (2011).

1. Regional metamorphism of the Corella Formation forming biotite-scapolite schist and amphibolite. Metamorphic scapolite is documented as being ovoid in shape, restricted to layer parallel zones in the schists and has a meionitic (Ca-Cl-rich) composition (Thomas, 1994).
2. Scapolite-magnetite alteration - First alteration event at Little Eva characterised by pervasive, texturally destructive magnetite and scapolite alteration of the host rocks including Corella Formation schists but is absent from the Felsic Porphyry unit (Gniel, 2011). Hydrothermal scapolite is described as having a pale pink, flower-like appearance, marialitic (Na-Cl-rich) composition, and is not constrained to the rock fabric (Thomas, 1994).

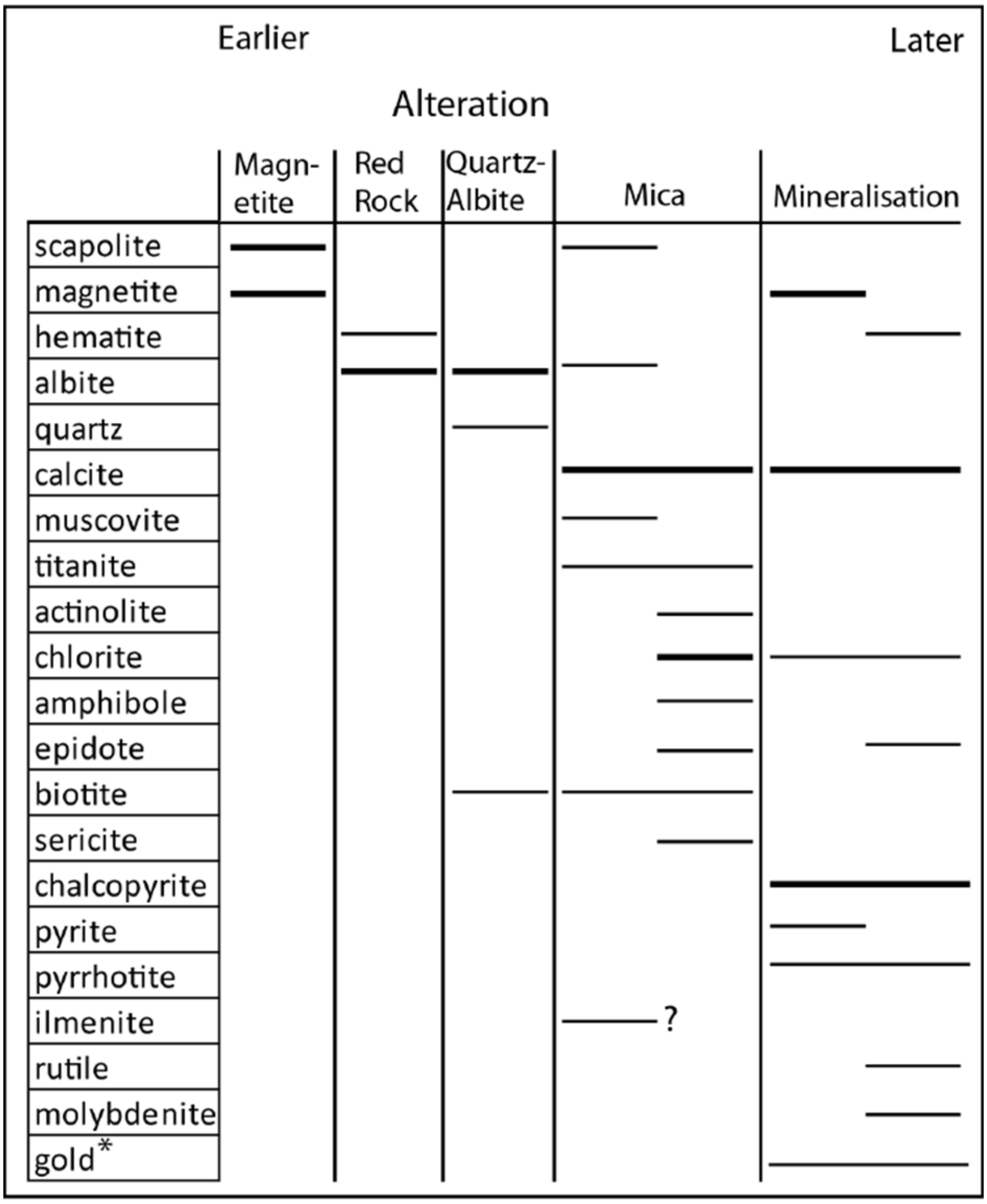


Figure 17.11: Generalised paragenesis of the Little Eva deposit from Gniel (2011).

3. Quartz-albite-chlorite alteration - This assemblage has multiple overprinting relationships with hematite – K-feldspar alteration and has a pervasive, texturally destructive nature (Thomas, 1994; Gniel, 2011). Albite is stained by fine grained hematite inclusion (hematite dusting) common in oxidised hydrothermal systems. Thomas (1994) suggests that albite-chlorite alteration is extensive at Little Eva, extending beyond the hematite – K-feldspar halo.
4. Hematite – K-feldspar (albite) – chlorite - sericite alteration ('red rock alteration') Regionally extensive 'red-rock' alteration comprising hematite-albite is described by Copper Mountain (2018) at Little Eva. Through extensive mineralogy and chemical staining (Thomas, 1994; Gniel, 2011) K-feldspar is shown to be the dominant feldspar (over albite) associated with this alteration stage. K-feldspar is also hematite dusted making visual differentiation between albite and K-feldspar difficult. This is associated with magnetite destruction by oxidation and results in slightly lower magnetic susceptibilities (Thomas, 1994).
5. Calcite vein and breccia infill + chalcopyrite + gold, quartz-biotite-crystalline hematite-K-feldspar-magnetite-chlorite-laumonite-prehnite-albite (Thomas, 1994). Veins, of variable thickness from <10 to 200 mm are associated with mineralisation. The assemblage also forms mineralised breccia cement/infill. Thomas (1994) describes abundant prehnite and laumontite in this assemblage associated with copper-gold mineralisation, indicating hydrothermal fluid temperatures of around 300 to 270°C.

Blackard

No deposit-scale paragenetic study is known to have been carried out at Blackard. CMMC (2019) describe alteration associated with stratabound primary sulphide mineralisation comprising chalcocite, chalcopyrite and bornite disseminations and clots, to comprise pervasive carbonate alteration and veining.

Bedford

Extensive potassium feldspar and magnetite alteration are reported from Bedford Universal Resources, (2006). CMMC (2018) report that magnetite-biotite alteration assemblages with quartz veining are concentrated in the ore zones, above a strongly feldspar-hematite altered footwall.

Lady Clayre

Habermann (1999) and Gniel (2011) described the alteration features at Lady Clayre as comprising dominantly hydrothermal breccias with quartz-tourmaline and quartz-albite domains. In summary those domains comprise:

- Calc-silicate breccia: Forming large outcrops in the Lady Clayre prospect, dominating on the western side. This comprises dark grey to light brown, subangular to subrounded clasts of albitised and silicified calcareous metasiltstone up to 200 cm diameter. The matrix is quartz-albite-scapolite-chlorite altered.
- Red-rock breccia: A variant of the calc-silicate breccia with highly hematite stained clasts (0.5 to 50 cm diameter) with calcite-hematite-chlorite-quartz altered matrix which overprints an earlier albite alteration.
- Quartz-tourmaline: Occurs north of, and overprints, the red-rock breccia. This assemblage comprises quartz, muscovite, biotite and tourmaline forming fine grained, dark grey rocks with light grey clots of quartz-tourmaline.
- Quartz-albite: Fine grained, light-pink to white rocks dominated by albite and quartz forming silicified breccias and pervasive alteration of fine grained metasediments (e.g., biotite schists).
- Gossan and secondary Cu-carbonate: Fe-rich gossan comprising hematite, goethite and limonite form small outcrops close to mineralisation. Locally, secondary malachite in thin veins and fractures occurs in albitised rocks.

The Lady Clayre alteration paragenesis is complex with likely multiple stages of overprinting hydrothermal alteration events. Habermann (1999) and Gniel (2011) both documented paragenetic alteration-mineralisation sequences which involve early quartz-albite alteration and later muscovite-chlorite alteration followed by mineralisation (Fig. 17.13).

HYMAP DATA

HyMap data was acquired in 2006-2007 over the district as part of the Block E Pilgrim Fault survey. Figure 17.14 to 17.17 are representative images of the HyMap data, which covers the Roseby deposits. The spatial resolution of the HyMap sensor is 3-10m depending on flight height.

The data was flown on behalf of the Geological Survey of Queensland and CSIRO, and is available at: https://qdexdata.dnrme.qld.gov.au/gdp/search

The principal reference for the program is Cudahy et al (2008).

Figure 17.14 provides a false colour image.

