Mary Kathleen U-REE Deposit

PREAMBLE

The Mary Kathleen U-REE deposit is a uraninite-allanite-garnet dominated hydrothermal deposit hosted within a garnet-pyroxene skarn. It is located in the high strain Mary Kathleen Fold Belt.

It was mined over two phases between 1958 and 1982. Uranium was extracted, but the rare earth elements remain as a significant resource in the tailings.

LOCATION

Geological Domain

Mary Kathleen Domain (Figures 18.1, 18.2).

Co-ordinates

Latitude: 20°44' 43" S
Longitude: 140° 0' 42" E
MGA Zone 54/GDA94: 397,115 mE; 7,705,700 mN

NATURE OF MINES

Mined Commodities

Uranium was mined from the deposit, with production as uranium oxide. The deposit contained elevated levels of rare earth elements (to 7.6%, Cruickshank et al, 1980) and thorium, but these were never extracted.

Mining Method & Depth of Mining

The ore was mined via open pit mining, and the mill had a nominal capacity of 760t U/year. The 0.13% U ore was upgraded by radiometric sorting to 0.20% U, before crushing, grinding and processing to produce uranium oxide.

The processing method during 1958-1963 comprised the use of sulphuric acid to leach the ore, ion exchange to separate the uranium and then magnesia to precipitate the yellowcake. During the period 1976-1982 solvent extraction was instead used as the processing technique. (McKay and Miezitis, 2001).

Open pit mining occurred to a maximum approximate depth of 230m (Costelloe, 2003).

PRODUCTION AND RESOURCES

Mineralised Bodies

The uranium mineralisation occurred within a single orebody, but comprised multiple lenses and anastomosing ore shoots (Figure 18.3).

Dimensions

The orebody had a thickness of between 50 -100m (considering all lenses grouped), a strike length of approximately 250m (based on the size of the open pit), and a down-dip extent of approximately 300m (Figure 18.3).

Orientation of Mineralised Bodies

The lenses strike approximately NNW, but in section view steepen downwards and to the west (Figure 18.3) from approximately 40° to more than 60° (Oliver et al, 1999).

Production

The first stage of uranium production from the Mary Kathleen deposit was between 1958 and 1963. Production during that period comprised treatment of 2.947Mt @ 0.2% U of ore for total production of 3,460t of uranium (4080t of U3O8). The 0.2% U grade was after radiometric ore sorting, with the run-of-mine ore grading 0.13% U (McKay and Miezitis, 2001).

The second stage of production was between 1976 and 1982, in which production totaled 4072t U (4802 t U3O8). There has been no further production beyond 1982.

Mineral Resources

The pre-mining mineral resource at Mary Kathleen comprised 9.483Mt @ 0.131% U_3O_8 (Hawkins 1975).

There is a reported remaining mineral resource below the open pit of approximately 1018 t U (1200t U_3O_8) (McKay and Miezitis, 2001; McKay et al, 2013).

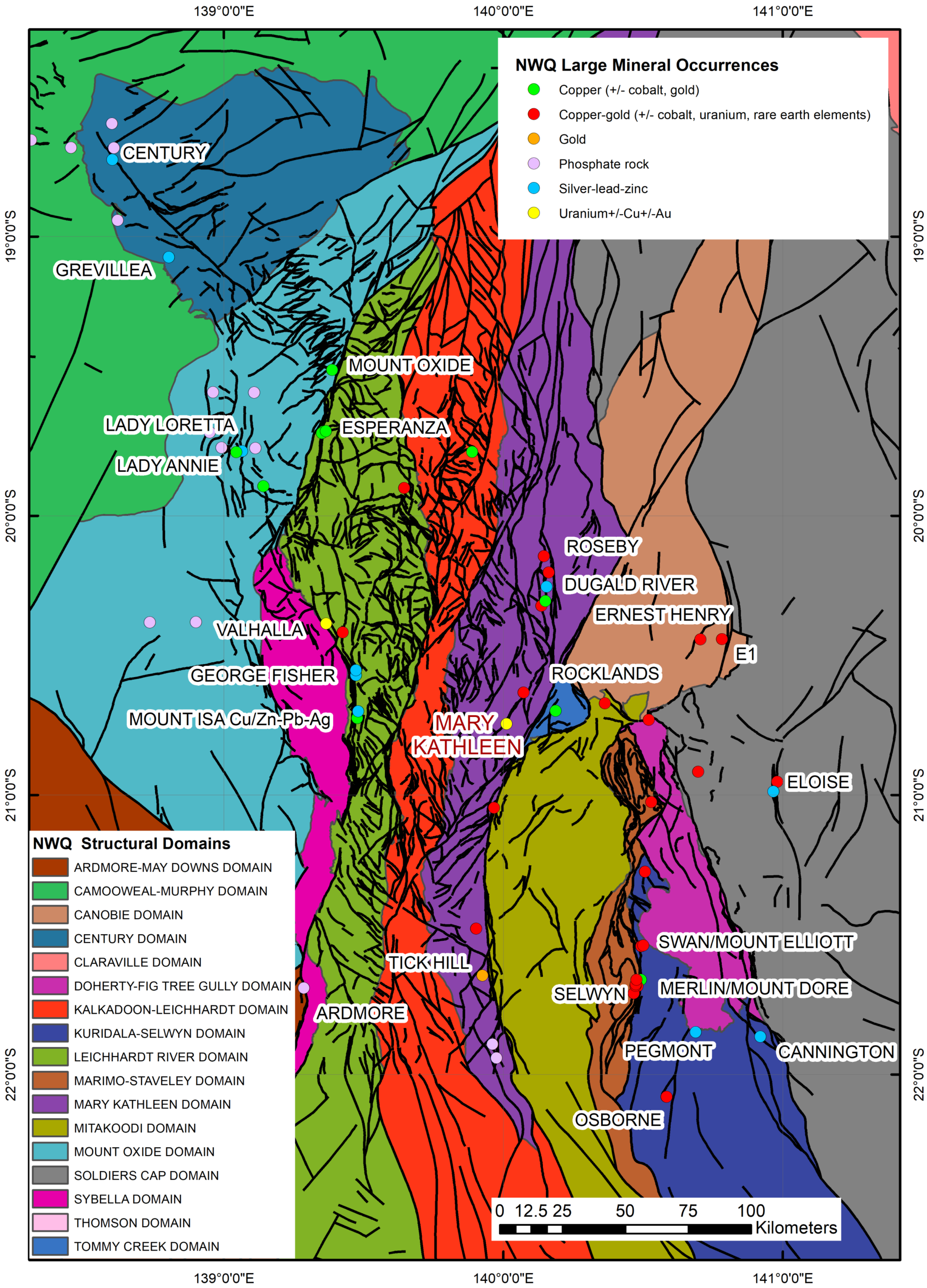


Figure 18.1: Location of the Mary Kathleen deposit shown with respect to the Mount Isa Structural Domain Map from the 2010 NWQMEP GIS

The historical tailings at Mary Kathleen are classified as one of the world's 25 highest grade REE deposits by Weng et al (2015) with an estimated 5.5 million tonnes at 6.4 % TREO+Y (total rare earth oxides plus yttrium oxide).

HOST ROCKS

Mine Stratigraphy

The deposit is located within the Mary Kathleen Syncline, in which the rocks are dominated by hornfelsed calc-silicate rocks, skarns, quartzite and marble. These rocks are interpreted as belonging to the upper part of the 1780 – 1760 Ma Corella Formation (Derrick, 1978).

Major Host Rock

The Mary Kathleen deposit is hosted by garnet-diopside skarn, thin-bedded calc-silicate granofels, feldspar-rich cobble and boulder conglomerate, impure marble, mica schist, quartzite and amphibolite (Derrick, 1977; Hoatson et al, 2011). In addition there is an ophitic-textured 'monzonitic' intrusion (interpreted by Oliver et al 1999 as possibly an altered gabbro).

The host metaconglomerate, 'monzonite' and skarn display relict, partly recrystallised skarn textures as well as variably recrystallised clinopyroxene–garnet aggregates.

Relict ophitic texture of the igneous ('monzonite') host is locally preserved, suggesting predominantly replacive processes as inferred for most skarns worldwide. However, the distribution of early skarn at metre -scales indicates that this replacement process probably occurred outwards from a complex array of thin fractures, made worse by the initial heterogeneity of the metaconglomerate, and culminating in a breccia formed largely by replacement with a relatively minor component of infilling (Oliver et al 1999)

INTRUSIVE ROCKS

Granitoids

The dominant large intrusive felsic body in the vicinity of the orebody is the 1740 Ma Burstall Granite, outcropping approximately 2km to the east of the deposit. (Figure 18.4).

The Burstall Granite is a foliated coarse-grained batholith consisting of a number of discrete plutons, as well as a network of porphyritic rhyolitic apophyses near its western margin (Page 1983).

The Burstall Granite is recognised as associated with the production of the calcic skarn host rocks, although not the mineralisation itself (Oliver et al, 1999). The felsic dykes extending out from the batholith towards the deposit are interpreted as late stage differentiates of the Burstall Granite magma, and may have been directly involved with the skarn-forming process (Oliver et al 1999).

Mafic Intrusives

A large gabbroic intrusion (Lunch Creek Gabbro) crops out on the eastern margin of the Burstall Granite (Figures 18.4, 18.5). It has been dated at approximately 1740Ma and is generally considered to have been emplaced at a similar time to the Burstall Granite (Page 1983).

The NE-trending Lakeview Dolerite is an extensive late-stage mafic dyke present approximately 5km to the southeast of the Mary Kathleen deposit. It has been dated at 1116 ± 12 Ma by Page (1983) and is significantly younger than the mineralisation

METAMORPHISM

The host rocks to the Mary Kathleen deposit were subject to amphibolite facies metamorphism (Reinhardt, 1992; Oliver, 1995). The large garnet-pyroxene skarn bodies hosting the deposit are interpreted to have formed at depths of 4-6km (Oliver et al, 1999). Derrick (1977), using contact metamorphic nomenclature, terms the metamorphic grade as hornblende hornfels. Local contact metamorphism and metasomatism was associated with the intrusion of the Burstall Granite (1750-1730 Ma; Page, 1983). Metamorphic conditions reached 520-650°C and 100-200 MPa (Oliver et al, 1991) and depths of around 4 to 8 km.

Regional metamorphism was associated with D2 deformation, which reached a peak metamorphic grade of upper amphibolite facies reaching conditions of 600-650°C and 350-400 MPa (Oliver et al, 1991), equivalent to depths of approximately 15 km (Reinhardt, 1992; Oliver et al., 1999).

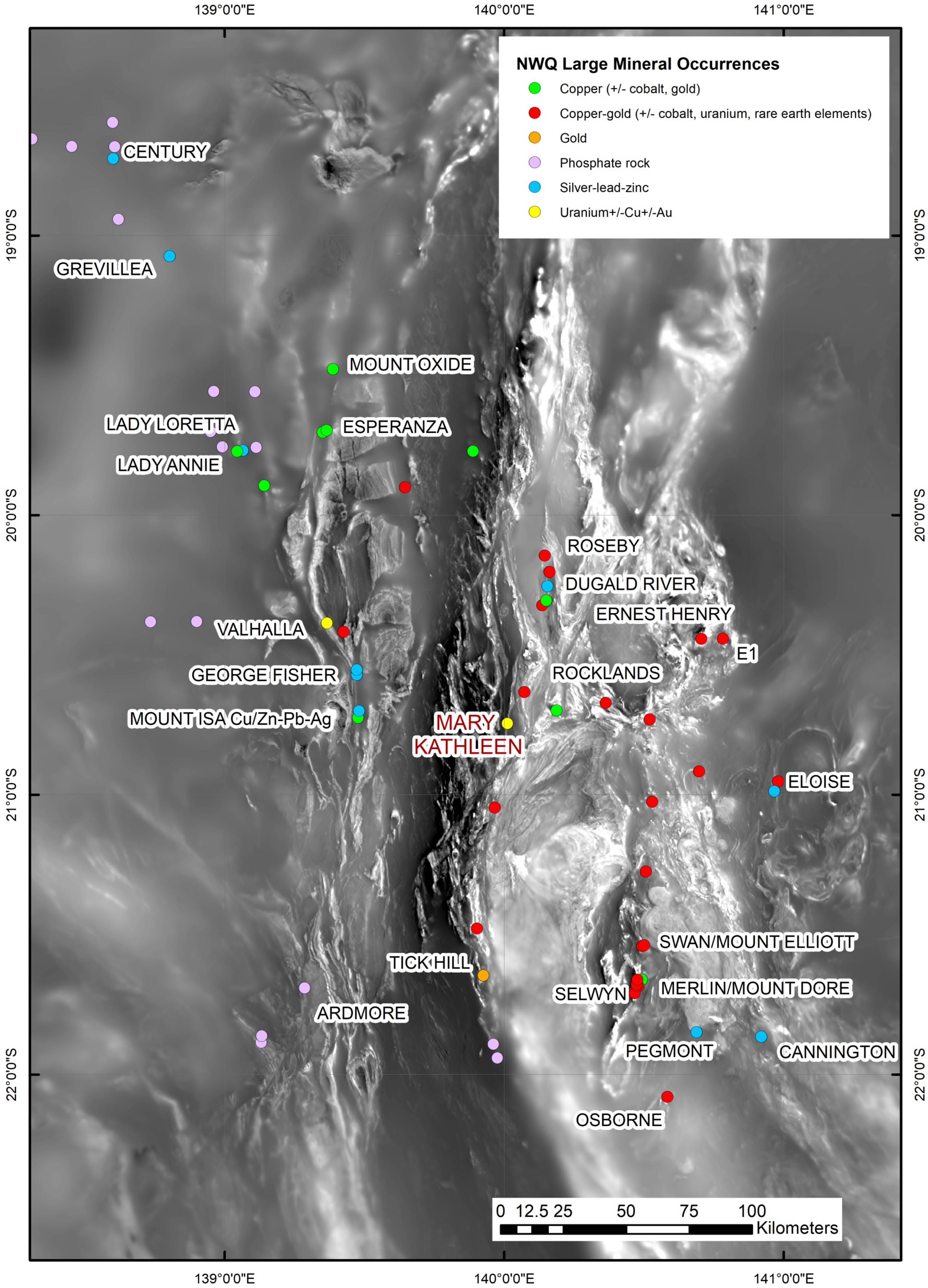


Figure 18.2: Location of the Mary Kathleen deposit overlain on an image of total magnetic intensity from the GADDS data for the region

STRUCTURAL CHARACTERISTICS

Structural Setting

Regionally, the Mary Kathleen deposit occurs in the Mary Kathleen Fold Belt, which forms an elongate zone up to 30 km in width and over 200 km in length (Fig. 18.4). Holcombe et al (1992) indicate that this defines a median belt of amphibolite facies rocks within the Mount Isa Inlier. The Corella Formation, the host rocks to mineralisation at Mary Kathleen, together with the underlying Argylla Formation were subject to post-burial extension related to phase 1 (D1) deformation. Regionally, this major lower plate ductile shearing was accompanied by upper plate brittle deformation, intrusion of igneous bodies (1750 – 1730 Ma; Page, 1983), contact metamorphism and metasomatism (Holcombe et al., 1992; Oliver, 1999).

The Mary Kathleen Syncline is a D2 structure forming a tight, doubly plunging synform with a half-wavelength of 5 km with the eastern limb dipping regularly 50-60° to the west (Oliver et al., 1999). The rocks in this part of the Mary Kathleen Syncline are dominated by hornfelsed calc-silicate rocks, skarn, marble and quartzite with the pre-alteration protolith likely represented by a calcareous cobble to pebble conglomerate and a distinctive monzonitic to gabbroic intrusion (Oliver et al., 1999).

