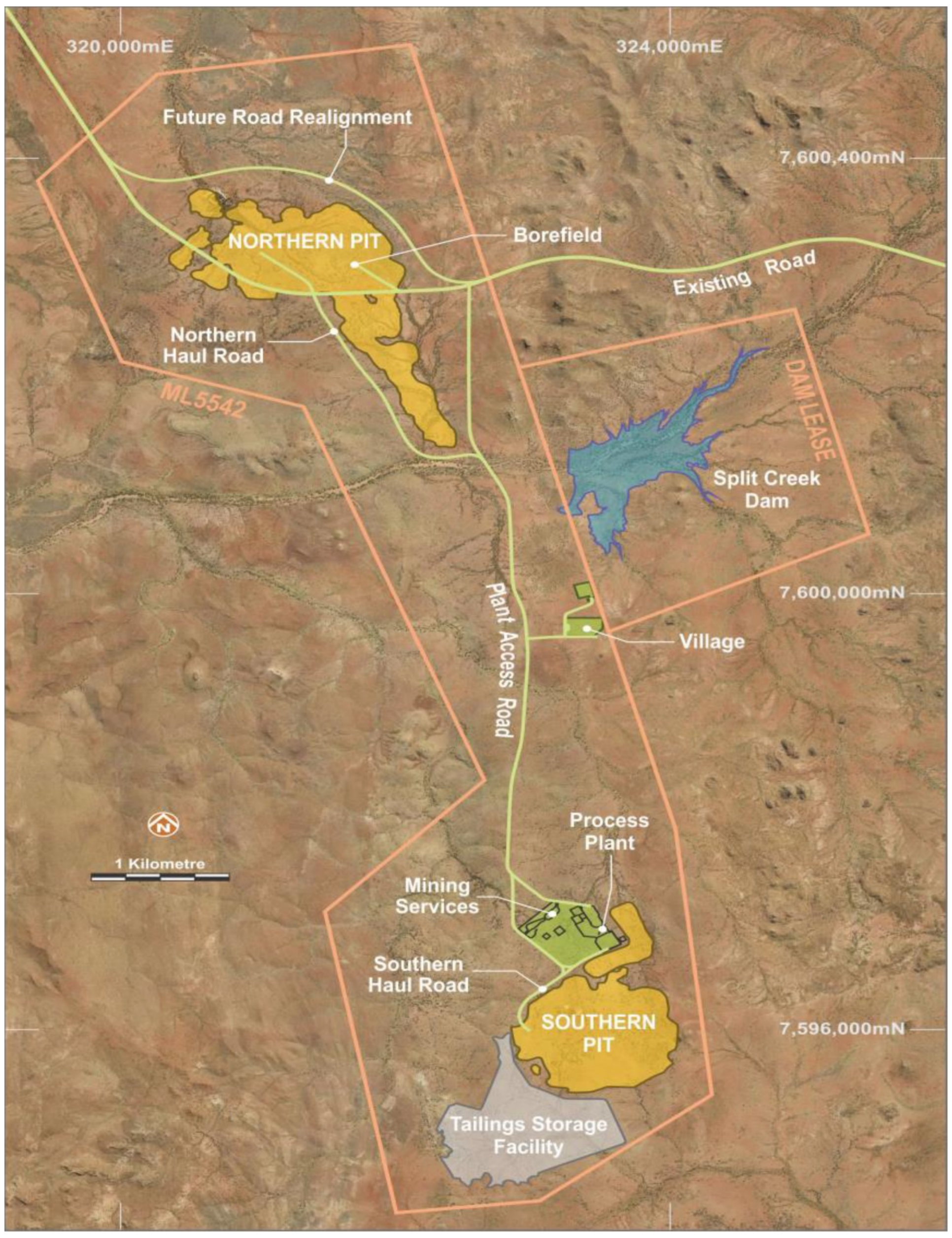