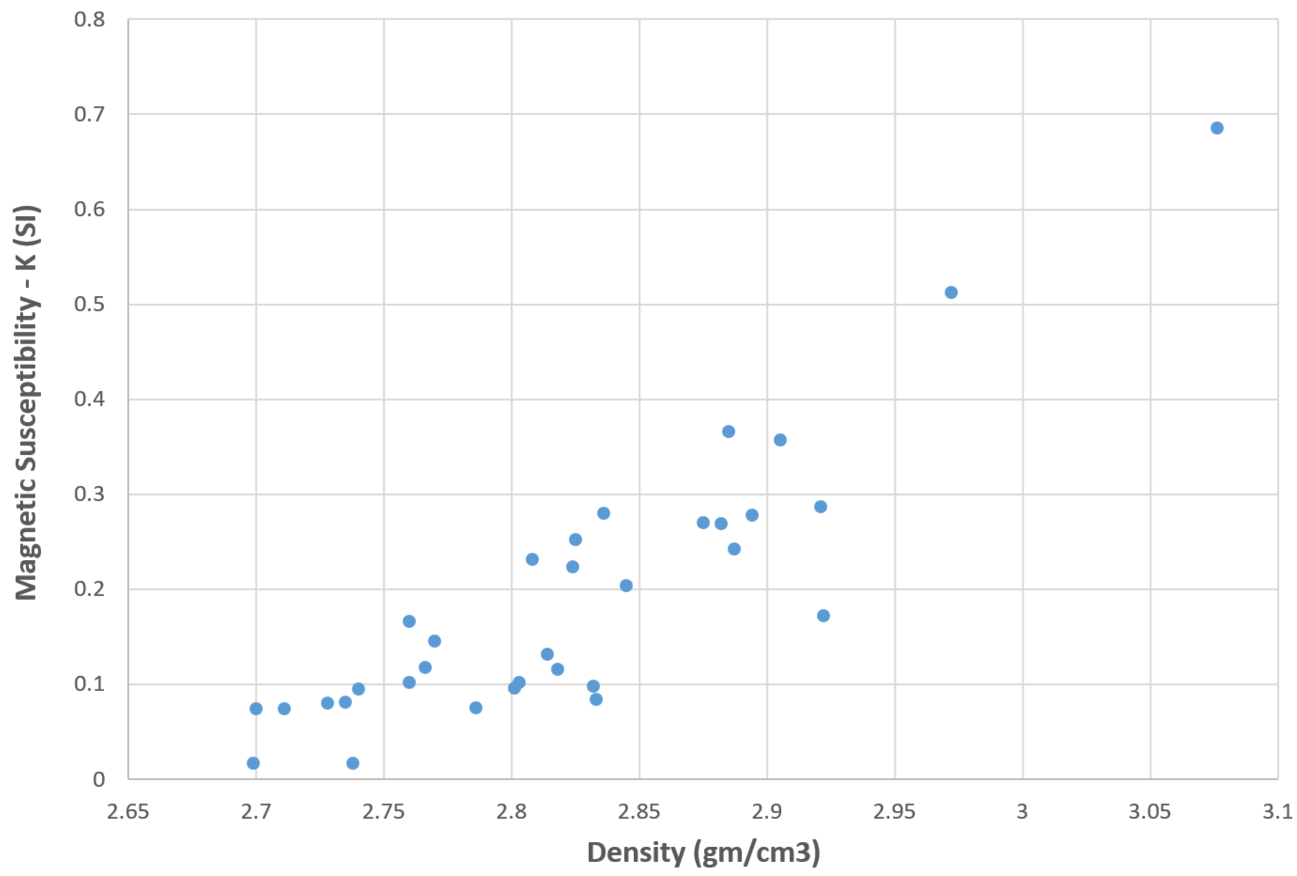


Figure 17.12: Plot of magnetic susceptibility (K) and density data from the Little Eva deposit. All data from drill holes LED209 and LED 591. Collected by the CSIRO Uncover Cloncurry project (Gazley et al, 2016).

Figures 17.15, 17.17 and 17.18 map white mica abundance, composition (muscovite/ paragonite versus phengite), and crystallinity, respectively.

The mica composition mapping is sensitive to the Al-content of the white mica that ranges from paragonite/muscovite (Al-rich) to phengite (Al-poor) and driven by coupled "Tschermak" substitution (Cudahy et al., 2008). Blue colours represent the Al-rich mica (muscovite, paragonite), whilst red is Al-poor mica (~phengite).

The mica crystallinity processing highlights "wet" illitic compositions in blue, versus "dry" muscovite in red (see Cudahy et al, 2008)

PETROPHYSICAL PROPERTIES

The Roseby deposit was subjected to extensive petrophysical testing by Gazley et al (2016), including measurement of magnetic susceptibility, and remanent magnetisation.

The majority of the magnetic susceptibility values range from 0.07 to 0.36 SI, but several outliers produce a minimum-maximum range of 0.016 to 0.68 SI.

The density data provided values between 2.7 and 3.08 gm/cm^3. (Fig. 17.12)

GEOPHYSICAL EXPRESSION

Aeromagnetic

Unsurprisingly, given its IOCG affinities and the petrophysical data documented by Gazley and Collins (2016), the Little Eva deposit represents a significant positive aeromagnetic anomaly of approximately 2,500nT (Fig 17.7). The other deposits do not have appreciable magnetic signatures.

Airborne EM

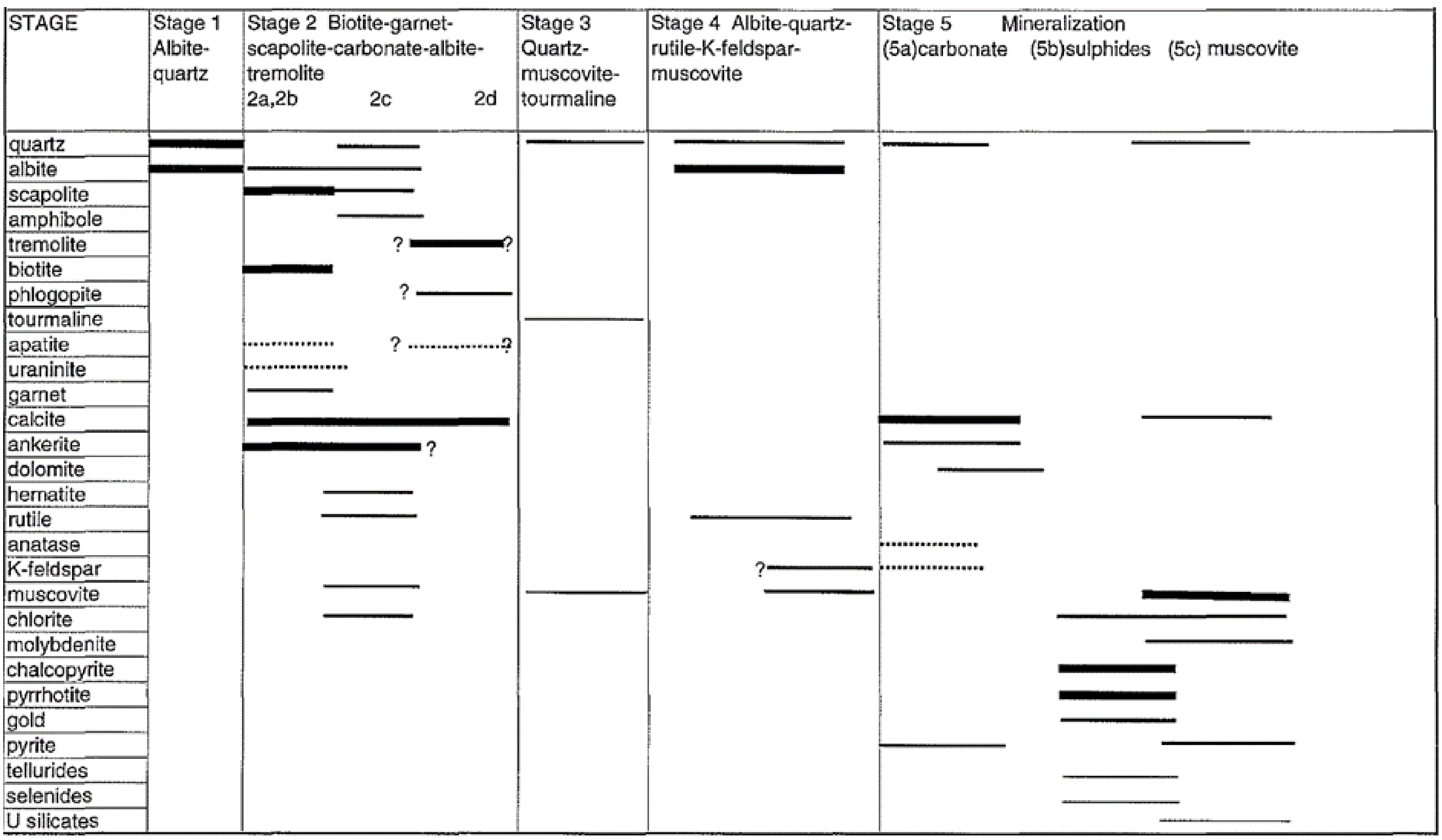
The Mount Roseby GeoTEM survey was flown by CRA in 1991 (archived with the GSQ as Survey No. 495). Plots of raw gridded GeoTEM data from a variety of early to late time channels are provided in Fig 17.18. The Blackard deposit is obvious as a positive response in the early time channels, presumably related to the shallow oxidised (± native copper) body. The Dugald River stratigraphy (or orebody?) is notable in the late time channels.

Radiometric

The Lady Clayre deposit demonstrates a potentially uranium-enriched radiometric signature (Fig 17.22). The Coocerina Formation (Ppc) is locally uranium anomalous, based on the airborne data, but it appears to be more so in the Lady Clayre area.