The Mary Kathleen orebody occurs in the axial zone and western limb of the Mary Kathleen Syncline. Detailed structural analysis indicates that the ore lenses cross-cut the axial surface of the Mary Kathleen Syncline, and suggest a relationship between mineralisation and D2 or D3 deformation (Oliver et al. 1999). The eastern limb of the syncline contains very few parasitic folds because of the effects of the competent Phase 1 skarns (see below). Along the western limb there are abundant isoclinal to transposed folds, especially in a marble unit that has not been affected by Phase 1 skarn, and the limb is near-vertical at large scales (Oliver et al, 1999) (Figure 18.4).

A steeply dipping, 30 to 50 metre wide shear zone, the Mary Kathleen Shear Zone, trends broadly parallel to the north-striking axial trace of the Mary Kathleen syncline. Close to the ore body, the shear zone truncates the skarn host rock on the western limb of the syncline. Oliver et al. (1999) indicate that shearing occurred under high-grade metamorphic conditions (amphibolite-grade). Skarns are absent to the west of the shear zone, but small pods occur within it. Significantly, however, although the shear truncates skarn, it does not cut ore veins. Although the shear is apparently unrelated to the younger, brittle strike-slip faults of the region (e.g. Cameron, Fountain Range Faults) (Figure 18.4), it may have been partly reactivated during these young faulting events. (Oliver et al, 1999). The east dipping, western limb of the Mary Kathleen Syncline is truncated by the steeply dipping, north-east striking Cameron Fault.

Structural History

Emplacement of the Burstall Granite and associated rhyolite dykes (1740 -1730 Ma) under regionally extensive, largely extensional conditions, pre-dates regional D2 deformation in the Isan Orogeny (ca 1550-1500 Ma) which formed the Mary Kathleen Syncline in response to east-west directed compression (Oliver et al. 1992). The east-west trending rhyolitic dykes were oriented parallel to the D2 deformation direction, and are relatively unfolded.

High strain deformation, late in the D2 deformation history, was synchronous with peak metamorphism and was related to the development of the Mary Kathleen Shear Zone (Oliver et al. 1999). Structural and textural evidence provided by Oliver et al. (1999) indicates that ore formation at Mary Kathleen post-dated peak metamorphism, was un-related to the Mary Kathleen Shear, but involved brecciation and ore shoot development under brittle conditions. Ore shoots cross-cut S2 fabrics developed during D2 deformation (Oliver et al., 1999).

Modelling by Oliver et al. (1999) suggests that brittle deformation and mineralisation at Mary Kathleen was controlled by rheological and mechanical competency contrasts between the skarn and carbonate-rich domains in the Corella Formation (see below).

Structural Control on Mineralisation

The structural control on mineralisation has been well documented by Oliver et al (1999), including coupled deformation/fluid flow numerical modelling.

In summary, the thesis of Oliver et al (1999) is that the intense skarn alteration has acted as a rigid body, with veins within the ore

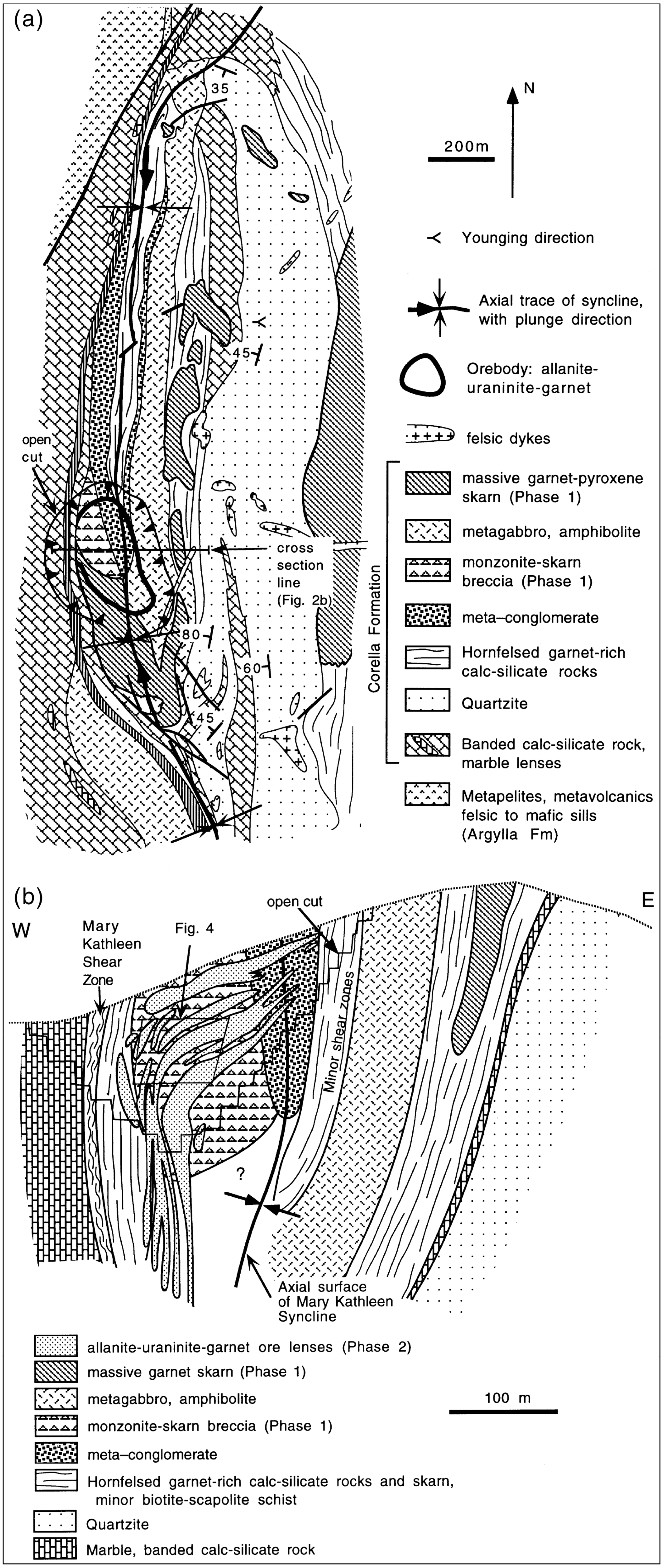


Figure 18.3: Detailed geology of the Mary Kathleen deposit A) Map showing the localisation of the Mary Kathleen deposit at the northern end of a skarn body and curvature of the Mary Kathleen Shear Zone. B) W-E cross-section through the Mary Kathleen deposit. From Oliver et al. (1999).

shoots forming as tensile or shear fractures during coupling of the competent skarn host with the late-D2 Mary Kathleen Shear Zone. This is cited as the cause of the change in orientation of the ore shoots (shallowing) with distance away from the shear zone.

Oliver et al. (1999) describe the geometry of a range of ore shoots at the Mary Kathleen deposit. High grade ore zones in the open cut comprise replacement-style veins 2 to 30 centimetres wide, containing a high grade assemblage of uraninite, allanite, garnet which coalesce to form several sub-parallel ore zones 1 to 5 m in diameter dipping irregularly to the west.

Several sets of ore shoots have been identified, despite their broadly anastomosing nature and the dominant sets (sets 1 and 2) tend to steepen with depth, and towards the west) with proximity to the Mary Kathleen Shear Zone (Oliver et al., 1999).

- Set 1: Dipping 60 to 70° west (270°)
- Set 2: Dipping 40 to 65° WSW (225°)
- Set 3: Dipping 50° south (180°)

Oliver et al. (1999) emphasise that brecciation, shearing and veining is a common feature of more competent blocks during D2 deformation, particularly in the hinges of folds, in the Mary Kathleen Fold Belt. The brittle behaviour of the more competent units (phase 1 altered skarn), allowed fluid flow and development of veins and ore shoots under conditions of high fluid pressure. Oliver et al. (1999) propose two possible mechanical methods of vein development:

1. en echelon tensile fracture of the competent skarn with limited shear deformation. Steepening of the veins towards the Mary Kathleen Shear Zone was potentially due to either stress reorientation or greater dilation closer to the shear, or increasing transpressional strain which may account for incorporation of skarn blocks into the shear zone (Oliver et al., 1999).
2. Secondary shear failure or splays (akin to Riedel Shears) developed in the skarn which are related to the Mary Kathleen Shear Zone which represents the master shear. Fluid flow and resultant veining may explain the anastomosing nature of the ore shoots.

MINERALISATION

General Characteristics

The ore mineralogy at Mary Kathleen comprises allanite and uraninite within an allanite-uraninite-garnet assemblage (Figure 18.8).

Apatite is also commonly found in ore zones, and a lanthonon-bearing borosilicate stillwellite has been described from ore zones (MacAndrew and Scott, 1955).

This ore assemblage is assigned to a second stage of alteration by both Derrick (1977) and Oliver et al (1999). Derrick interpreted this mineralizing phase as genetically related to the dyke swarm associated with the Burstall Granite, but dates from Page (1983) from the uraninite-allanite ore of approximately 1550-1530 Ma suggest the mineralisation post-dates the dyke emplacement. This is consistent with the description of the alteration and mineralisation phases by Oliver et al (1999), as follows:

(1) Host rocks: recrystallised clinopyroxene + garnet ± calcite ± quartz skarn

(2) Marginal zone: fractured clinopyroxene–garnet skarn with semiregular allanite vein networks

(3) Ore zone: coarse bladed allanite, second-generation garnet, granular apatite, spheroidal uraninite sheathed by silica, and a host of rare accessory minerals.

(4) retrograde ore stage: allanite + calcite + prehnite + albite ± epidote ± garnet ± chalcopyrite ± hematite, as both patchy alteration and infill in post-ore minor fractures.

This fourth alteration phase is cut by the late calcite veins, which contain accessory chalcopyrite, garnet and rare clinopyroxene.

Other sulfides are found in small quantities, including pyrrhotite, pyrite and galena, the latter most likely being produced by uraninite breakdown, possibly as recently as 270 Ma (Oliver et al, 1999; Page 1983).

ALTERATION HALO

General Characteristics

The Mary Kathleen deposit area represents a zone of intense alteration, although the strong early skarn alteration of the Phase 1 of Oliver et al (1999) is interpreted as not directly genetically related to the mineralisation.

The high-grade mineralisation comprises uraninite-bearing allanite±garnet veins and irregular patches and networks of Phase 2 'skarn', which are present in several subparallel 1-5m-scale ore zones (Oliver et al, 1999).

Inner Halo

Based on the paragenesis and diagrams presented by Oliver et al (1999) the "marginal zone" of fractured clinopyroxene-garnet skarn with semiregular allanite vein networks could be considered as the inner halo to the higher grade veins.

Outer Halo

Whilst certainly not restricted to the environs of mineralized systems in the Mary Kathleen Fold Belt, the set of late calcite veins present

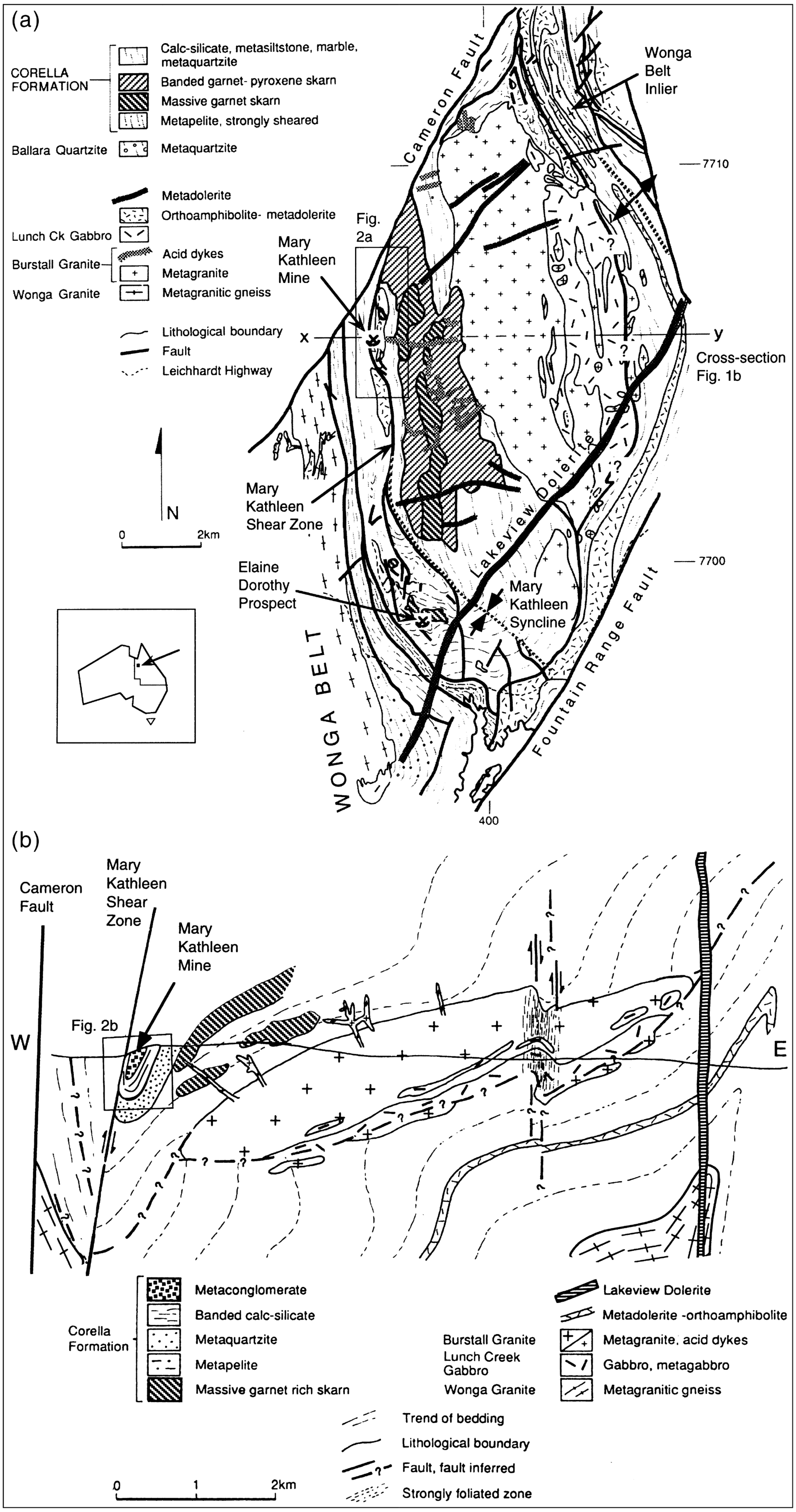
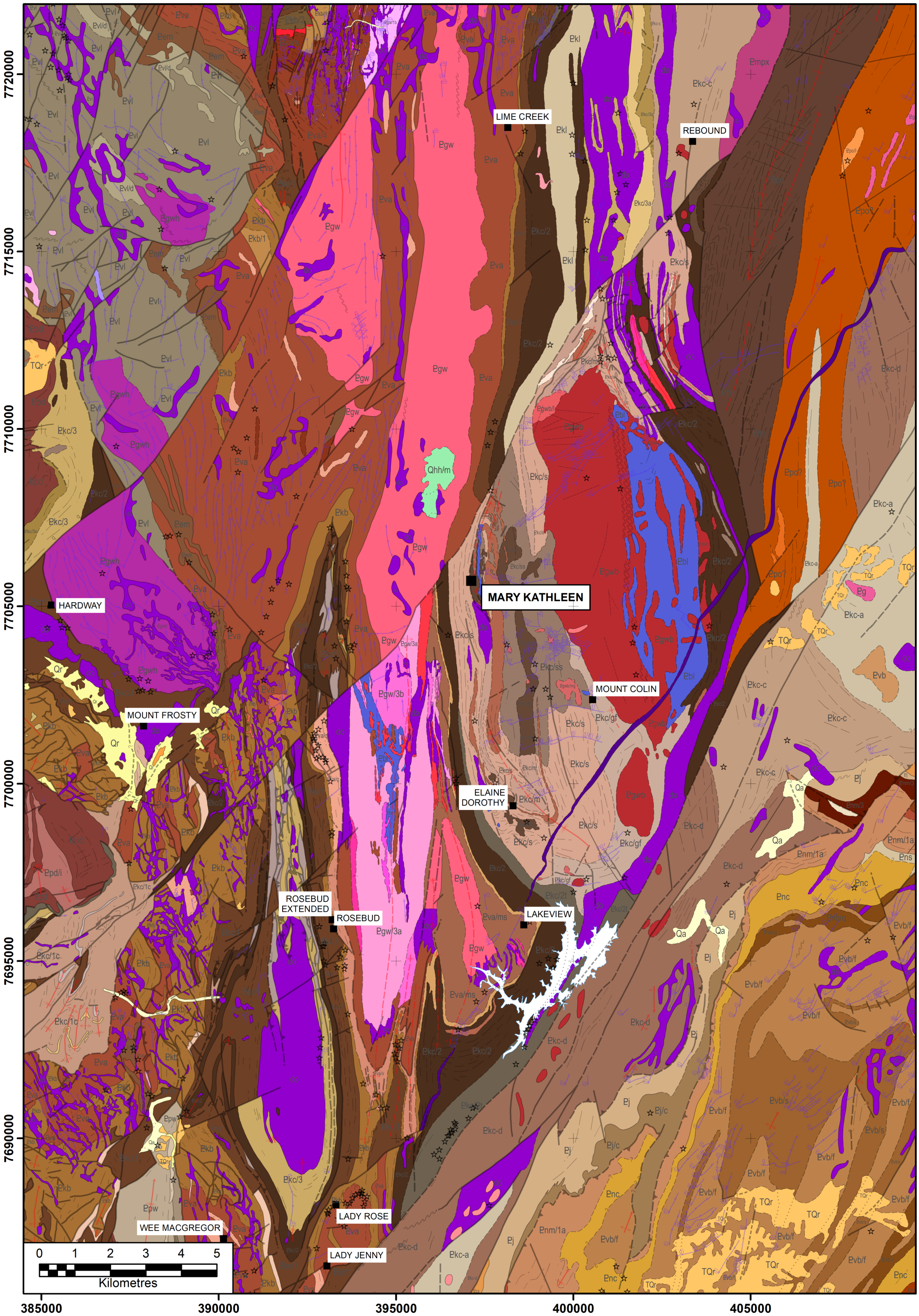