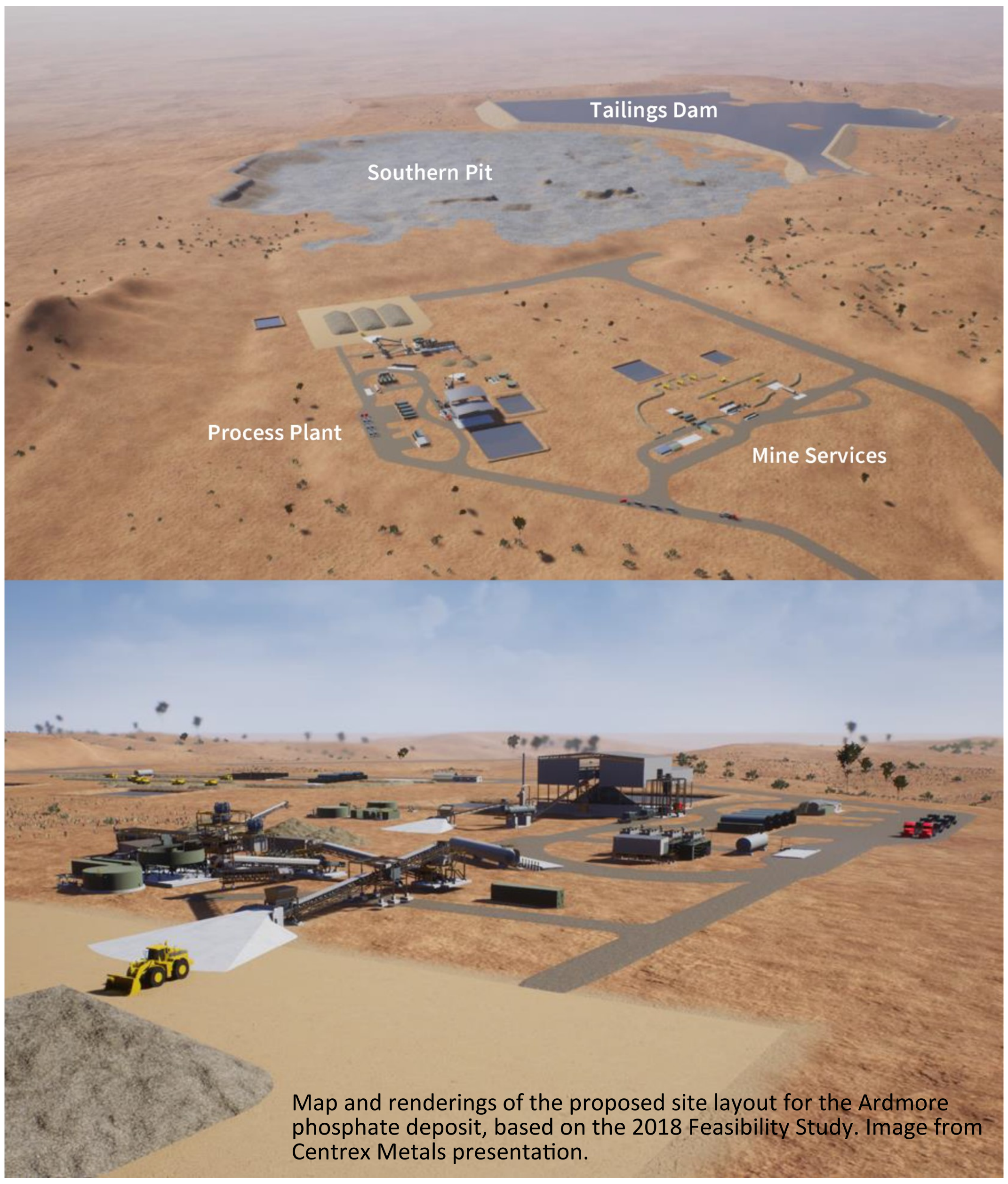
Ardmore Phosphate Deposit