In addition, discrete high uranium zones are related with numerous unnamed prospects in the Mount Roseby Schist (Ppo) in the south-central portion of this area (presumably as a result of hydrothermal alteration).

Figure 17.13: Alteratiion paragenesis of the Lady Clayre deposit. From Habermann (1999).



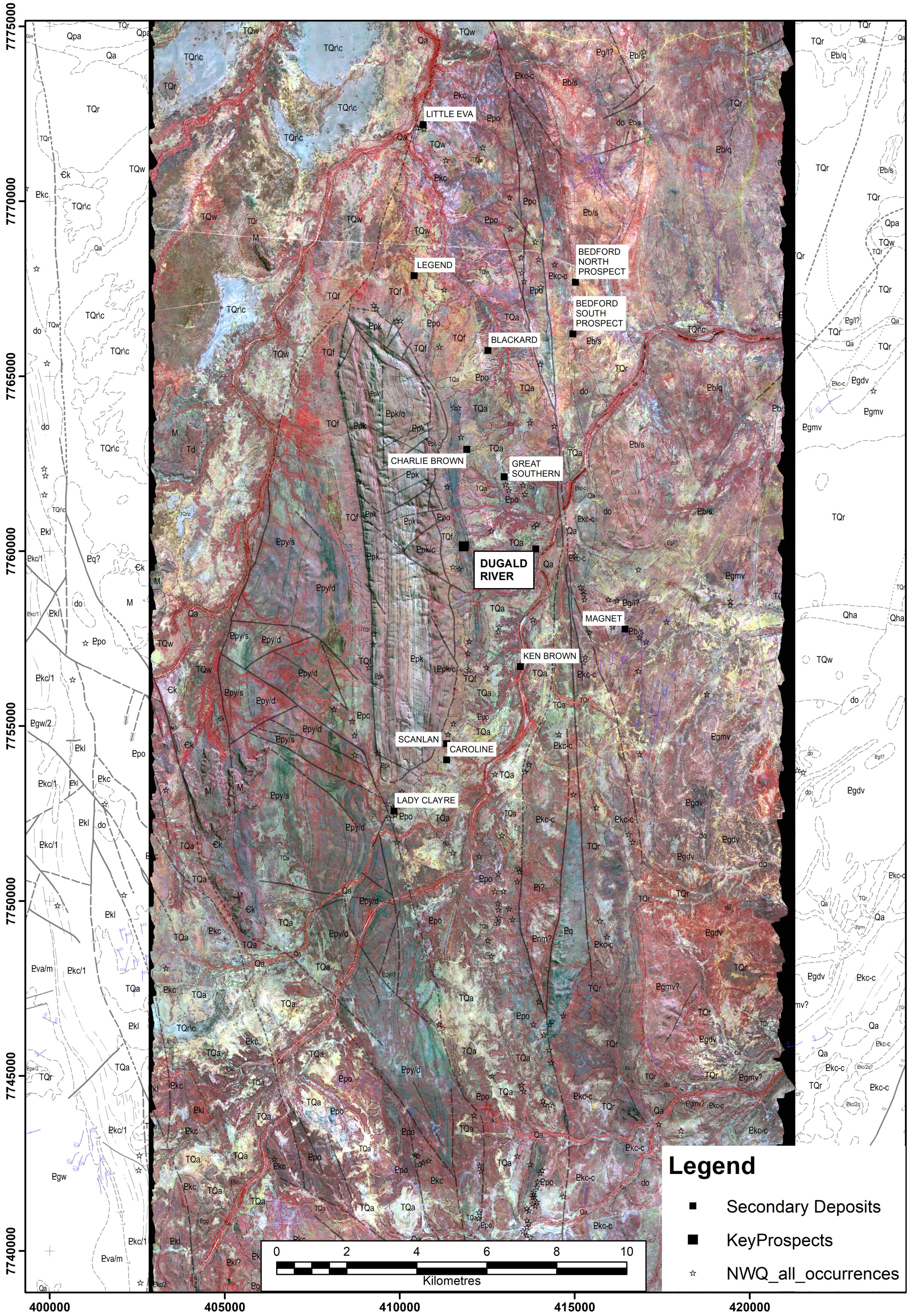


Figure 17.14: HyMap false colour image (from QDEX Data). From Stage 1 (Pilgrim Block E) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise.

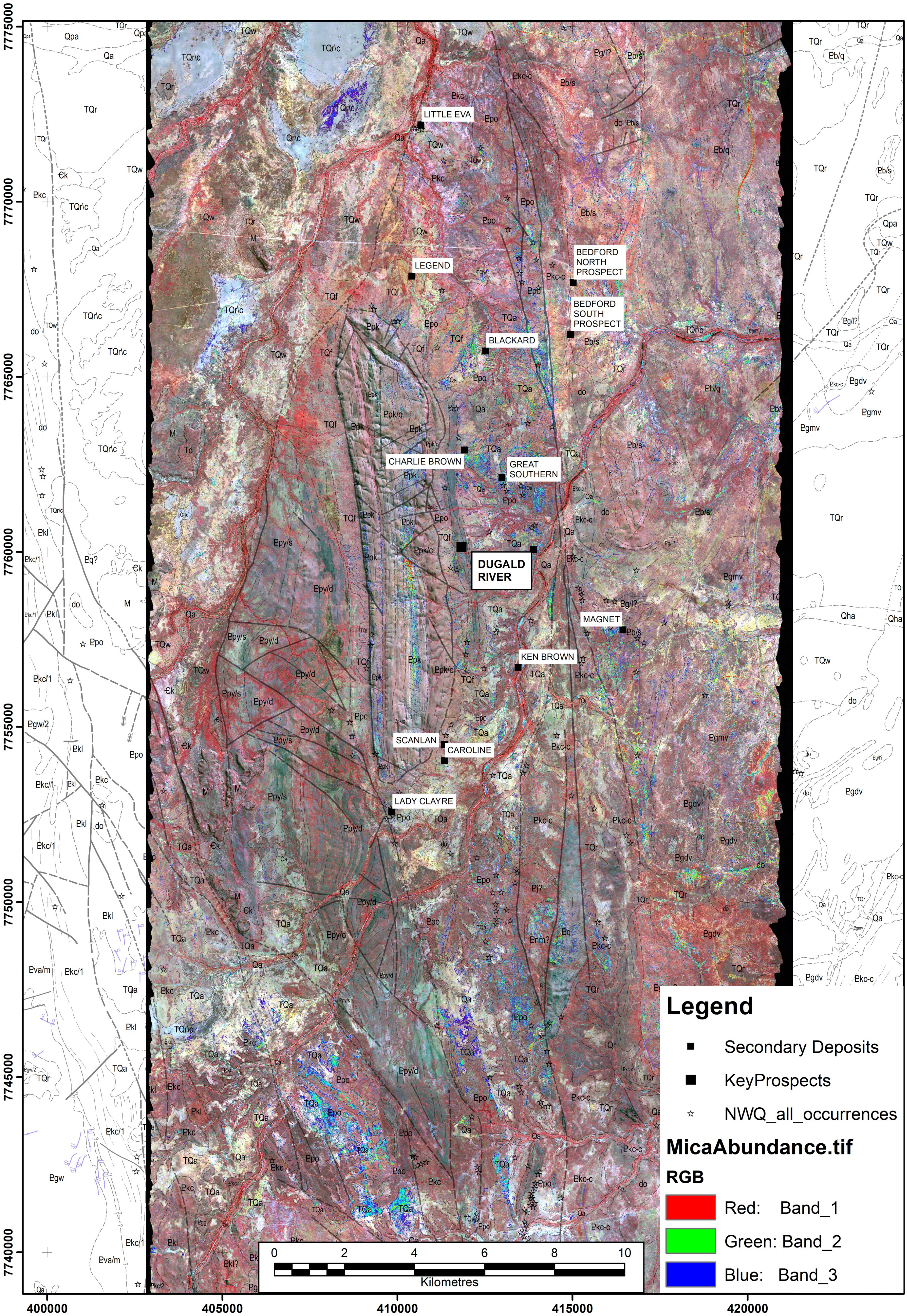


Figure 17.15: HyMap mica abundance image (from QDEX Data). From Stage 1 (Pilgrim Block E) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise. Blue colours represent the lower muscovite abundance, whilst red is higher abundance.