Figure 18.4: Geology and structural setting of the Mary Kathleen deposit within the Mary Kathleen Syncline. A) Map of the localisation of the Mary Kathleen deposit in the Mary Kathleen Shear Zone. B) Cross-section along line X – Y. From Oliver et al. (1999).


LIME CREEK
REBOUND
MARY KATHLEEN
HARDWAY
MOUNT FROSTY
MOUNT COLIN
ELAINE DOROTHY
ROSEBUD EXTENDED
ROSEBUD
LAKEVIEW
LADY ROSE
LADY JENNY
WEE MACGREGOR
0 1 2 3 4 5
Kilometres
7720000
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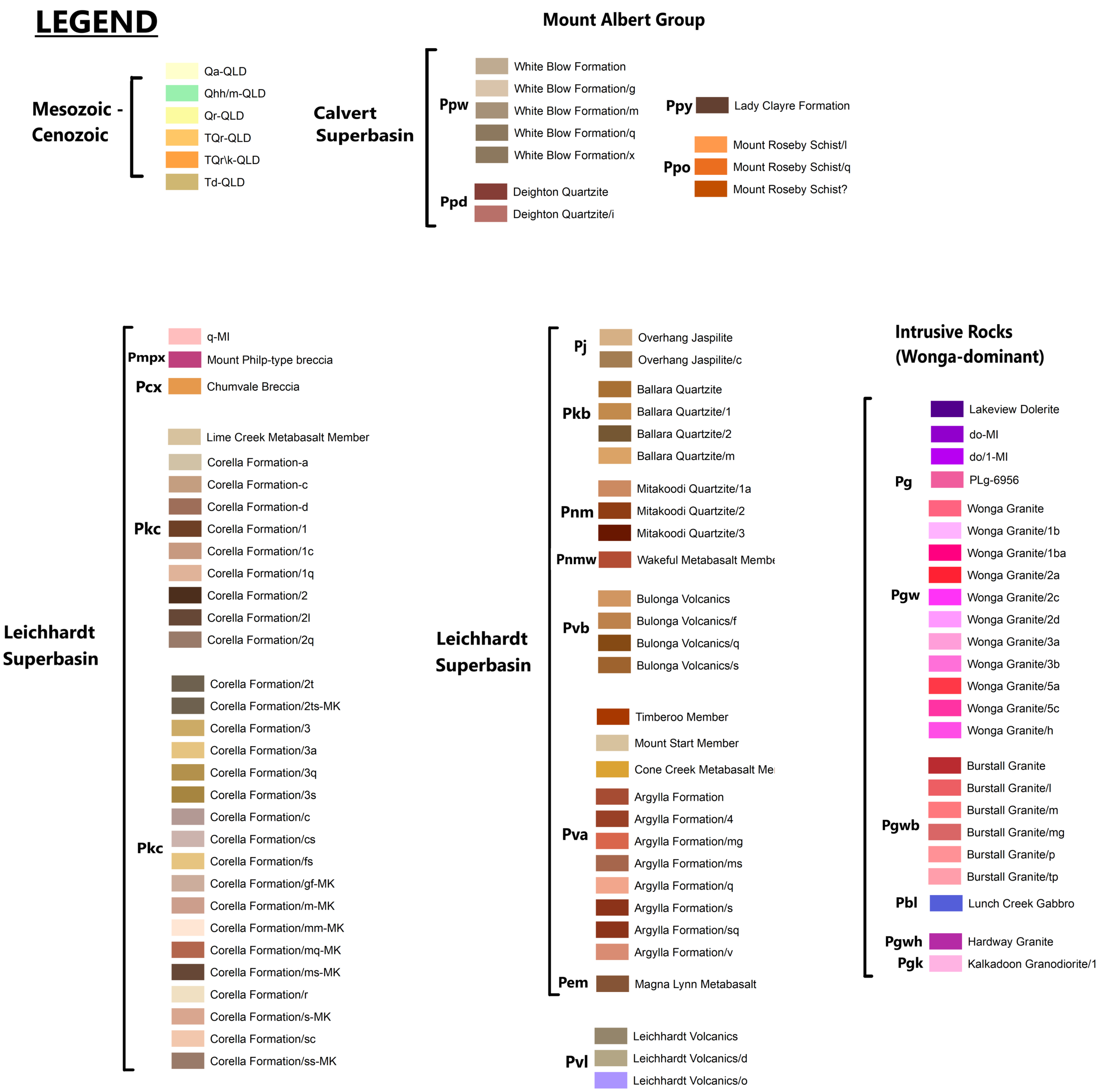

Figure 18.5: Geological map (previous page) and stratigraphic legend (right) from the 1:100,000 mapping from the Geological Survey of Queensland of the Mary Kathleen area.

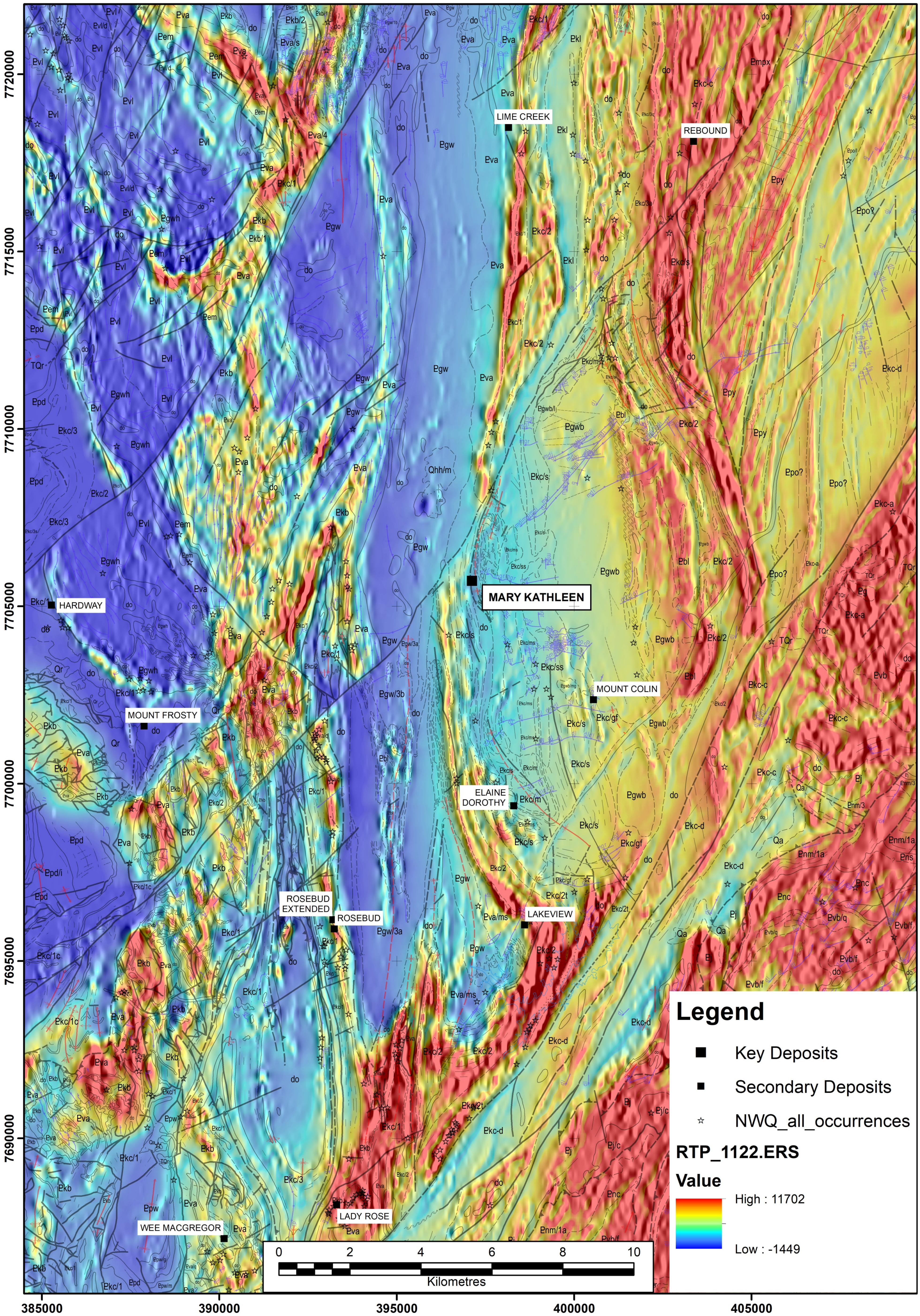

Figure 18.6: Reduced-to-pole aeromagnetic image with 1st vertical derivative sharpening (dataset sourced from QDEX Data https://qdexdata.dnrme.qld.gov.au/GDP/Search).

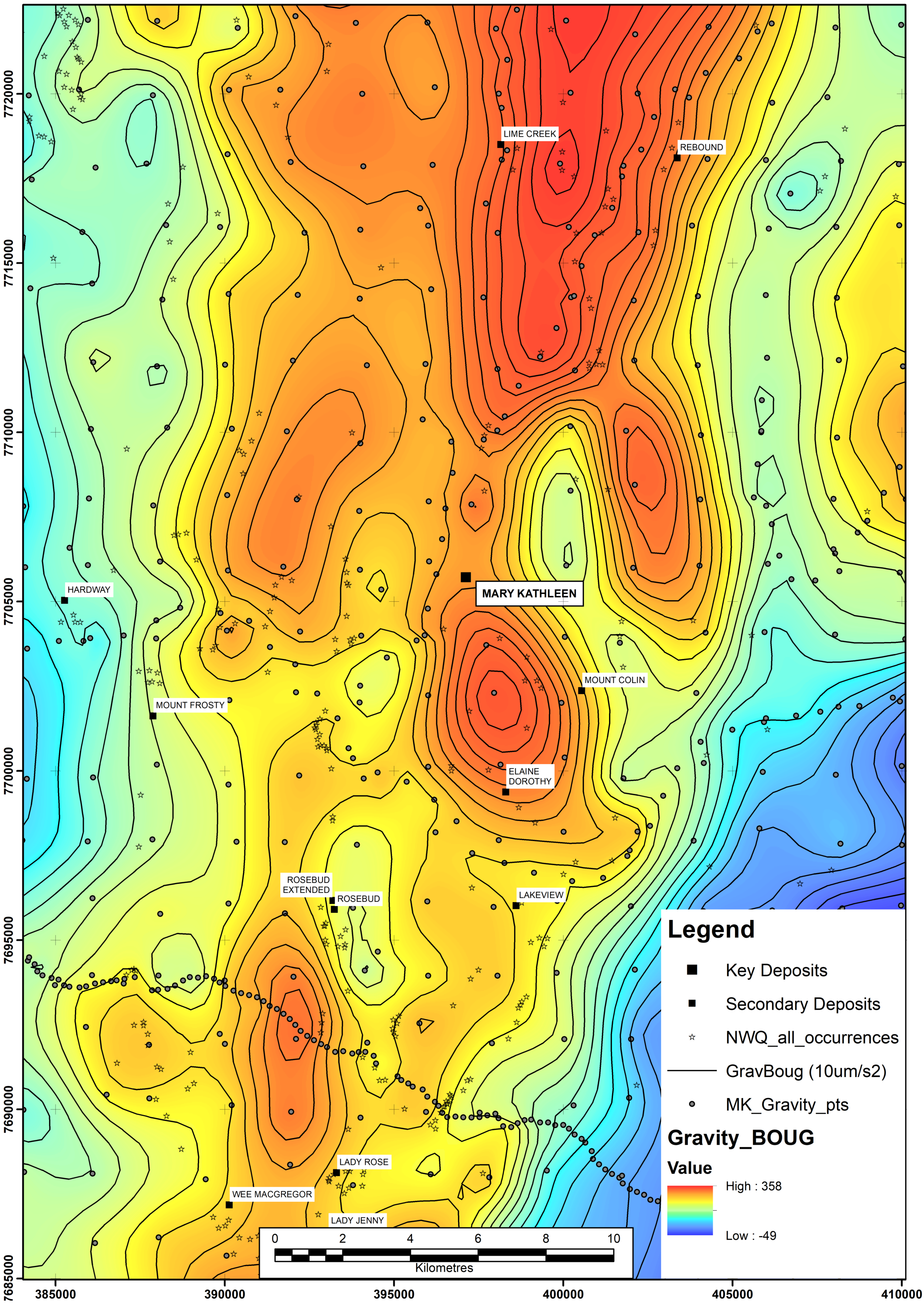

Figure 18.7: Bouguer gravity image (dataset sourced from QDEX Data https://qdexdata.dnrme.qld.gov.au/GDP/Search).

throughout the deposit may represent an outer halo. The spatial distribution of these late stage veins is not well documented, but Derrick (1977) notes the presence of prehnite with the calcite, and has wollastonite (denoted as II—second stage) chabazite and fluorite late in the paragenesis, which may also be part of a late halo.