Map and renderings of the proposed site layout for the Ardmore phosphate deposit, based on the 2018 Feasibility Study. Image from Centrex Metals presentation.

PREAMBLE

The Ardmore phosphate deposit is a development-stage project that has a long history extending from initial discovery in 1966 through to the completion of a Feasibility Study in 2018.

The deposit is hosted in pelletal facies phosphorites, and is relatively high grade with a 30% P_2O_5 average grade Ore Reserve.

LOCATION

Geological Domain

Ardmore – May Downs Domain (Figures 20.1, 20.2).

Co-ordinates

Latitude: 21°41' 32" S

Longitude: 139° 17' 08" E

MGA Zone 54/GDA94: 322,600 mE; 7,600,300 mN

NATURE OF MINES

Mined Commodities

Phosphate Rock

Mining Method &

Mining would occur from two open pits (Northern and Southern) and would utilise truck and excavator strip mining with overburden backfilled progressively. The life of mine strip ratio would be 5.6. Ore would be crushed to -2mm and deslimed to produce the final phosphate rock concentrate.

Depth of Mining

The majority of the open pit area would be mined to approximately 1-20m depth, with the eastern wall of the northern pit a little deeper at 40-50m (see Figure 13 of Centrex Metals Limited, 2018).

PRODUCTION AND RESOURCES

Mineralised Bodies

The target high-grade phosphorite occurs as a single, generally flat lying unit within two separate areas, the Northern Zone and the Southern Zone (Figure 20.4).

Dimensions

The Northern Zone has a strike extent of approximately 4.0 km (N-S) and the Southern Zone has a strike extent of approximately 1.6 km (E-W).

Based on drilling to date the average depths of the hanging wall and footwall contacts are 8.0 m and 12.0 m, respectively, representing an average thickness of 4m.

Table 20.1: Mineral Resources and Ore Reserves as published for the Ardmore deposit in 2018 (Centrex Metals Limited, 2018).

16% P_2O_5 Grade Cut-Off		
Mineral Resource Category	Million Tonne	P_2O_5 %
Measured	3.3	29.8
Indicated	11.1	27.4
Inferred	1.7	26.8
Total Mineral Resources	16.2*	27.8

Ore Reserve Category	Million Tonne	P_2O_5 %
Probable	7.3	30.2
Proven	2.8	30.3
Total Ore Reserves	10.1	30.2