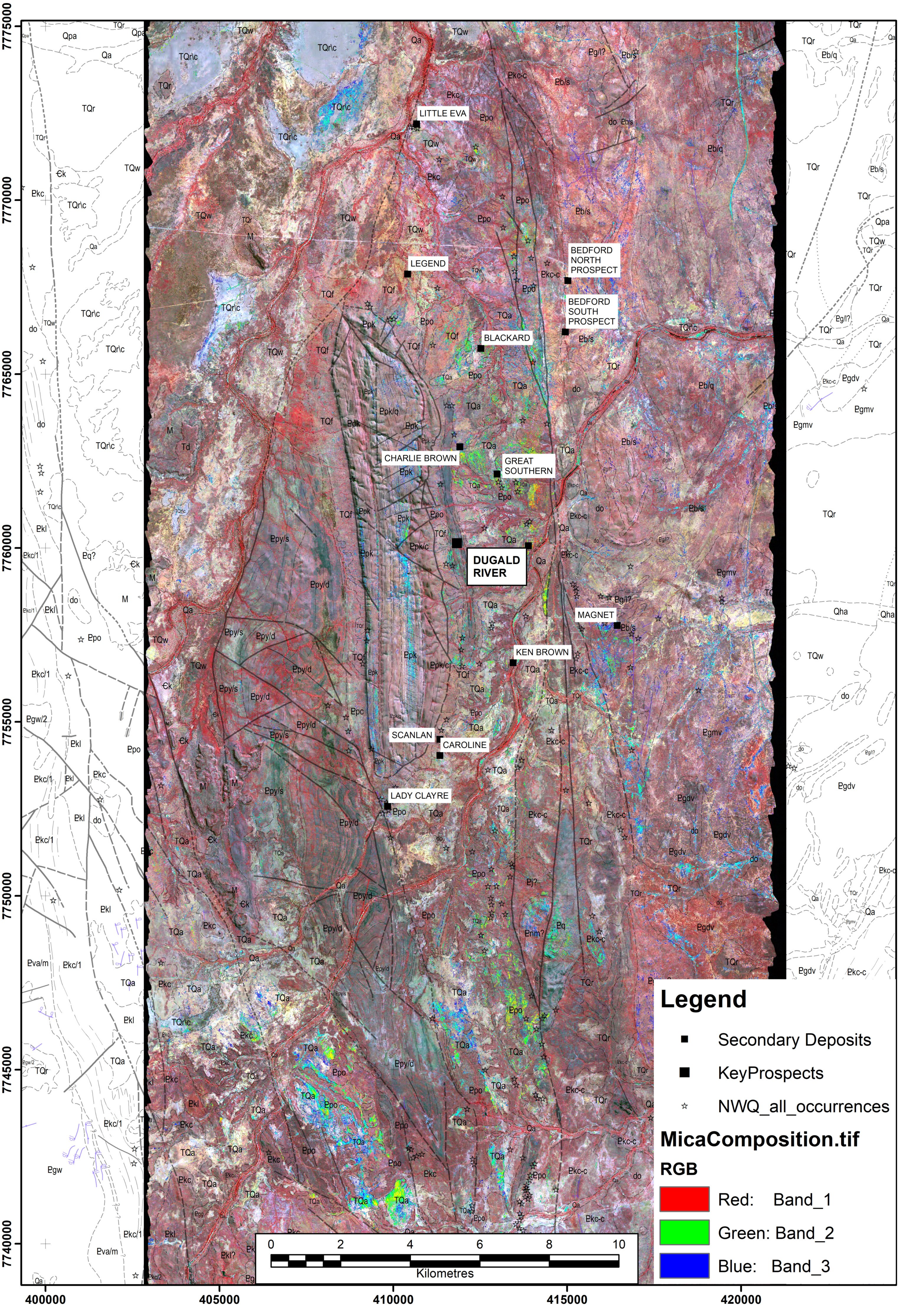


Figure 17.16: HyMap mica composition image (from QDEX Data). From Stage 1 (Pilgrim Block E) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise. Blue colours represent the Al-rich mica (muscovite, paragonite), whilst red is Al-poor mica (~phengite).

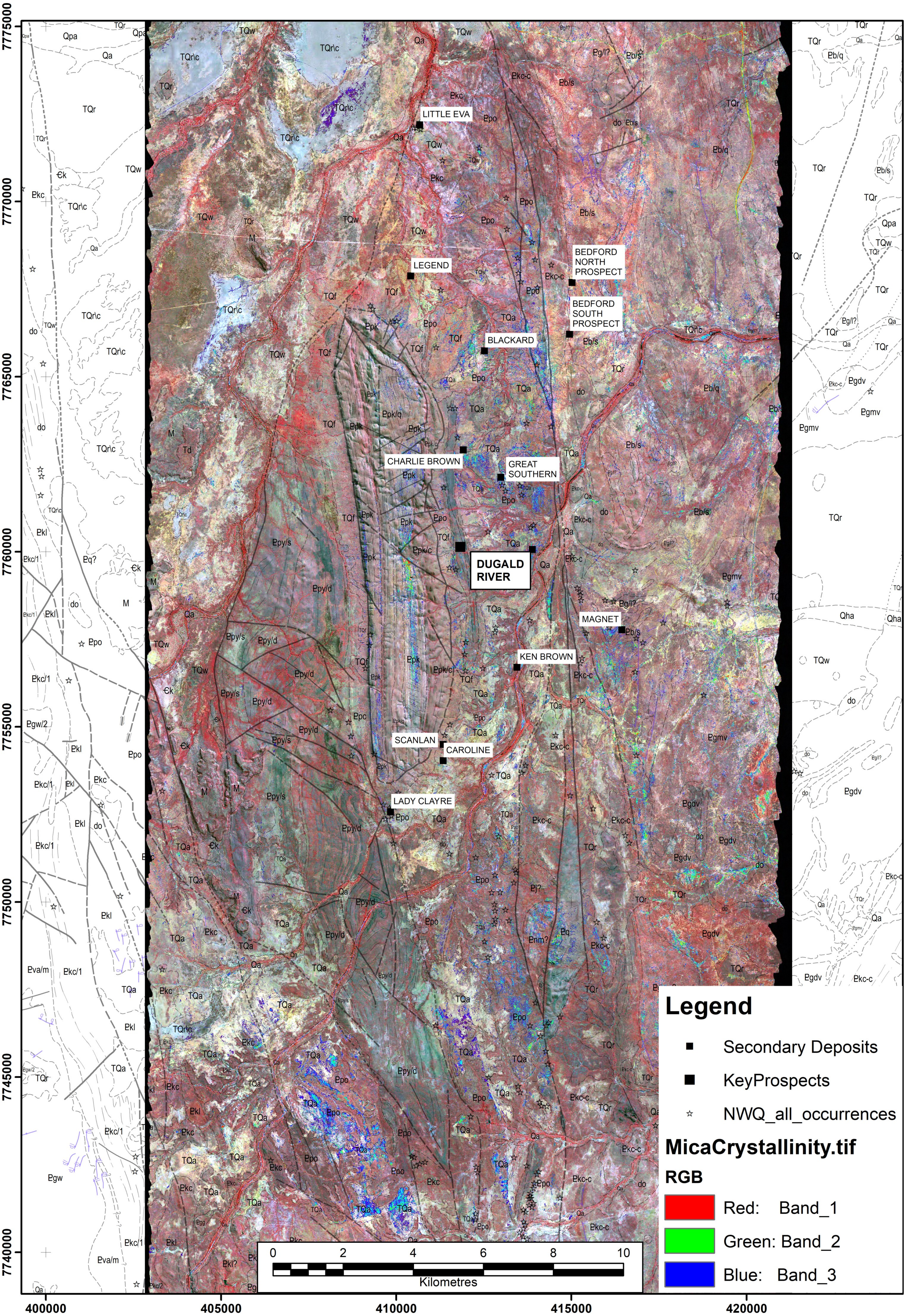


Figure 17.17: HyMap mica crystallinity image (from QDEX Data). From Stage 1 (Pilgrim Block E) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise. This processing highlights "wet" illitic compositions in blue, versus "dry" muscovite in red (see Cudahy et al, 2008)