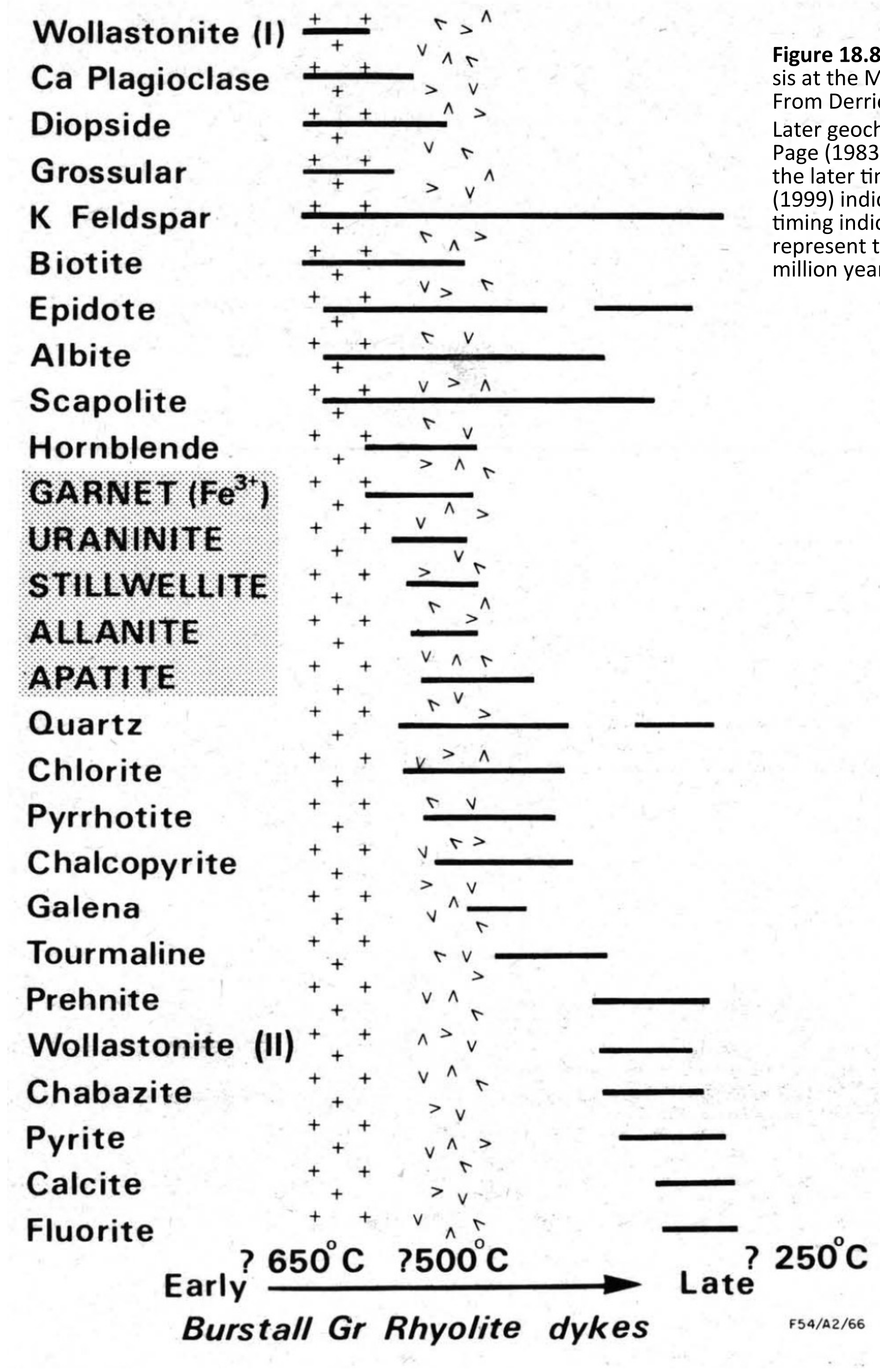

Figure 18.8: Interpreted paragenesis at the Mary Kathleen deposit. From Derrick (1977).
Later geochronology data from Page (1983) and documentation of the later timing by Oliver et al (1999) indicate the early to late timing indicated in this figure may represent two events spanning 200 million years.

HYMAP DATA

HyMap data was acquired in 2006-2007 over the district as part of the Stage 1 Block F Pilgrim Fault survey. Figures 18.12 to 18.16 are representative images of the HyMap data, which cover the Mary Kathleen deposit. 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 imagery is available at: https://gdexdata.dnrme.qld.gov.au/gdp/search

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

The images presented in this document are as follows:

– False colour image: with RGB representing the reflectance bands 750nm, 650nm, 550nm, respectively (Figure 18.12).
– Epidote abundance: blue to red with increasing abundance, no data (white) is below the threshold. It utilizes the presence of absorption at 1550nm, with low product confidence. (Figure 18.13)
– Amphibole-chlorite mineralogy: blue approximates chlorite and red approximates amphibole. This product attempts to separate amphibole from chlorite based on the relative heights of the 2300 and 2250 nm absorptions. Low product confidence. (Figure 18.14)
– Ferrous iron abundance: blue to red represent low to high abundance of Fe2+ minerals including chlorites, amphibole (e.g. actinolite), pyroxene, olivine and carbonate. Moderate confidence (Figure 18.15).
– Ferric oxide abundance: Attempts to map hematite, goethite, 'limonite', and Fe3+ pyroxenes, olivines and carbonates by using the normalized depth of the 900nm absorption feature. Blue to red represents low (~10% Fe_2O_3) to high (~60% Fe_2O_3) abundance. High confidence (Figure 18.16).

The HyMap response of the Mary Kathleen deposit is investigated in more detail by Sales et al (2017).

PETROPHYSICAL PROPERTIES

Density values used for mine planning at the Mary Kathleen deposit were 3.59 t/m^3 for ore and 4.12 t/m^3 for waste (Mary Kathleen Uranium Limited, 1967). It is not clear what data these values were derived from.

Magnetite is not recorded as part of the mineral assemblage at Mary Kathleen (Derrick, 1977; Oliver et al, 1999), so the rocks are likely not magnetic. This is consistent with the lack of anomalism evident in the aeromagnetic data (Figure 18.10A).

GEOPHYSICAL EXPRESSION

The Mary Kathleen deposit does not display any appreciable magnetic signature (Figure 18.10A). The magnetic field over the deposit is low, but it cannot be determined if this is related to demagnetisation by a magnetite-poor skarn or the host rocks (hornfelsed calc-silicate rocks, skarns, quartzite and marble) are simply non-magnetic. Added to this complexity is that mining occurred prior to collection of the airborne geophysical data.

The highest intensity magnetic units are the north-south trending units of the Corella Formation (Pkc1, Pkc2) and Ballara Quartzite (Pkb), potentially enhanced within parallel magnetic shear zones (the Mary Kathleen Shear?). The Burstall Granite (Pgwb) provides a relatively quiet magnetic signature, as do the other Wonga age granites (Pgw).

There is a notable magnetic low under the tailings facility, with a gabbro mapped in this area (do) that is probably remanently magnetised.

The airborne radiometric signature of the deposit is complicated by the effects of historical mining. The uranium signature is overprinted by the pit, the waste dumps and the infrastructure. The tailings facility (Qhh/m on the geological map) also displays an elevated uranium signature (Figure 18.10D). The Burstall Granite is highly anomalous in potassium, thorium and uranium.

The deposit potentially displays elevated thorium levels (Figure 18.10C), but this could equally be related to ground disturbance related to mining.

EXPLORATION GEOCHEMISTRY

Stream Sediment Geochemistry

Plots of the regional stream sediment geochemical samples (BCL on varying mesh sizes for gold and –80# for Cu, Pb,Zn and U) are provided in Figures 18.21 to 18.24. The majority of samples in the deposit area were collected in either 1967 or 1981, which was after the first phase of mining in 1958-1963 and/or during the the second phase of mining in 1976-1982.

The immediate Mary Kathleen deposit environs are anomalous in the copper stream sediment data, with a cluster of +100 ppm Cu data points over approximately 5km x 2km. Additionally there are spot clusters in the region surrounding several prospects (Rosebud, Lady Rose and Lady Jenny to the south).

The uranium stream sediment values provide an anomalous cluster (5km x 6km) at 5-35 ppm U that is slightly larger than the copper anomalous zone. Both Pb and Zn provide the largest anomalous halo at 10km x 5km size with numerous samples of +50 ppm Pb and +100 ppm Zn. The Pb+Zn anomaly extends to the south to include the Mount Colin and Elaine Dorothy areas.

Soil Geochemistry

There is no information available regarding systematic soil sampling programs in the immediate mine environs.

TIMING OF MINERALIZATION

Relative Timing

Mineralisation post-dates the Phase 1 metasomatism of Oliver et al (1999) and likely occurred synchronous with the later brittle stages of D2 deformation (Oliver et al., 1999).

This summary is based on observations by Oliver et al. (1999), with reference to the sketch in Figure 18.11:

1. Emplacement of the Burstall Granite (1740 Ma) and genesis of the primary skarn assemblage of clinopyroxene – garnet – calcite – quartz (Phase 1) in the host Corella Formation
2. Intrusion of rhyolitic dykes (1730 Ma) from the granite, cross-cutting earlier skarn, generating localised contact skarn.
3. Block rotation of the eastern syncline limb during D2 deformation (ca. 1550 Ma), development of S2 foliation in the Burstall Granite
4. Formation of boudinaged banded skarn
5. Axial planar garnet-pyroxene veins indicating deformation of early skarn and deformation of later metasomatic rocks
6. Mary Kathleen Shear Zone, absent of mineralisation
7. Development of U-bearing mineralisation as structurally controlled ore shoots,

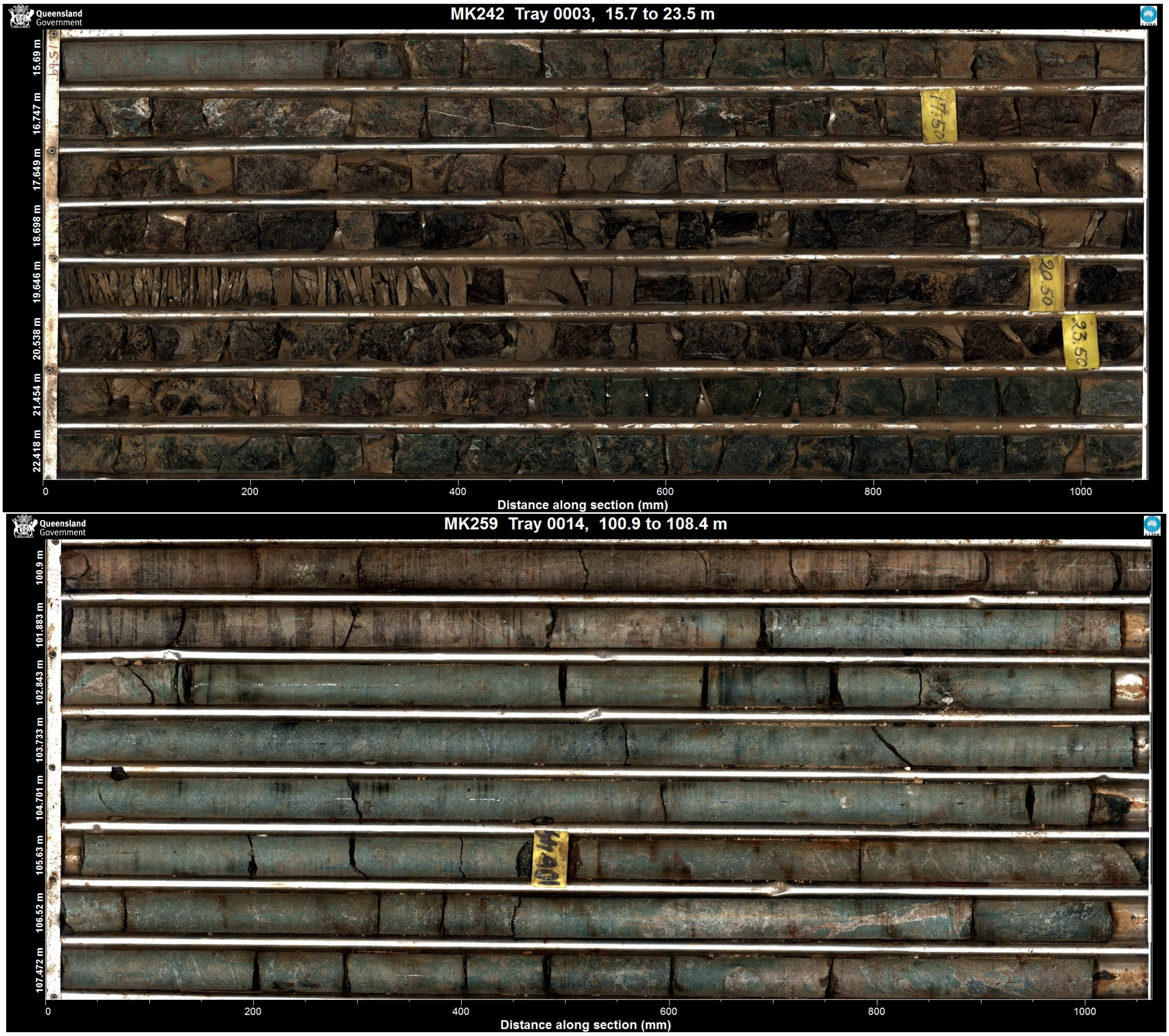

Figure 18.9: Examples of key rock types and mineralisation from the Mary Kathleen deposit. Data sourced from HyMap linescan imagery and rock descriptions from drill logs in Mary Kathleen Uranium Limited (1979):

A. (top) Garnet-diopside-feldspar granofels (15.7m-17.50m) and high grade uranium bearing garnetite with allanite (17.50-23.5m). Individual metres intervals of this material assay at >0.1% U_3O_8, with a maximum of 0.26% U_3O_8. (drill hole MK242)

B. (bottom) Garnetite (100.9m-102.6m), diopside granulite (102.6m-106.45m) and diopside-garnet granulite (106.45m-108.4m), (drill hole MK259)

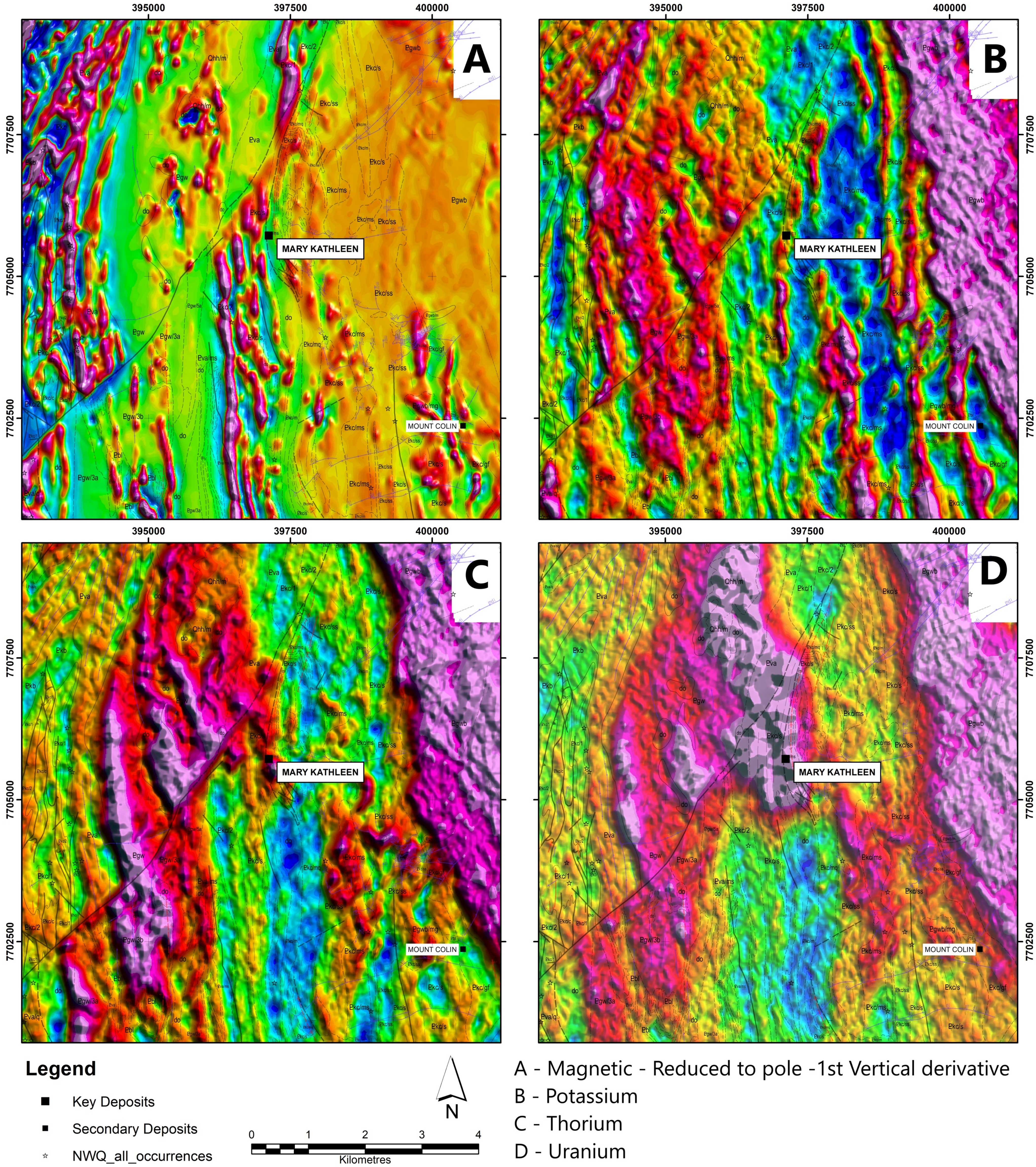

Figure 18.10: Detailed airborne geophysical data (GSQ survey 1371—Mary Kathleen).

A. Magnetic data, reduced to pole and 1st vertical derivative processing: The Mary Kathleen deposit itself does not provide a magnetic anomaly, with the highest intensity magnetic units being north-south oriented units of the Corella Formation (Pkc1, Pkc2) and Ballara Quartzite (Pkb), potentially enhanced within magnetic shear zones. The Burstall Granite (Pgwb) provides a relatively quiet magnetic signature.

B. Potassium data: The Burstall Granite (Pgwb) is extremely elevated in potassium, and the Corella unit (Pkc/ss) also appears to display anomalous potassium.

C. Thorium data: The Burstall Granite (Pgwb) and the Wonga granites (Pgw) in the west display elevated thorium. The Mary Kathleen deposit also displays potential thorium enrichment relative to enclosing host rocks.

D. Uranium: The Burstall Granite (Pgwb) is highly anomalous in uranium. The area surrounding the Mary Kathleen mine, infrastructure and tailings (Qhh/m) is also anomalous.

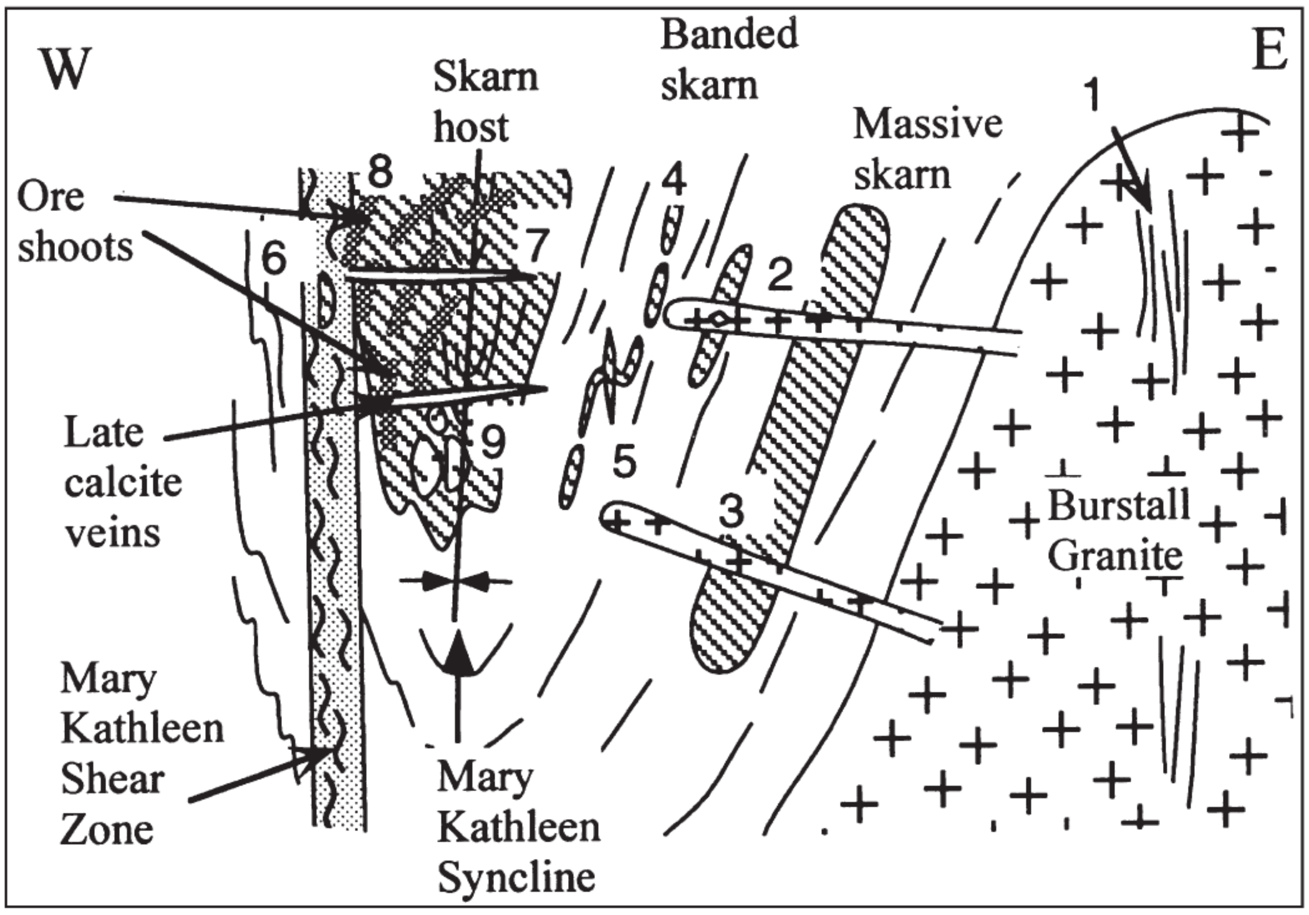

Figure 18.11: Key timing and geometric relationships indicating primary skarn genesis synchronous with emplacement of the Burstall Granite granite (ca. 1740 Ma)

cutting the trace of the Mary Kathleen Syncline

8. Steepening of ore shoots towards the Mary Kathleen Shear Zone, but not cross-cutting
9. Post-ore calcite veins cut earlier structures, except retrograde features of the Mary Kathleen Shear Zone.

Absolute Age

Page (1983) provided U-Pb age dates for the uraninite-allanite ore of 1550 ± 15 Ma and 1535 ± 20 Ma for a U-Pb whole rock analysis. Maas et al. (1987) generated Sm-Nd age dates for whole rock samples and mineral analyses which give a pooled age of ca 1470 Ma. Significantly, these ages are distinct from the age of the Burstall Granite (1740 – 1700 Ma).

GENETIC MODEL

Derrick (1977) and Cruikshank (1980) both implicate the intrusion of the Burstall Granite (1740 Ma) into the Corella Formation metasedimentary host sequence as a driving factor in mobilising an alkali- and chloride-rich pore fluid, enriched in uranium. This is inferred to have contributed to the formation of extensive, pre-mineralisation feldspar-diopside and scapolite-rich metasomites oriented sub-parallel to original sedimentary layering. Intrusion of later stage rhyolitic dykes (1730 Ma) and associated hydrothermal fluids were considered to have been enriched in U, Ca, CO_2 and H_2O and facilitated oxidation of Fe (Fe2+ to Fe3+) and the formation of garnet. Cruikshank also implicates the role of carbonate decomposition during alteration of marble to yield high CO_2 fluxes that may have facilitated transportation of uranium.

Maas et al. (1987) stipulated that a very LREE-enriched source was required to explain the Sm-Nd characteristics (including the negative εNd signature) of the uranium ores. Oliver et al. (1999) suggest that limited solubility of U-REE species in saline fluids would make mineralisation at Mary Kathleen effectively by in situ mobilisation from an enriched host, difficult. Instead, Oliver et al. (1999) implicate contact metamorphism of the Corella Formation at 1740 Ma related to emplacement of the Burstall Granite to account for skarn mineral assemblages observed at Mary Kathleen, with REE-rich (allanite) uraninite mineralisation being related to amphibolite-facies metamorphism during late-stages of D2 deformation related to the Isan Orogeny (1550-1500 Ma).

POST-FORMATION MODIFICATION

The deposit has undergone minimal post-formation modification. It is interpreted to have formed late in the D2 deformation of the Isan Orogeny (Oliver et al, 1999), so it is late in, or post-dates, the most extensive metamorphic episodes (D1, D2) in the Mary Kathleen Fold Belt.

However, Oliver et al. (1999) document post-mineralisation brittle deformation effects around the Mary Kathleen ore body associated with the Mary Kathleen Shear Zone. These include brittle fractures and brecciation and sub-horizontal calcite veins with uncertain timing, and contain minor sulphide and allanite. Some clayey fault gouge occurs in the core of the shear zone, overprinting high-metamorphic grade fabrics.

Younger, brittle deformation includes strike-slip faults such as the Cameron Fault which truncates the western limb of the Mary Kathleen Syncline.

The weathering and oxidation profile is not well developed, with drill logs recording the presence of pyrite and pyrrhotite from 8m depth (hole MK242, Mary Kathleen Uranium Limited, 1979).

EXPLORATION

Discovery Method

The discovery history of the deposit is well summarised by Matheson and Searl (1956) as follows:

- The Mary Kathleen deposit was discovered by prospectors of the Walton-McConachy Syndicate at the beginning of July, 1954.
- The prospectors originally found boulders of radioactive rock by using a handheld Geiger counter. The boulders comprised conglomerate breccia in a creek draining away from a hill on which the deposit occurs, which was then tracked back to the source.
- The Rio Tinto Group obtained a controlling interest in the area about the end of February, 1955, and completed extensive exploration activities.
- The exploration program involved regional and detailed geological mapping, radiometric prospecting, extensive diamond drilling, costeaning, underground prospect mining, petrological and mineralogical investigations and ore treatment tests.
- Mining commenced in 1958.

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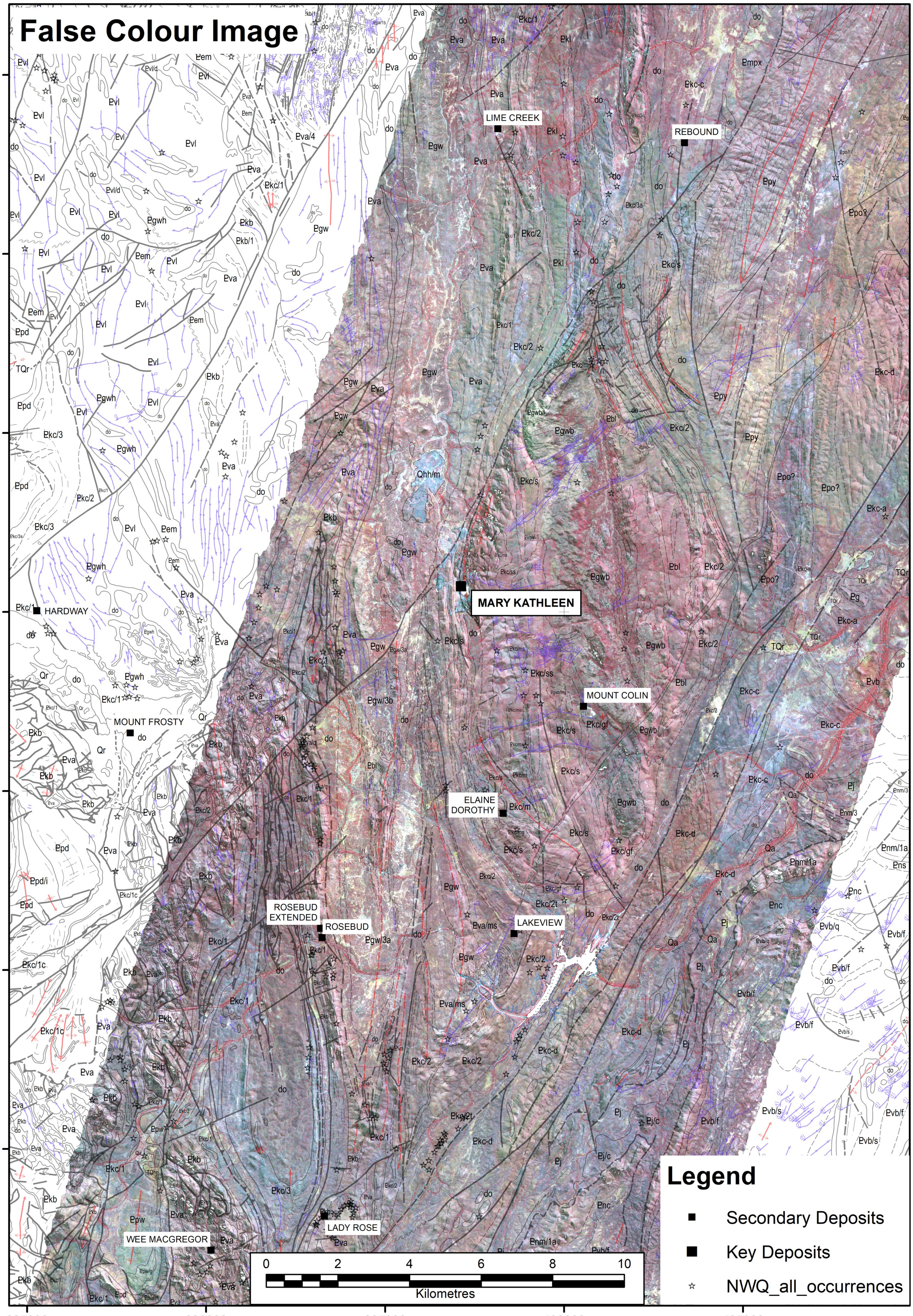

Figure 18.12: HyMap false colour image (from QDEX Data). From Stage 1 (Pilgrim Block F) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise. RGB colours are mapped from the reflectance bands 750nm, 650nm, 550nm, respectively.