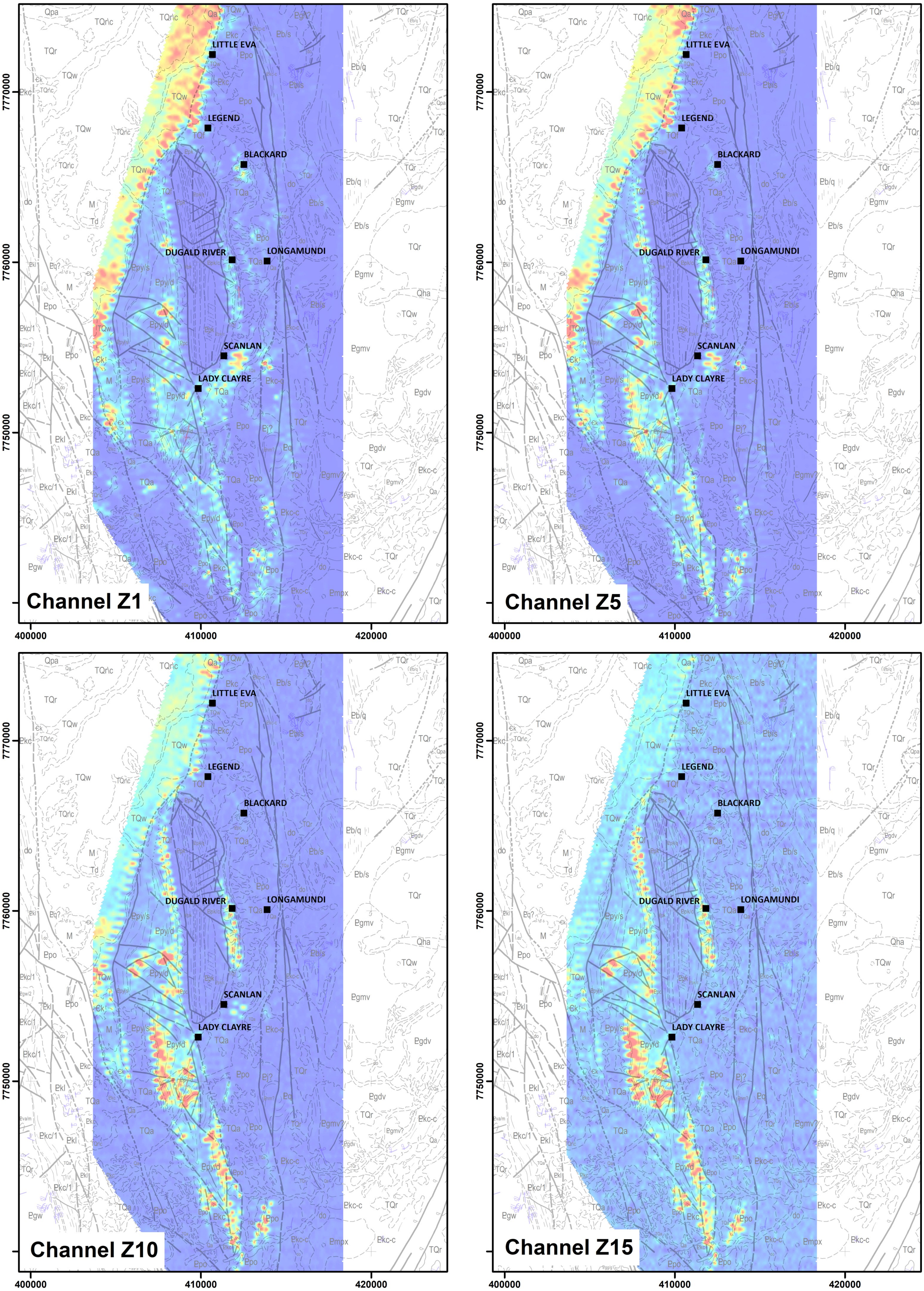


Figure 17.18: Plots of raw gridded GeoTEM data from the Mount Roseby GeoTEM survey flown by CRA in 1991, and archived with the GSQ as Survey No. 495. A variety of early to late time channels are shown. The Blackard deposit is obvious as a positive response in the early time channels, presumably related to the shallow oxidised (± native copper) body. The Dugald River stratigraphy (or orebody?) is notable in the late time channels.

EXPLORATION GEOCHEMISTRY

Stream Sediment Geochemistry

Plots of the regional stream sediment geochemical samples are provided in Figs 17.23-26.

Stream sediment geochemistry appears to function in the area. CRA (1982) note that the Blackard deposit was “rediscovered” by CRA in 1977 by stream sediment sampling. However, later surface geochemical work in the area moved towards the use of soil sampling and then auger sampling.

Soil Geochemistry

CRC-LEME completed a regolith geology and soil geochemistry study over the Little Eva copper prospect (Robertson et al, 2002, Robertson, 2003). The key conclusions were as follows:

- A shallow mantle of colluvium masks prospective ground to the south, and alluvium masks it to the north.
- copper and gold are the only indicator elements, from among 44 elements, which detect the Little Eva style of mineralisation in the soil (Fig. 17.19). With careful interpretation, these depict the bedrock Cu anomaly beneath the colluvium
- Fe, Co and V may be used to trace magnetite-rich rocks which may have exploration significance.

TIMING OF MINERALIZATION

Relative Timing

Assuming the Roseby deposits are epigenetic, the maximum age for the Roseby Schist (and the Dugald River Shale Member) of approximately 1686Ma (CMMC, 2018) provides a maximum age for the mineralisation.

Thomas (1994) suggests that the lack of a fabric in the altered hosts to the Little Eva mineralisation indicates the alteration and mineralisation was post-D3 deformation.

Absolute Age

No absolute age dates are available from the Roseby deposits.

GENETIC MODEL

Given the structurally controlled nature of the Roseby deposits, being commonly shear hosted and/or with tectonic breccias, they are typically considered as epigenetic deposits, and at least the Little Eva deposit is categorised as an IOCG deposit.

POST-FORMATION MODIFICATION

The deposits appear to have undergone minimal post-formation modification. Weathering has clearly modified the original sulphide deposits, with most deposits now having an oxide zone, and in the case of Blackard also having a native copper zone.

EXPLORATION

Discovery Method

The copper deposits of the Roseby area were typically discovered in the early 1900’s by traditional prospecting. Robertson (2003) notes in regard to Little Eva that “This small deposit (previously known as Cabbage Tree Freehold) was discovered by conventional prospecting, which probably detected the green Cu carbonates in the lag, still visible today. In 1942 a small shaft (8m) had been sunk and a production declared of 13t Cu, 8oz Ag and 4 oz Au.”

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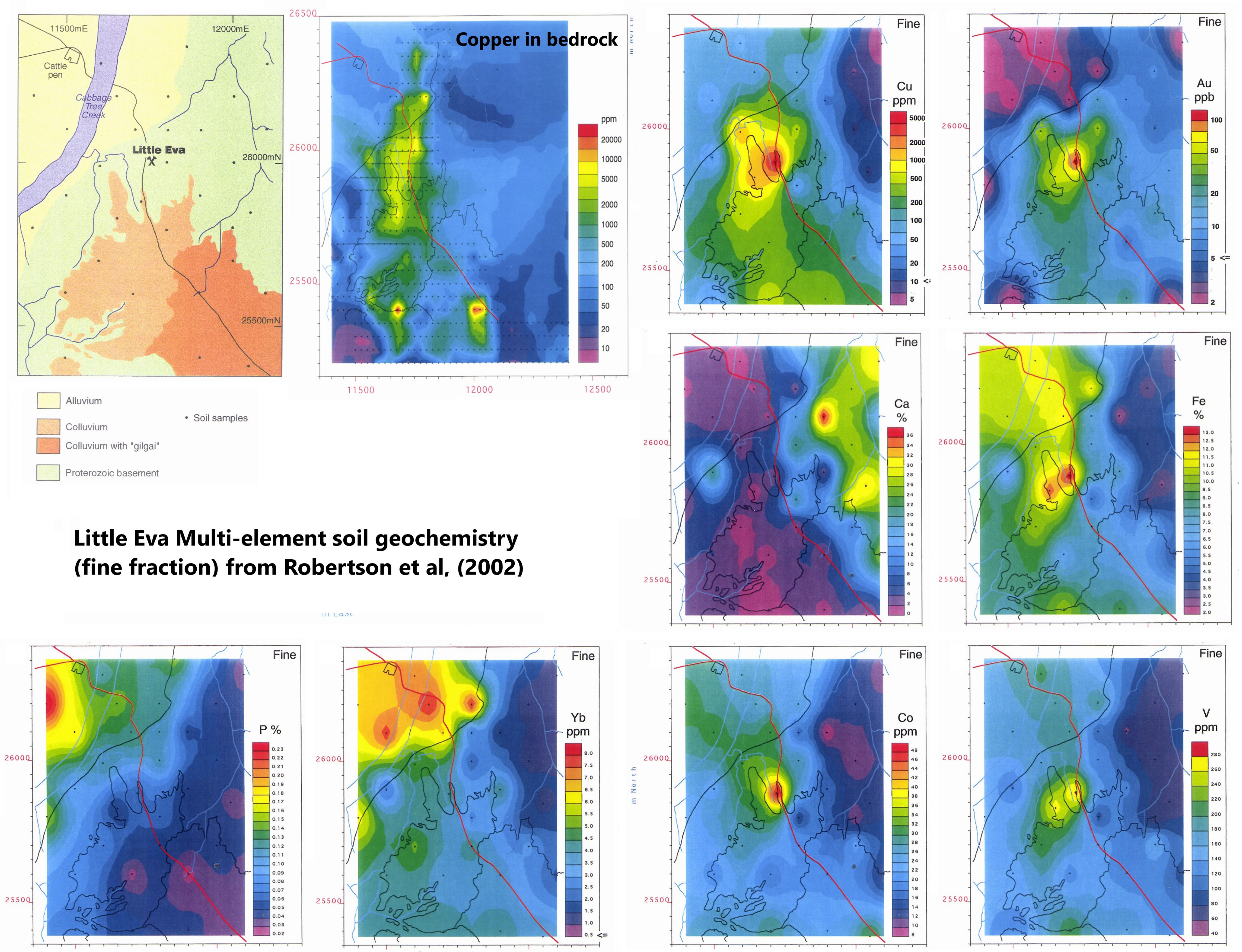

Figure 17.19: Maps of the bedrock copper anomaly from the Little Eva deposit, with corresponding soil geochemical results. The soil geochemical results are fro the fine fraction (<75µm). The black polylines on the map represent the CSIRO regolith mapping. From Robertson et al. (2002).