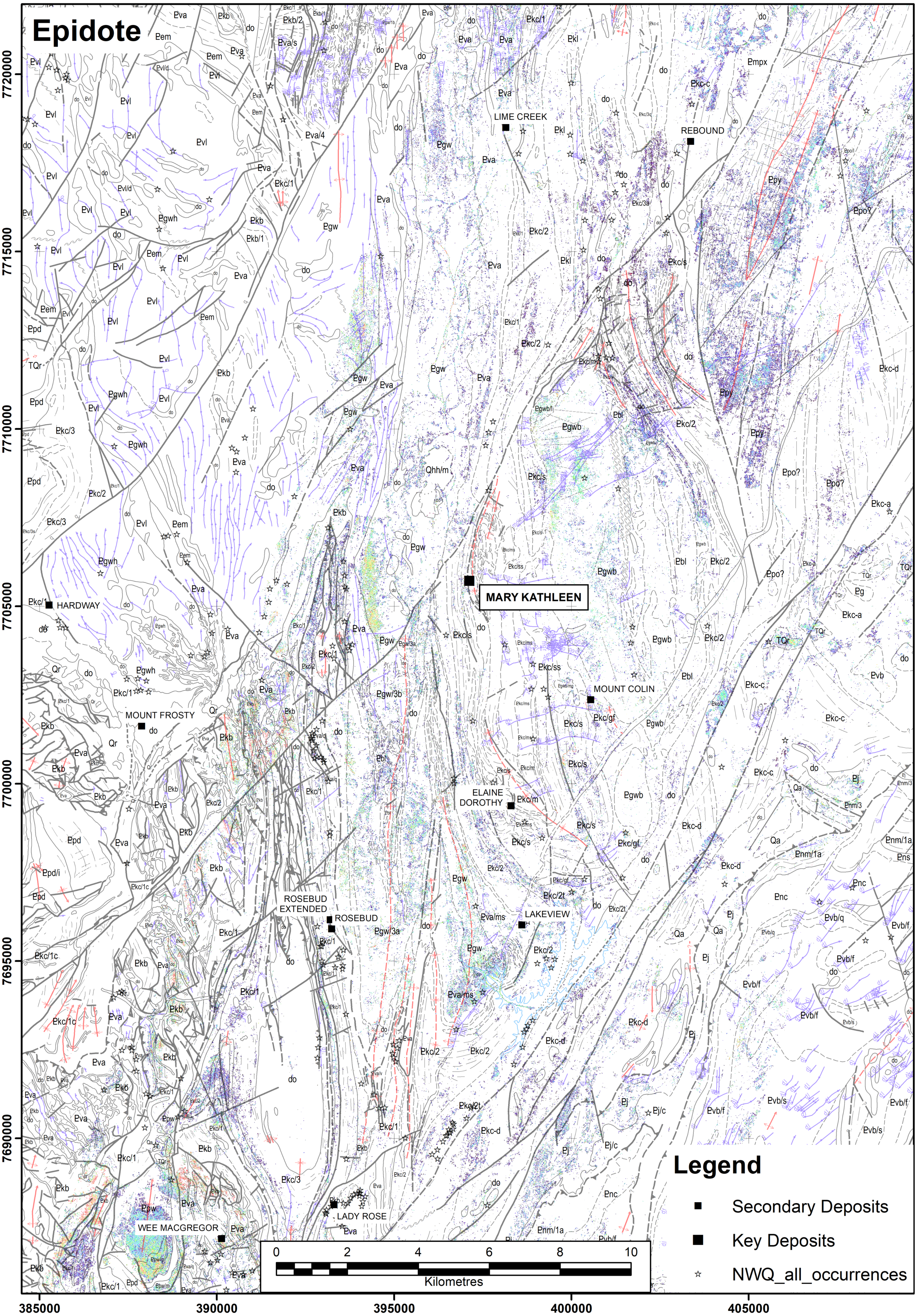

Figure 18.13: HyMap epidote abundance image (from QDEX Data). From Stage 1 (Pilgrim Block F) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise. Blue to red with increasing abundance, no data (white) is below the threshold. It utilizes the presence of of absorption at 1550nm.

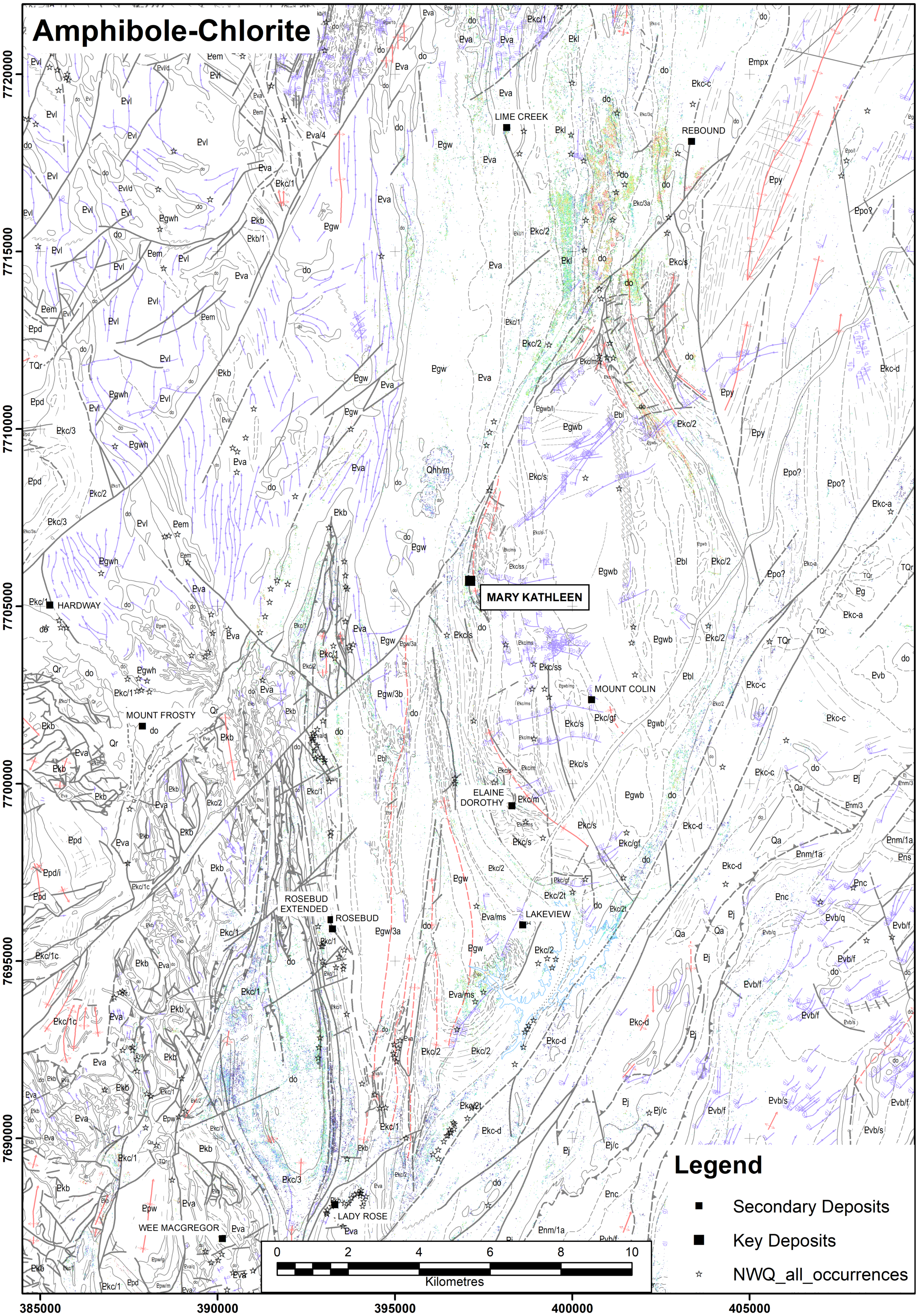

Figure 18.14: HyMap amphibole-chlorite image (from QDEX Data). From Stage 1 (Pilgrim Block F) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise. The blue colours approximate mapped chlorite and the red colours actinolite. This product attempts to separate amphibole from chlorite based on the relative heights of the 2300 and 2250 nm absorptions.

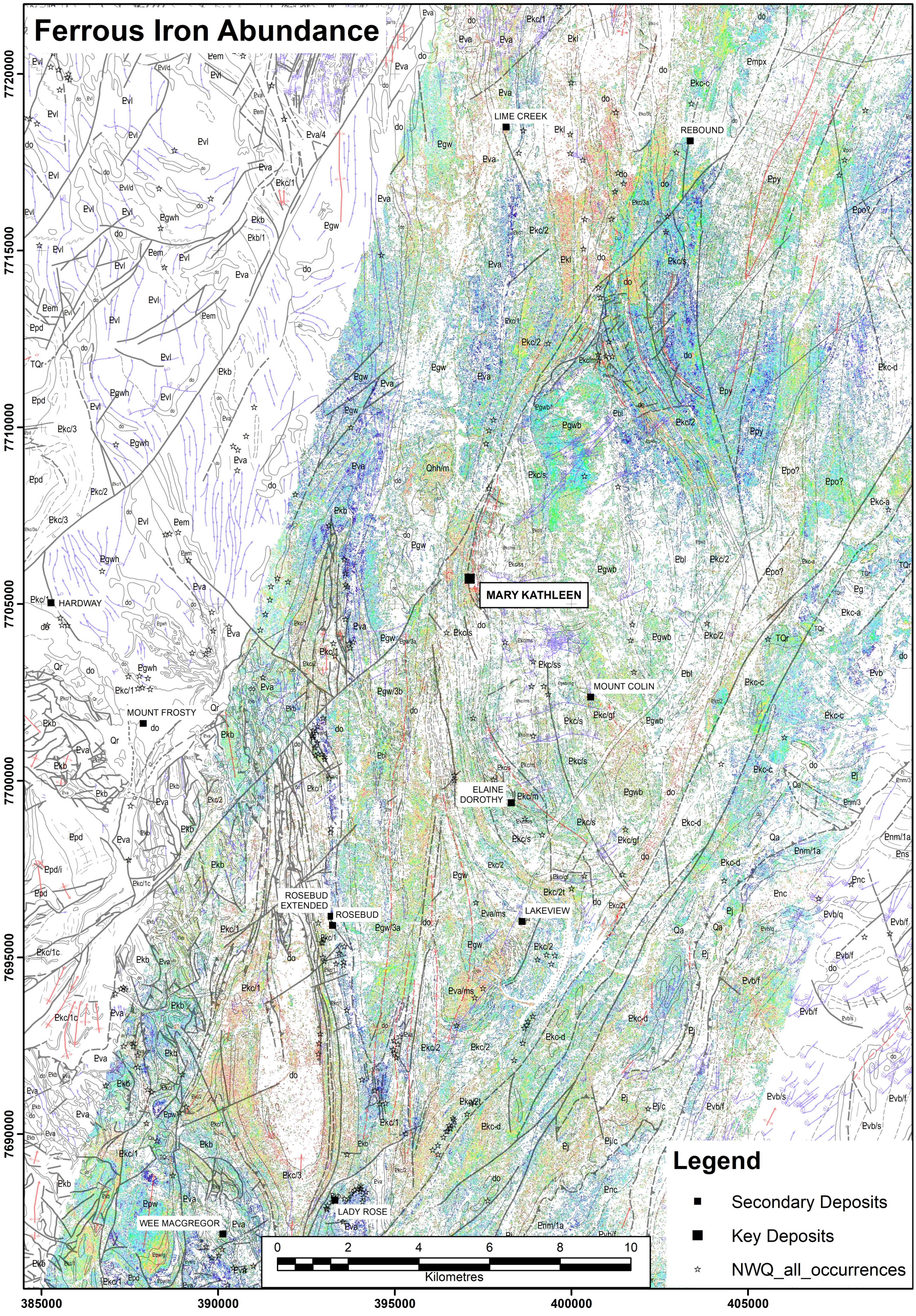

Figure 18.15: HyMap ferrous iron abundance image (from QDEX Data). From Stage 1 (Pilgrim Block F) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise. Blue to red represent low to high abundance of Fe2+ minerals including chlorites, amphibole (e.g. actinolite), pyroxene, olivine and carbonate.

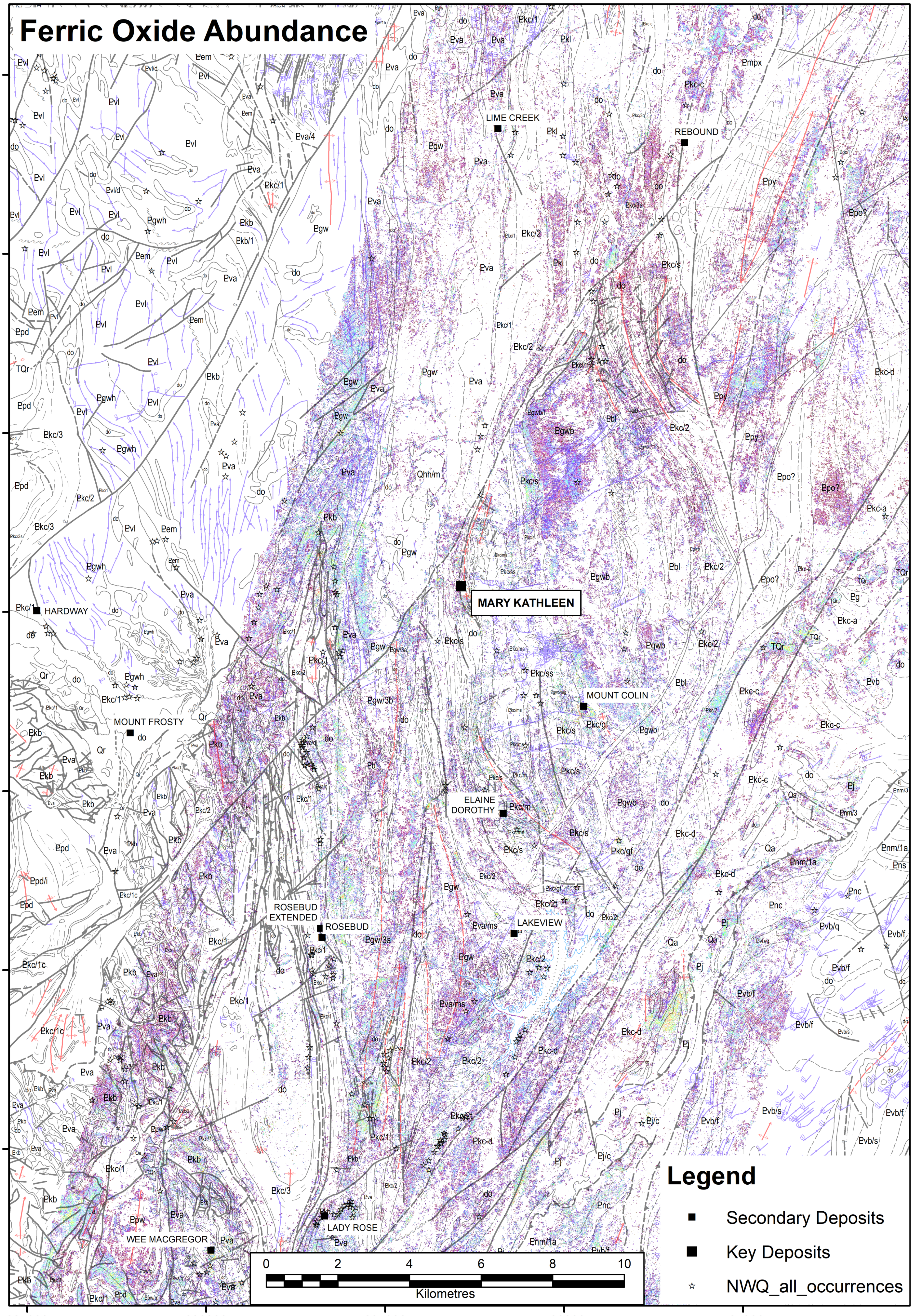

Figure 18.16: HyMap ferric oxide abundance image (from QDEX Data). From Stage 1 (Pilgrim Block F) of the GSQ/CSIRO 2006-2008 Queensland mineral mapping exercise. Attempts to map hematite, goethite, 'limonite', and Fe3+ pyroxenes, olivines and carbonates by using the normalized depth of the 900nm absorption feature. Blue to red represents low (~10% Fe_2O_3) to high (~60% Fe_2O_3) abundance.

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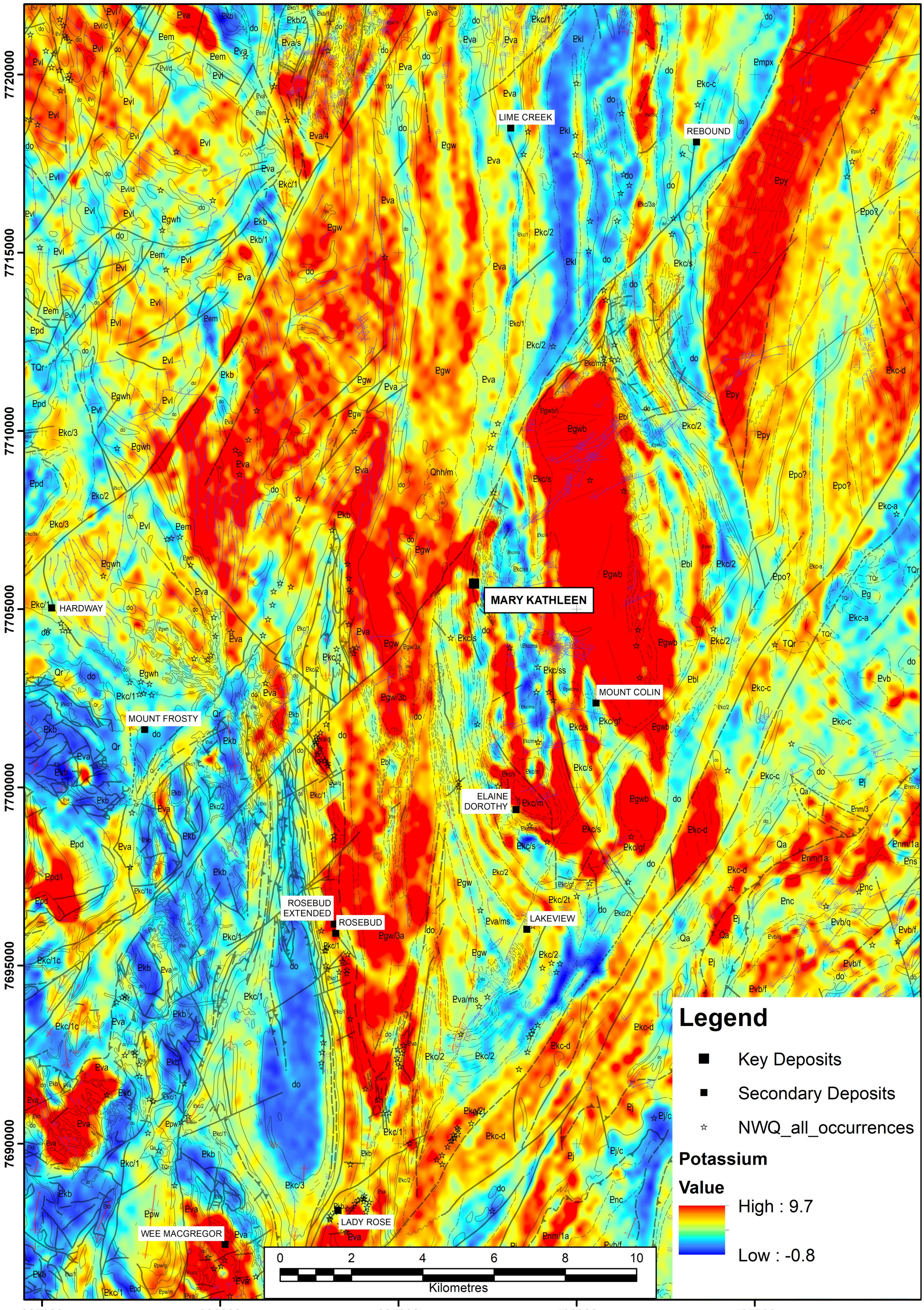

Figure 18.17: Potassium image (from QDEX Data). The high zones are dominated by the Burstall Granite (Pgwb), parts of the Argylla Formation (Pva), the Mitakoodi Quartzite (Pnm), and the Lady Clayre Formation (Ppy), and selected Wonga granites (Pgw).

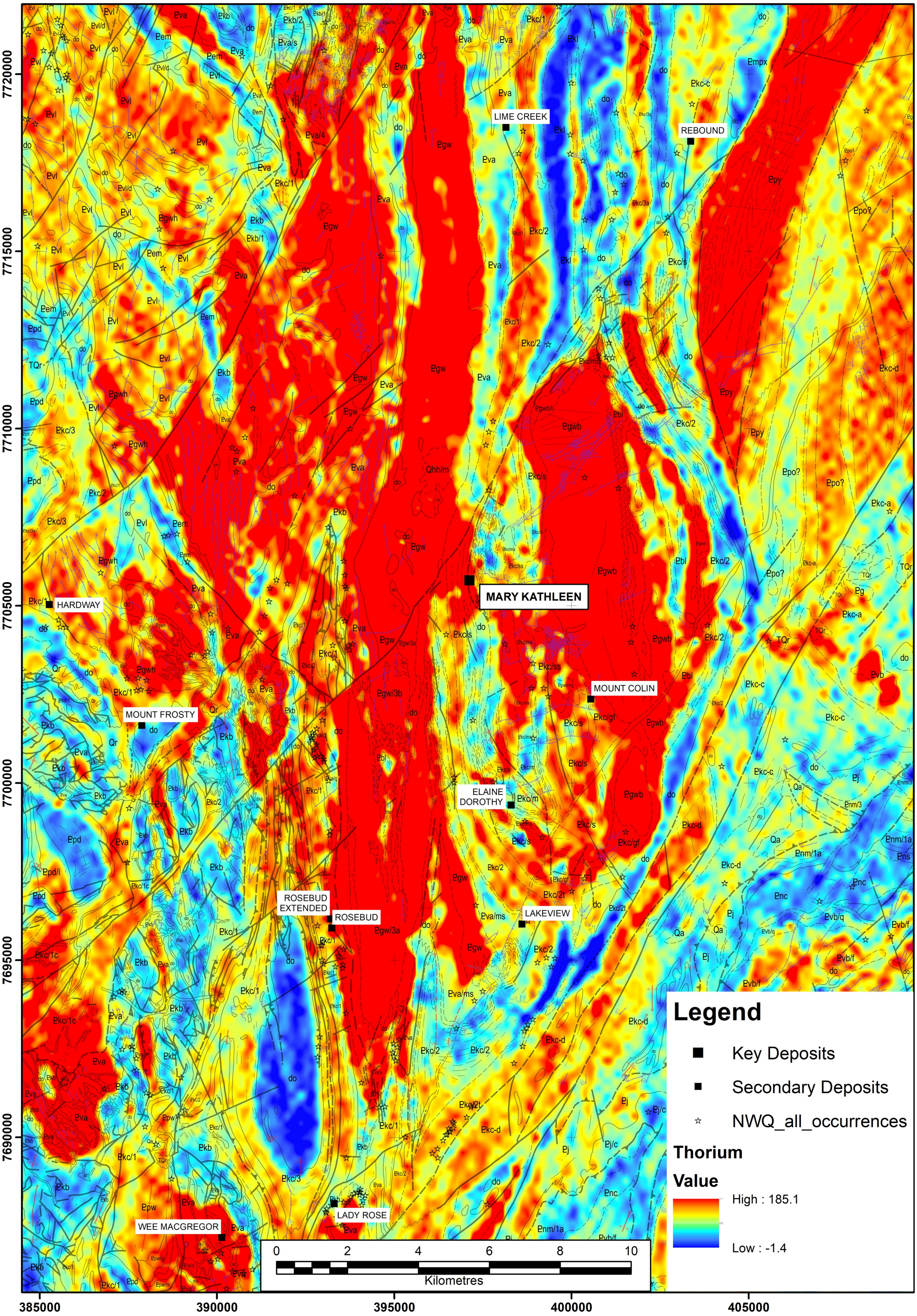

Figure 18.18: Thorium image (from QDEX Data). The high zones are strongly dominated by the Burstall (Pgwb) and other Wonga Granites (Pgw), the Lady Clayre Formation (Ppy), parts of the Argylla Formation (Pva) and the Corella Formation (Pkc/1c).

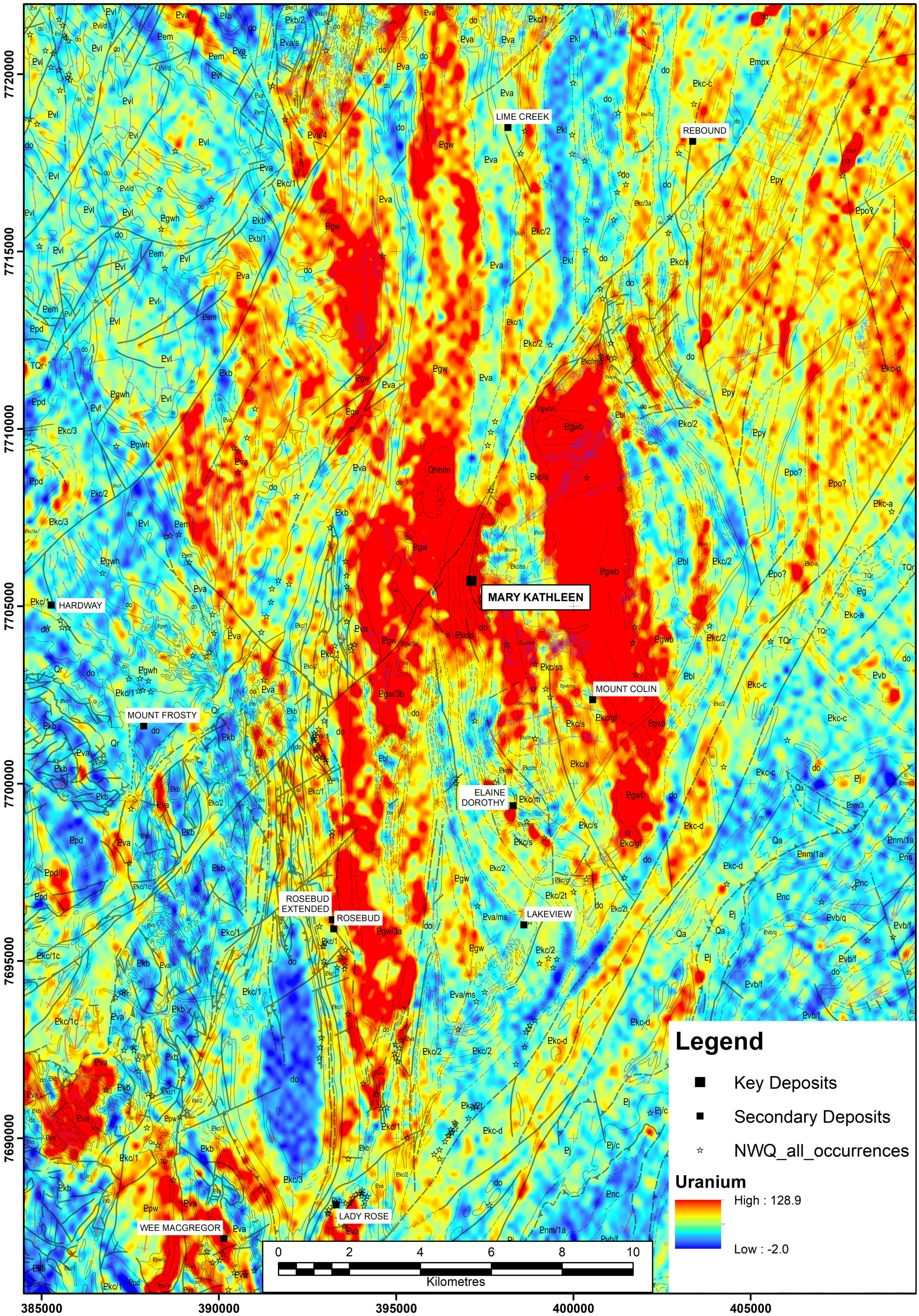

Figure 18.19: Uranium image (from QDEX Data). The high uranium zones comprise the Burstall (Pgwb) and other Wonga granites (Pgw), and parts of the Argylla Formation (Pva).

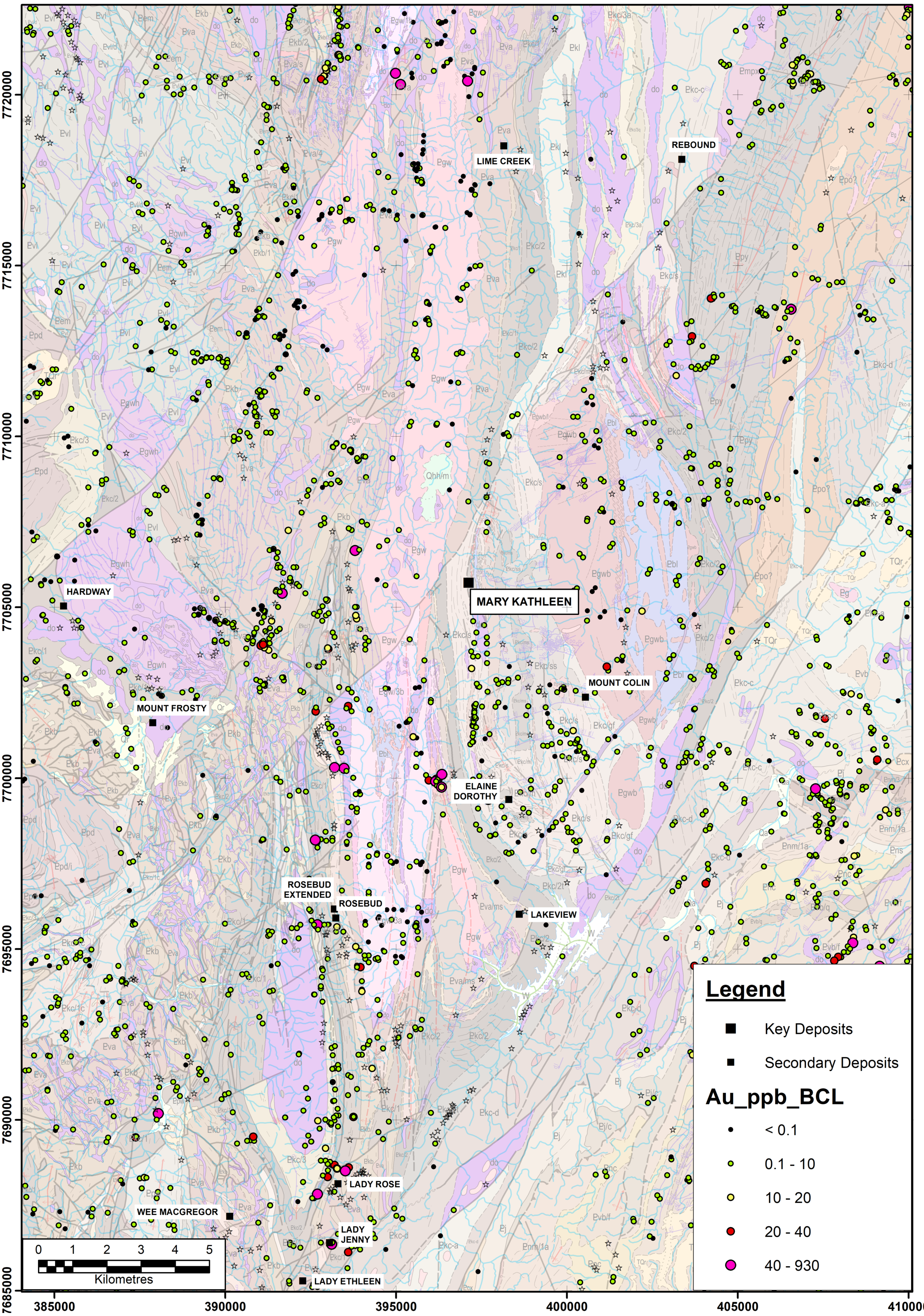

Figure 18.20: Plot of gold values from the open file stream sediment data in the Mary Kathleen district (from QDEX Data—East Isa collection). The data has not been levelled for mesh size used for collection, but a majority of samples utilised an approximate −2mm fraction and the analysis was via a bulk leach.