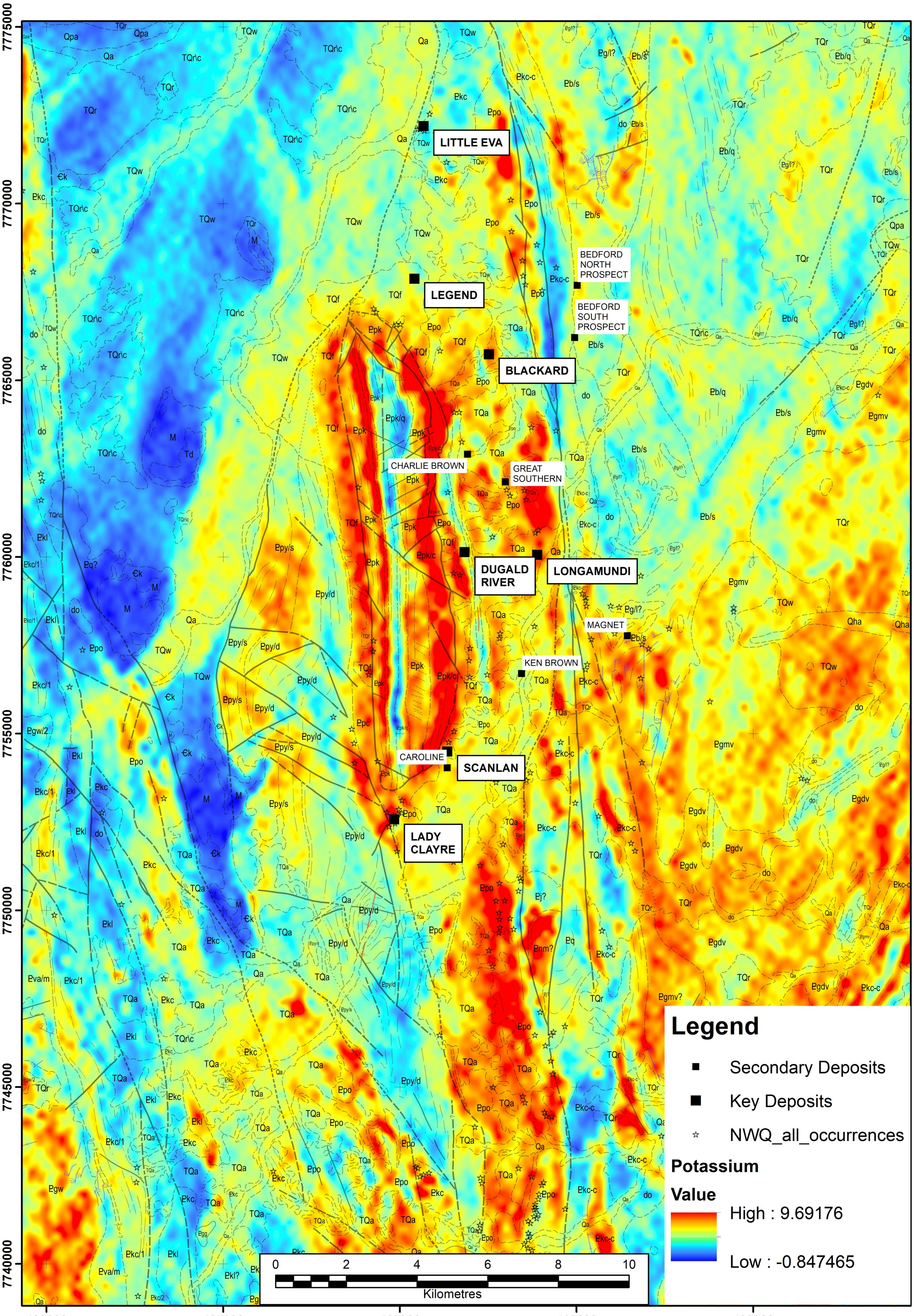

Figure 17.20: Potassium image (from QDEX Data). The high potassium zones are dominated by the calcareous feldspathic medium-grained sandstone and siltstone member of the Knapdale Quartzite (Ppk/c), and to a lesser extent the Mount Roseby Schist (Ppo). In contrast the white, fine grained, quartzose sandstone member of the Knapdale Quartzite (Ppk/q) demonstrates a low potassium signature.

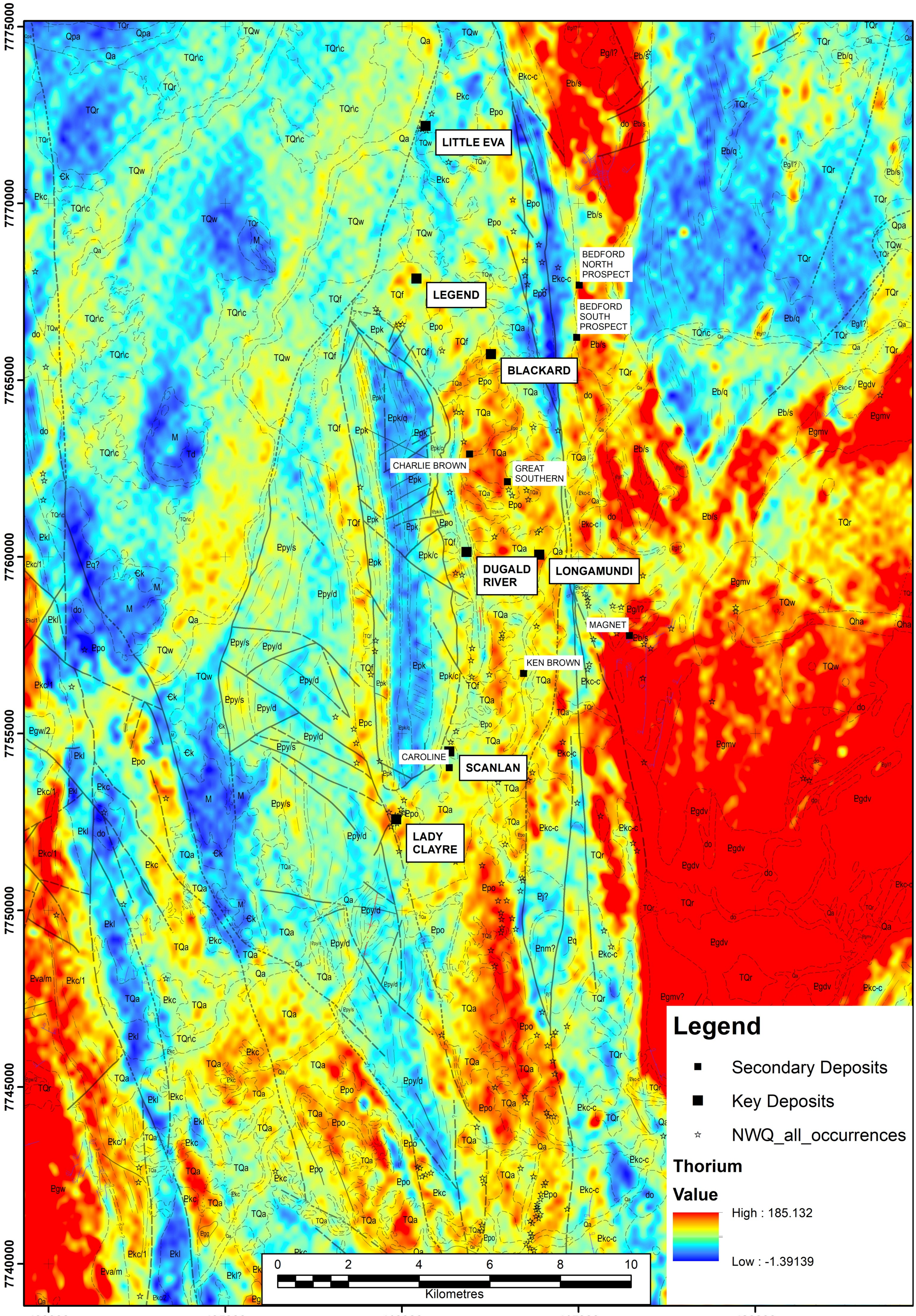

Figure 17.21: Thorium image (from QDEX Data). The high thorium zones are dominated by the Wonga Granite (Pgw) in the west, the Dipvale Granodiorite (Pgdv) and the Mavis Granodiorite (Pgmv) in the east, and parts of the Boomarra Metamorphics (Pb/s).