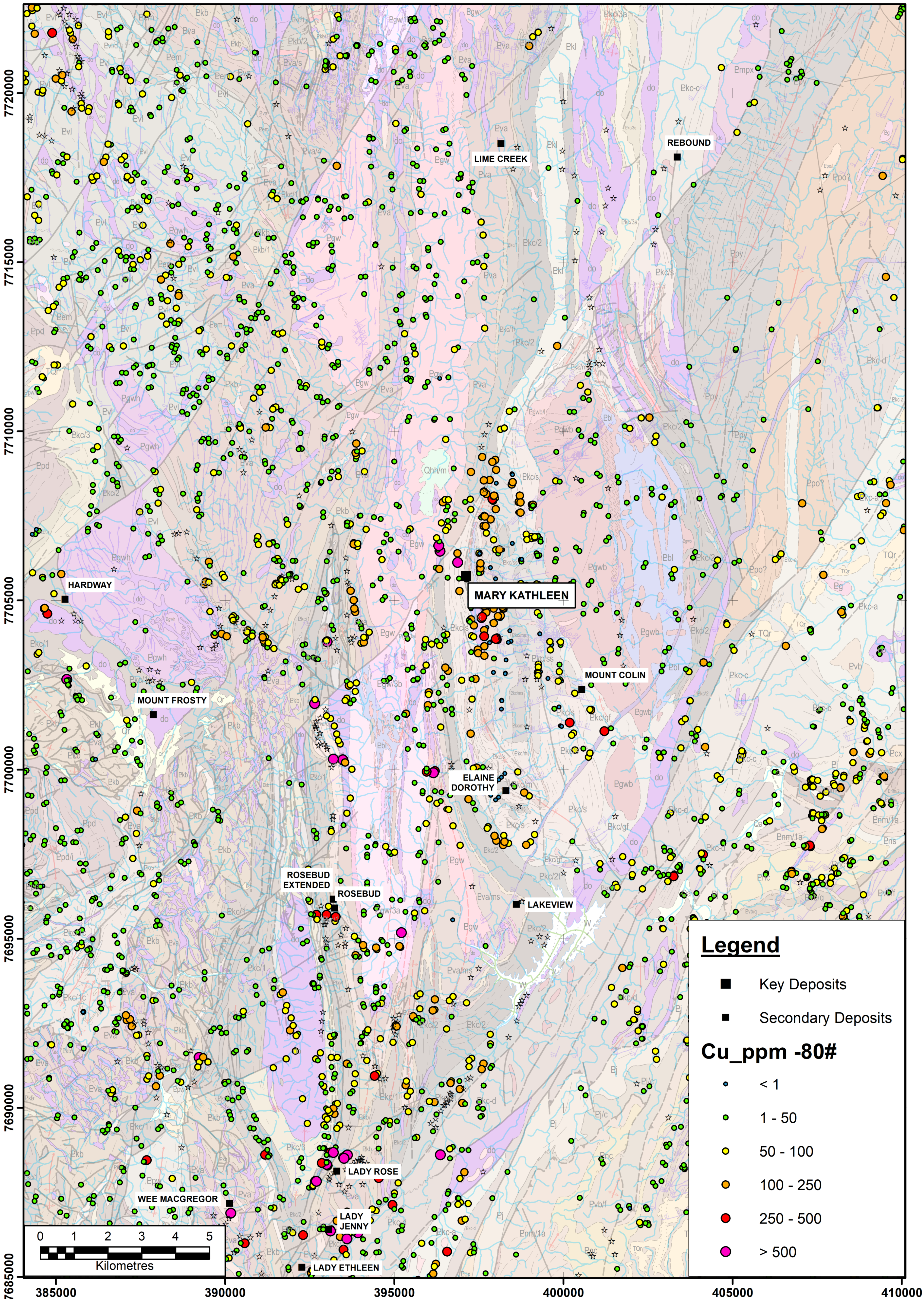

Figure 18.21: Plot of copper values from the open file stream sediment data in the Mary Kathleen district (from QDEX Data —East Isa collection). The data has not been levelled for mesh size, but the majority of data utilised a –80# fraction.

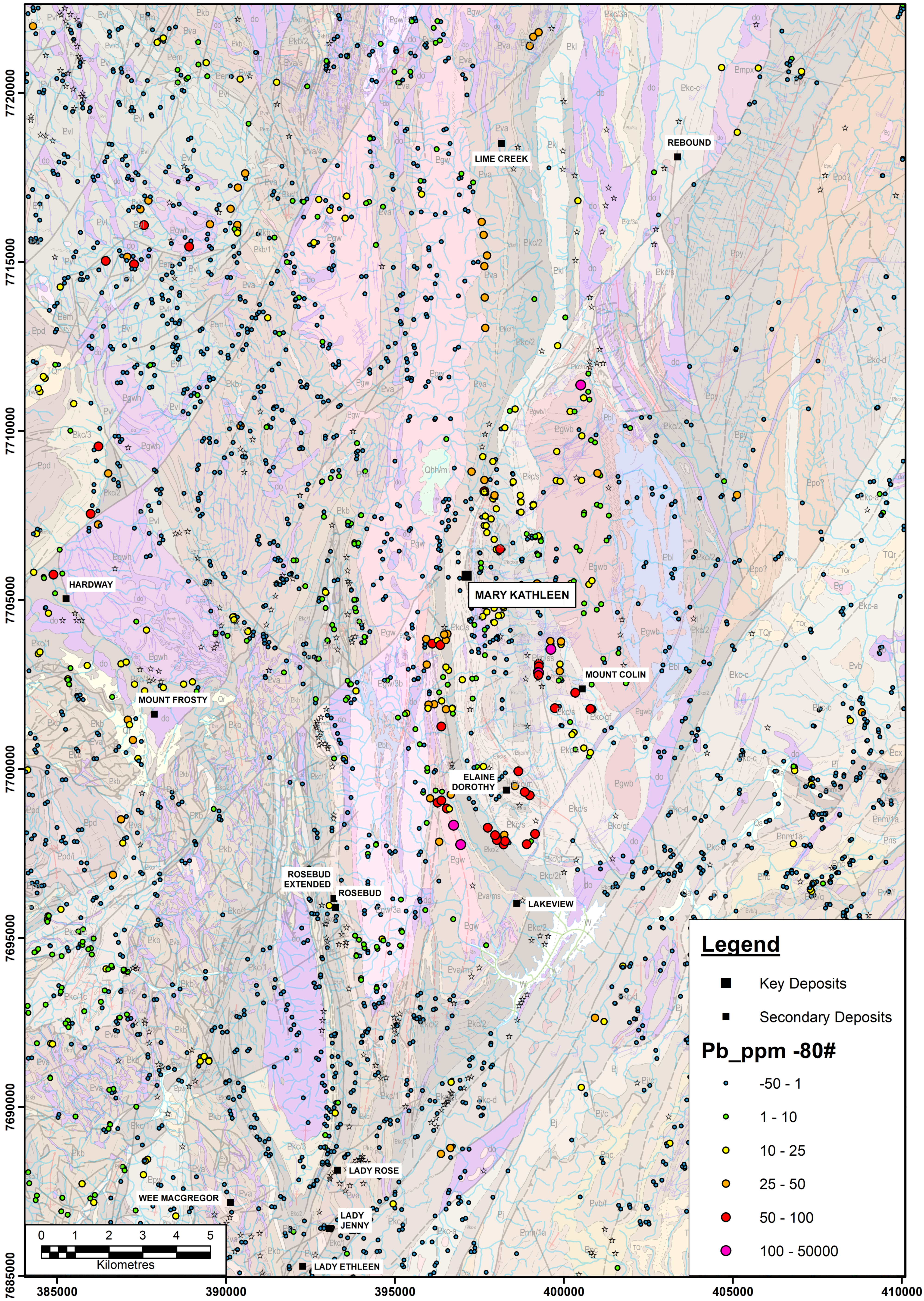

Figure 18.22: Plot of lead values from the open file stream sediment data in the Mary Kathleen district (from QDEX Data—East Isa collection). The data has not been levelled for mesh size, but the majority of data utilised a –80# fraction.

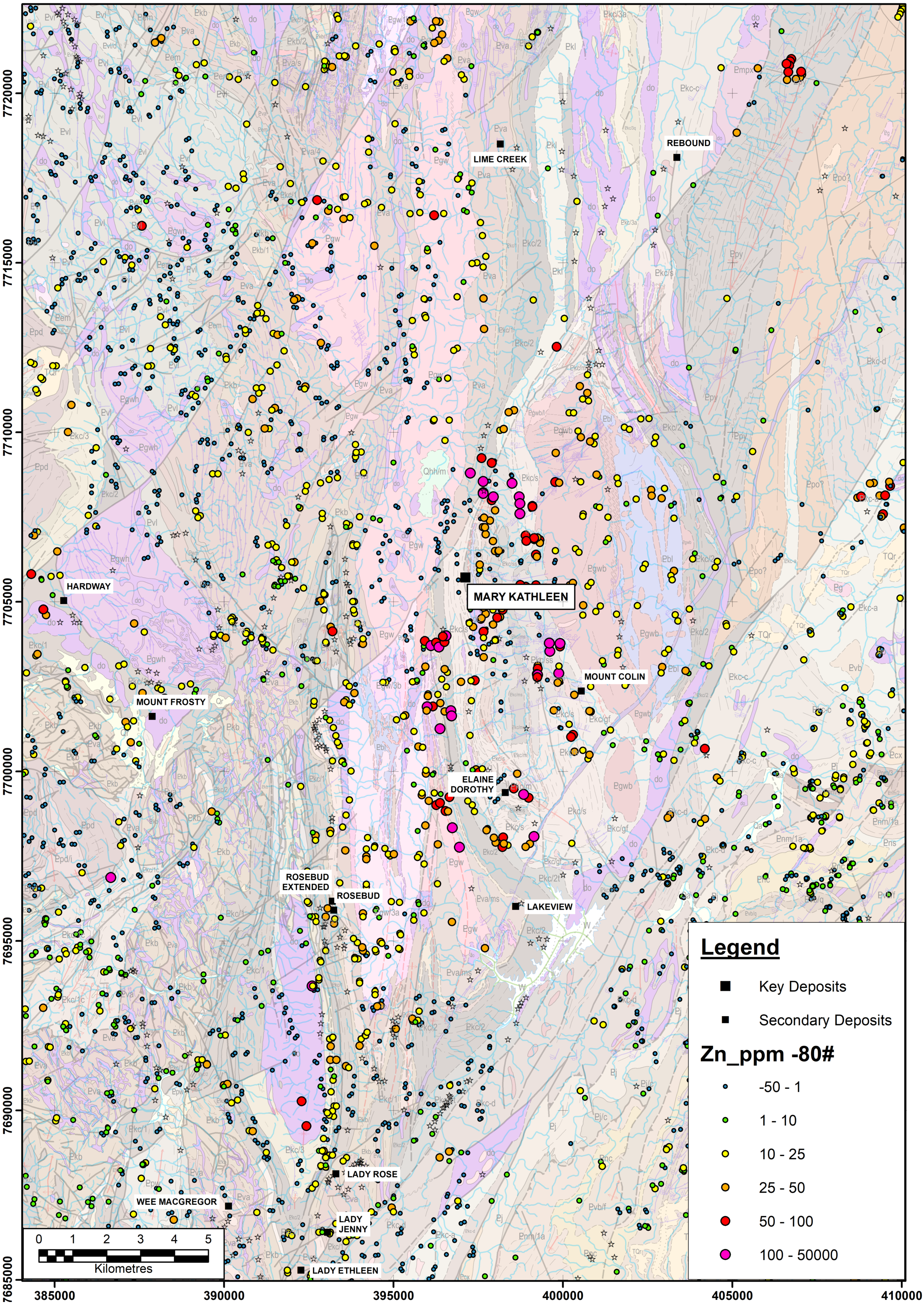

Figure 18.23: Plot of zinc values from the open file stream sediment data in the Mary Kathleen district (from QDEX Data—East Isa collection). The data has not been levelled for mesh size, but the majority of data utilised a –80# fraction.

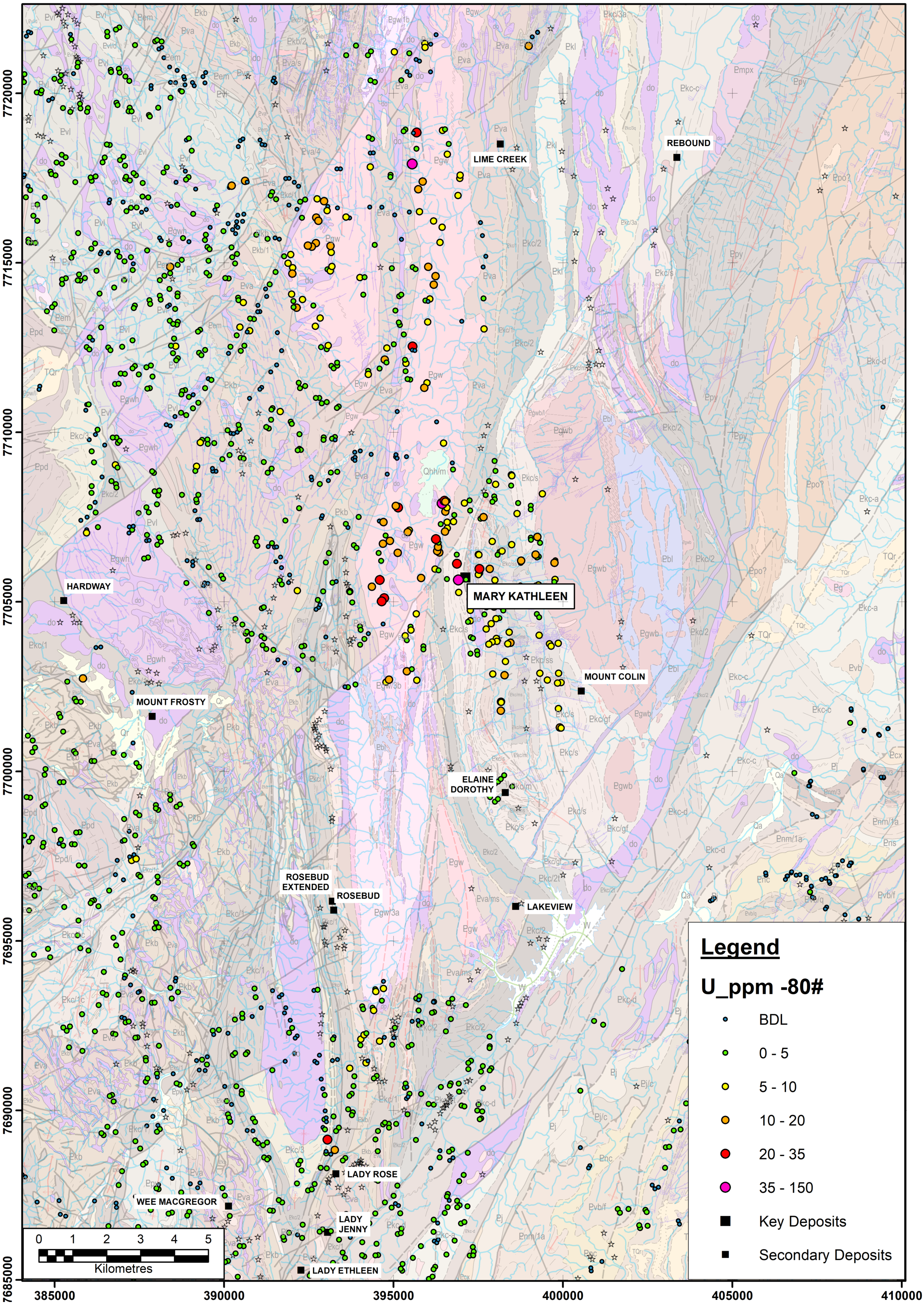

Figure 18.24: Plot of uranium values from the open file stream sediment data in the Mary Kathleen district (from QDEX Data —East Isa collection). The data has not been levelled for mesh size, but the majority of data utilised a –80# fraction.