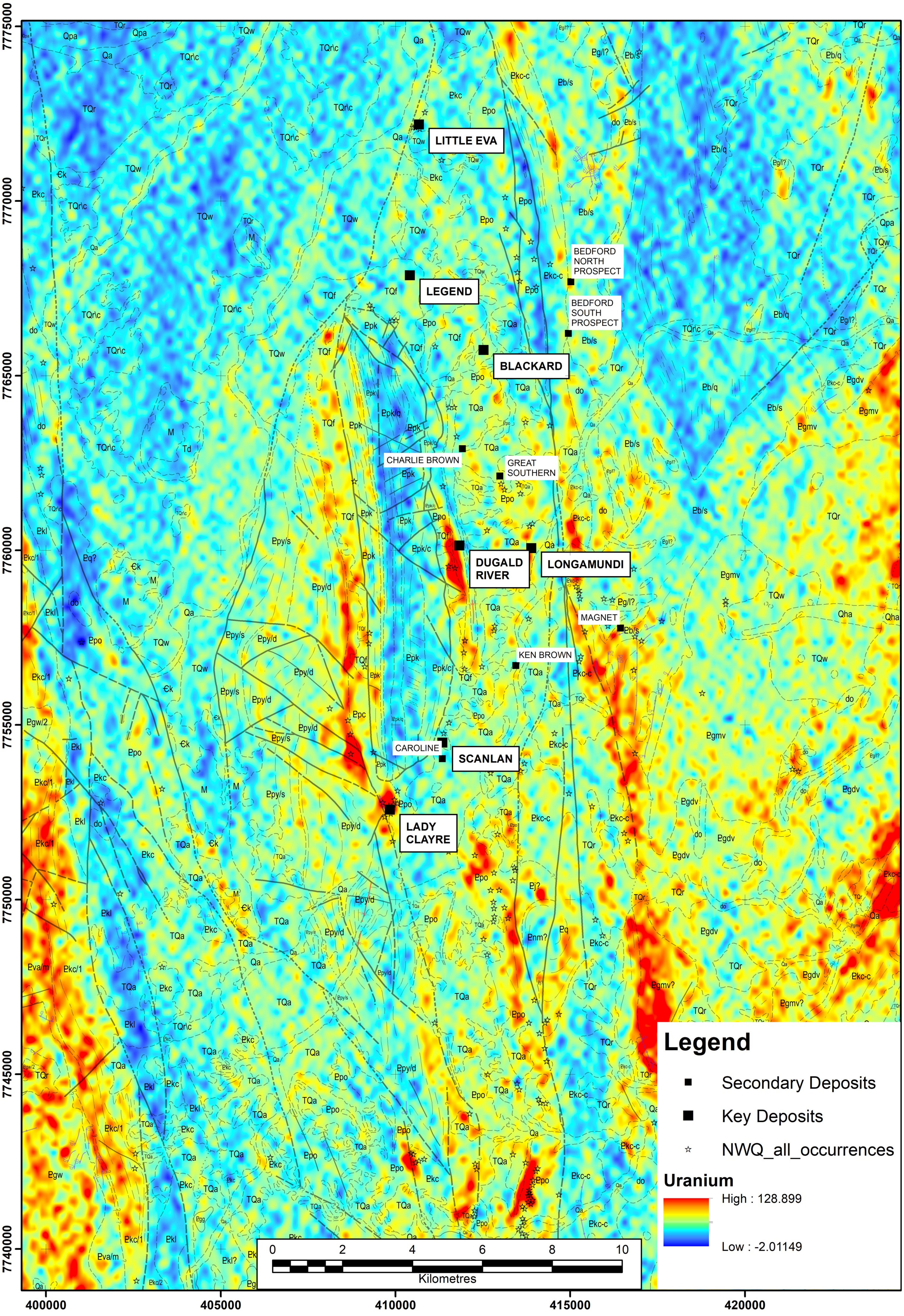

Figure 17.22: Uranium image (from QDEX Data). The high uranium zones comprise parts of the Mavis Granodiorite (Pgmv) and parts of the Coocerina Formation (Ppc), which is a black shale, most notably in the vicinity of the Lady Clayre deposit. In additional discrete high uranium zones are related with numerous unnamed prospects in the Mount Roseby Schist (Ppo) in the south-central portion of this area (presumably as a result of hydrothermal alteration). The Dugald River deposit area is also highly anomalous.

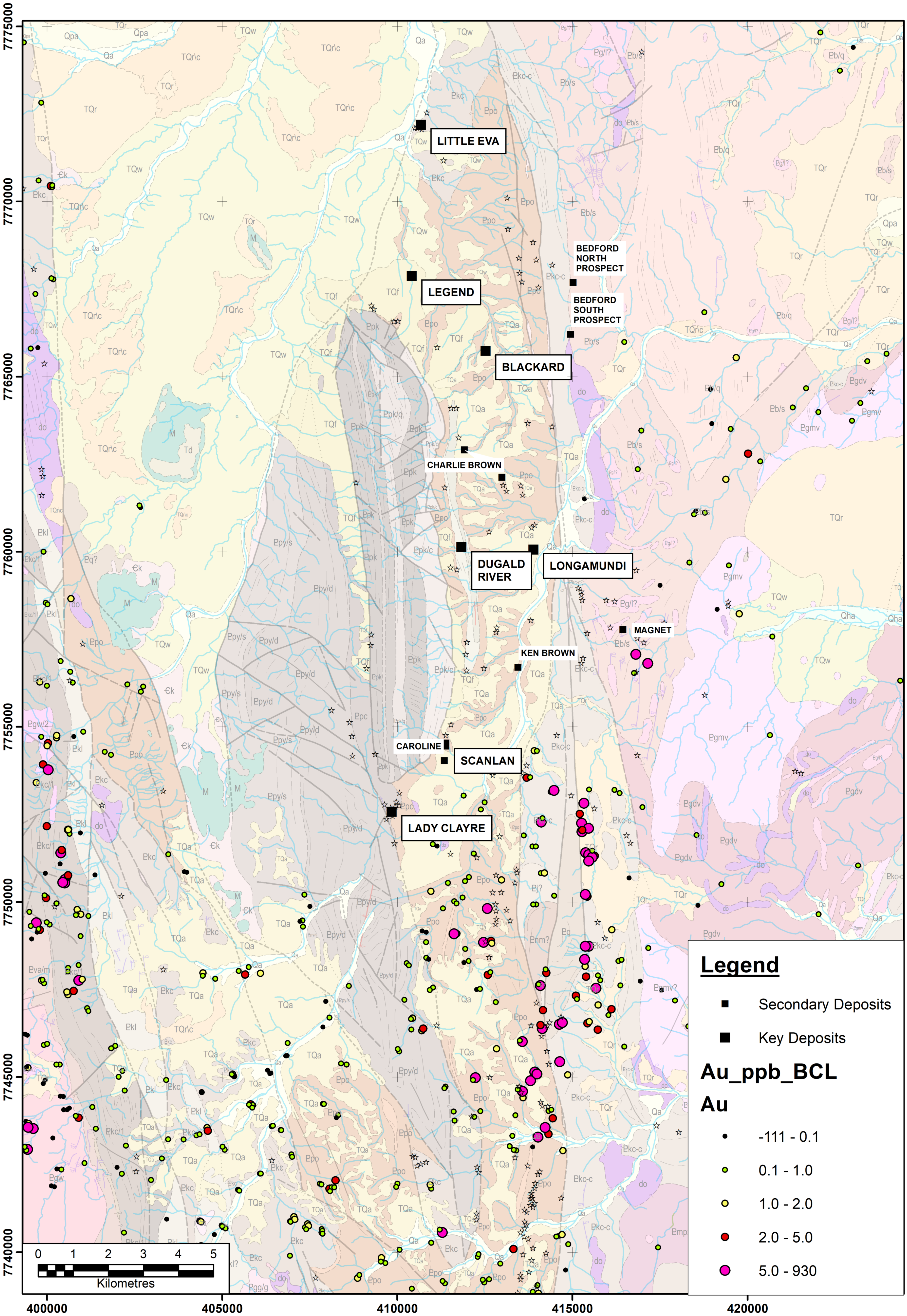

Figure 17.23: Plot of gold values from the open file stream sediment data in the Roseby district (from QDEX Data—East Isa collection). The data has not been levelled for mesh size used for collection, but a majority of samples utilised an approximate –2mm fraction and the analysis was via a bulk leach.

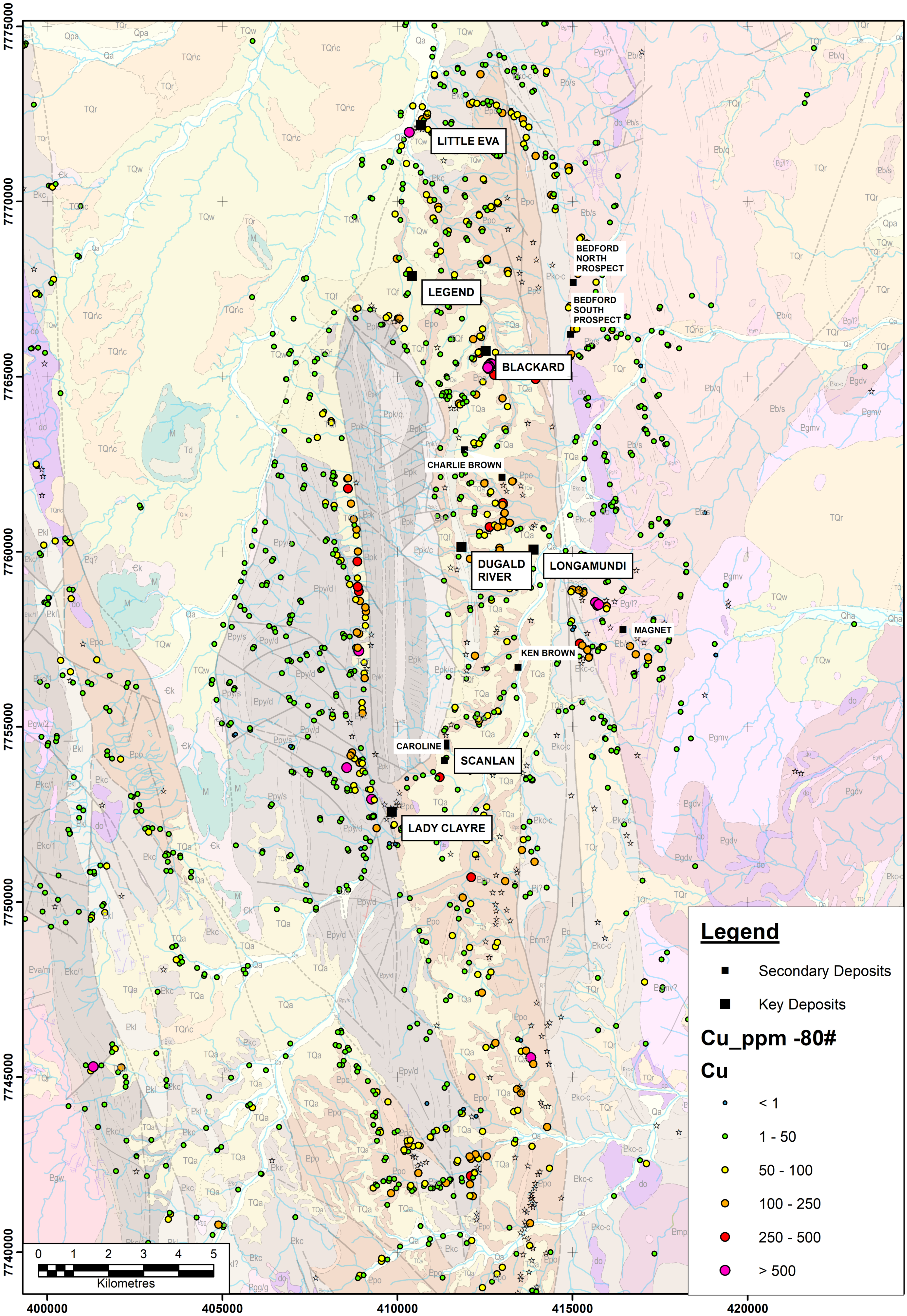

Figure 17.24: Plot of copper values from the open file stream sediment data in the Roseby district (from QDEX Data—East Isa collection). All data points shown utilised a –80# fraction.

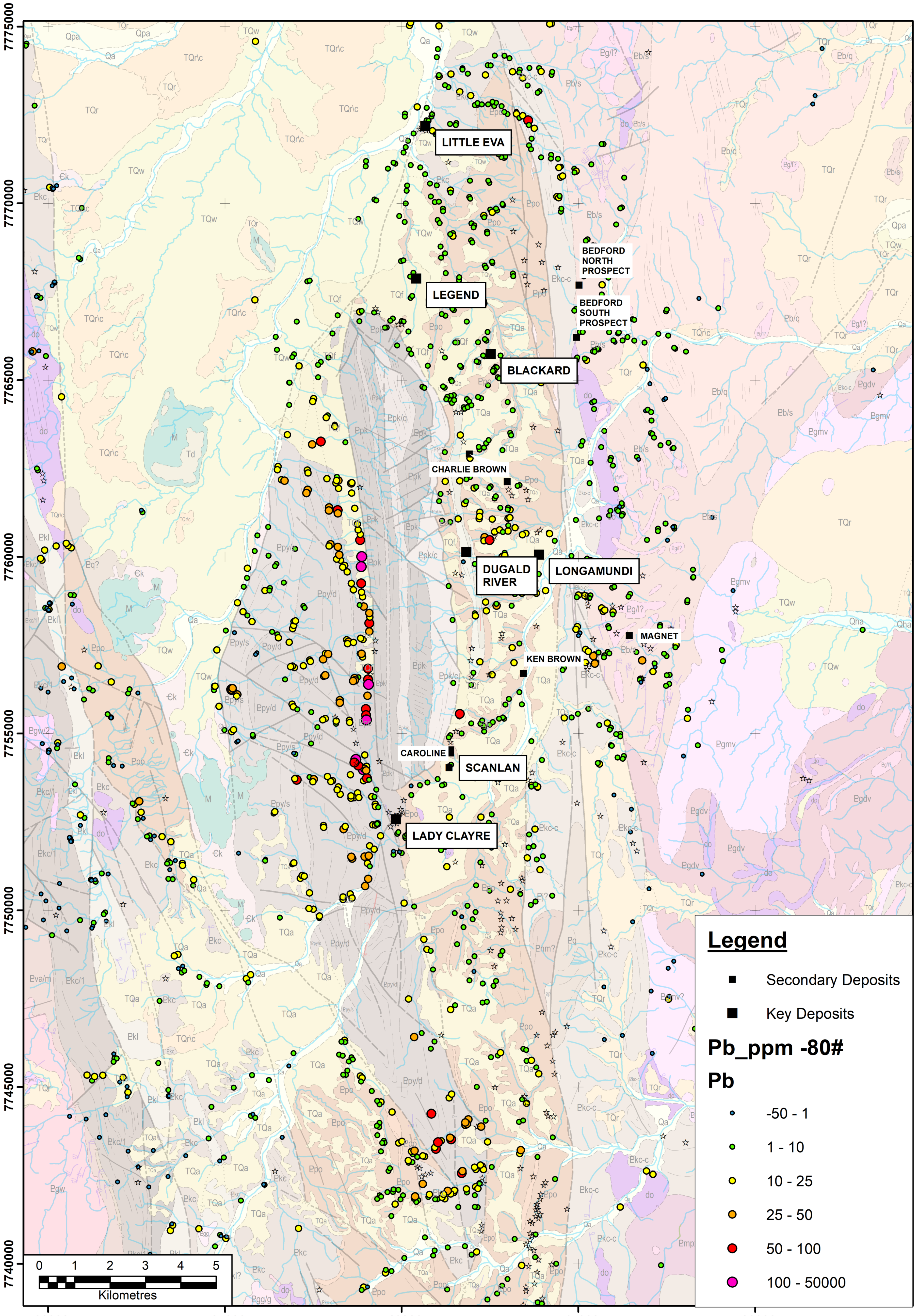

Figure 17.25: Plot of lead values from the open file stream sediment data in the Roseby district (from QDEX Data—East Isa collection). All data points shown utilised a –80# fraction.

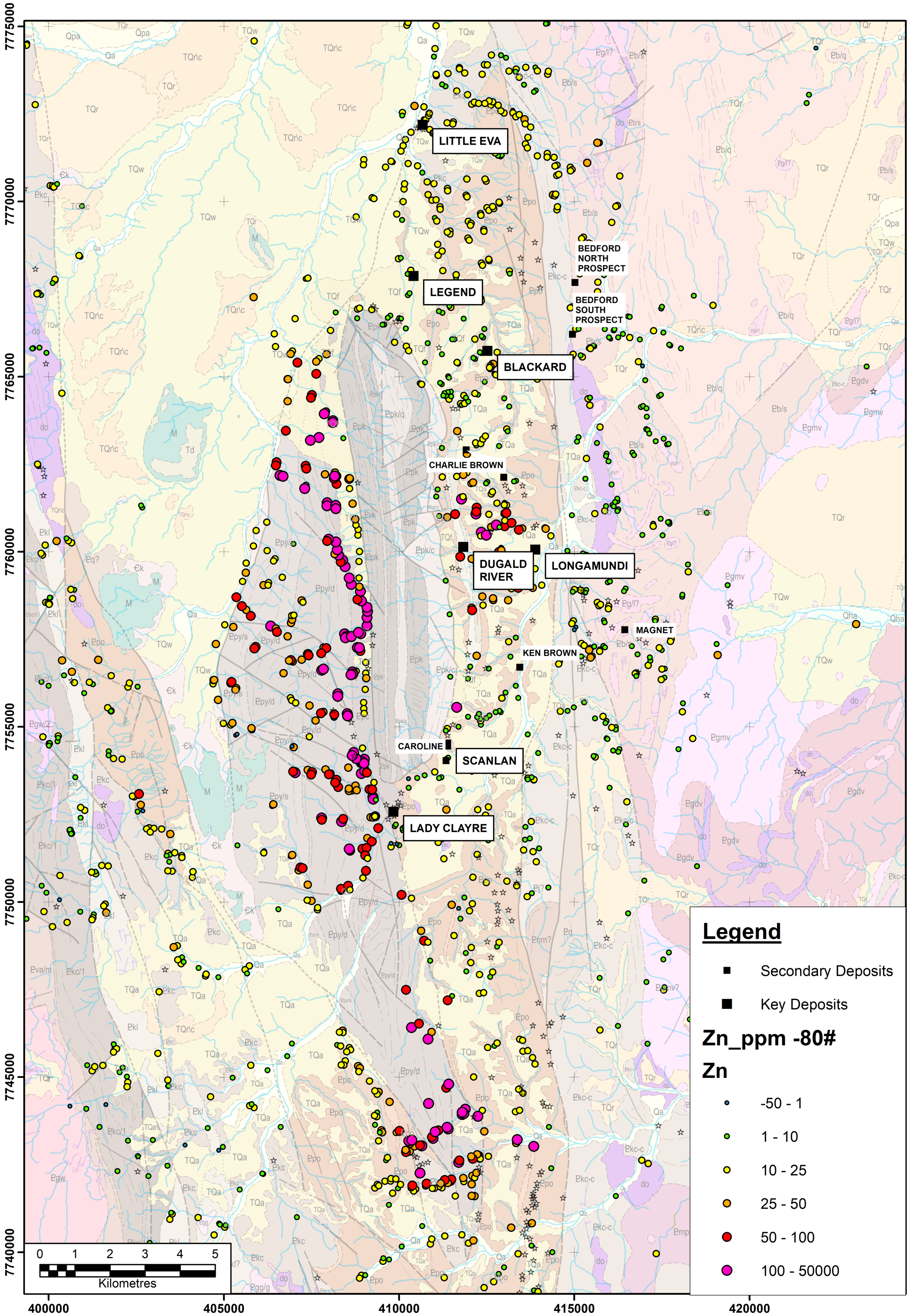

Figure 17.26: Plot of zinc values from the open file stream sediment data in the Kalman district (from QDEX Data—East Isa collection). All data points shown utilised a –80# fraction.