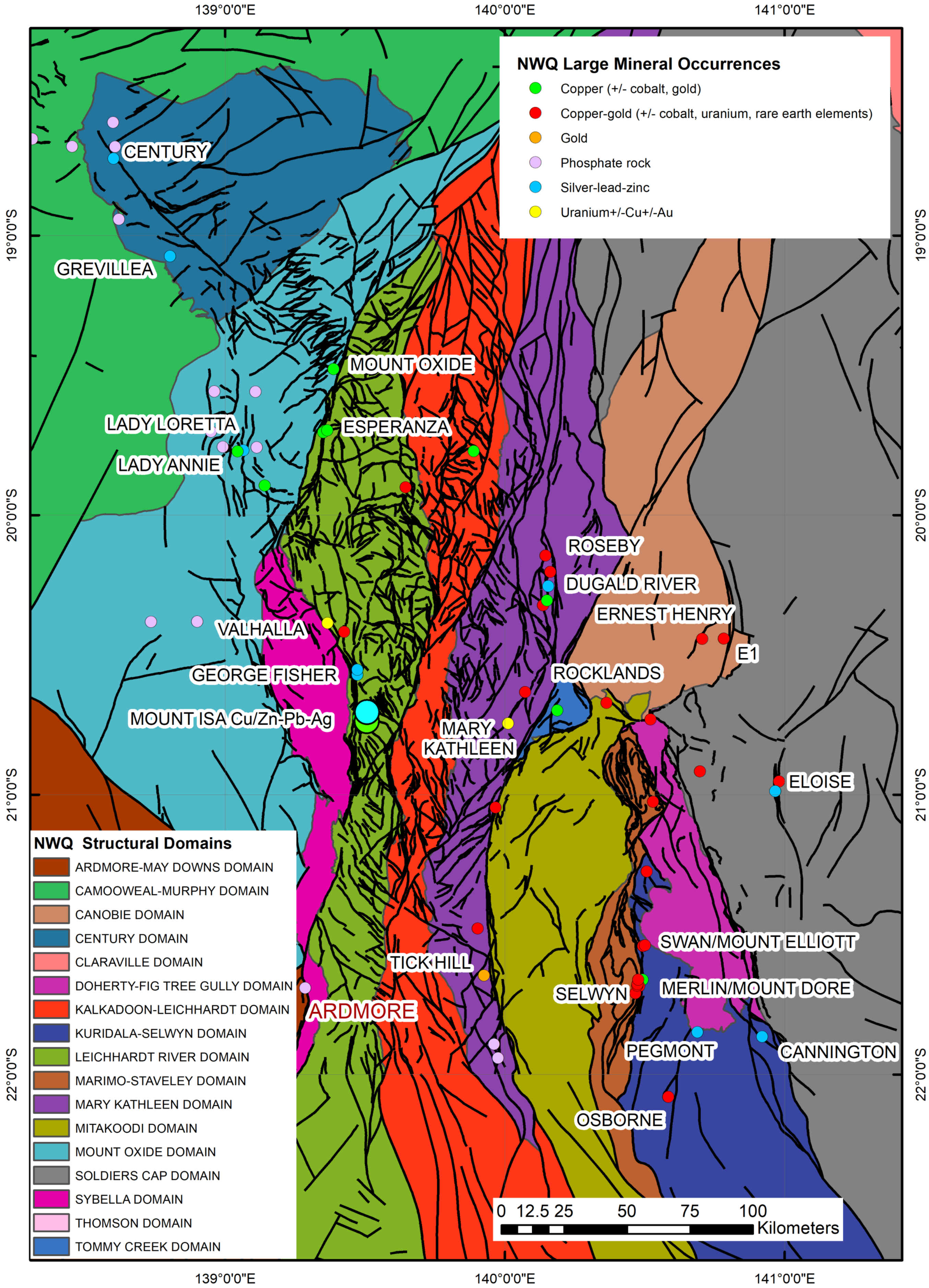


Figure 20.1: Location of the Ardmore deposit shown with respect to the Mount Isa Structural Domain Map from the 2010 NWQMEP GIS

Orientation of Mineralised Bodies

The target phosphorite unit is generally shallowly east-dipping (Figure 20.5). On a localized scale (less than 10m) the dip of the mineralised unit is variable, due to local structures, however it is considered generally flat lying or shallow dipping on a larger scale.

Production

There has been no production from the Ardmore deposit. The 2018 Feasibility Study envisages mining of 1,021,000 dry tonnes of ore for annual production of 800,000 wet tonnes of phosphate rock concentrate for a minimum 10 year mine life (Centrex Metals Limited, 2018).

Mineral Resources

The reported Mineral Resource for the Ardmore deposit comprises 16.2 Mt @ 27.8% P2O5 (Measured, Indicated and Inferred) at a 16% P_2O_5 cut-off grade (Table 20.1) as of 2018 (Centrex Metals Limited, 2018).

The Ore Reserve comprises 10.1 Mt @ 30.2% P_2O_5 (Proven and Probable) as at 2018 (Centrex Metals Limited, 2018).

GEOLOGICAL SETTING

The Ardmore phosphate deposit is hosted within Cambrian rocks of the Ardmore Outlier of the Georgina Basin. The Georgina Basin is a Neoproterozoic-early Palaeozoic epicratonic basin, having formed from a large shallow sea covering a craton. It covers part of northwest Queensland and eastern Northern Territory, and comprises 330,000 km^2.

The primordial origin of the basin dates back to the Palaeoproterozoic, when the Georgina Basin, together with the Amadeus Basin, Officer Basin and others, was part of the large Centralian Superbasin (Teasdale and Pryer, 2002). It hosted predominantly marine sedimentation. Later, from the Late Neoproterozoic, the tectonic history was more dynamic and alternated between contractional and extensional movement resulting in segmentation of the Georgina Basin into sub-basins.

During the Late Neoproterozoic Peterman Orogeny, a compressional event initiated foreland loading in the basin and created seaways with the Wiso and Daly Basins. Following this, a first rifting event caused extensional faulting and grabens, but the rifting failed due to the competent basement underlying the basin. During the Early to Middle Cambrian, a second foreland loading event resulted in quick subsidence, almost-absent sediment supply and relatively low oxygenation of the ocean floor; a set of conditions known as “starvation”. The “starvation” helped to initiate the phosphogenesis and hardground accumulation, forming the Middle Cambrian phosphate deposits below the wave base. A second unsuccessful rifting event in the Early Ordovician reinforced the extensional features of the basin and increased the topographic complexity.

This alternation in tectonic regime formed a heterogeneous landscape comprising embayments, islands and restricted deep basins. Within this scenario, the presence of coastal margins and shelf breaks increased and promoted the bifurcation and multiplication of upwelling pathways.

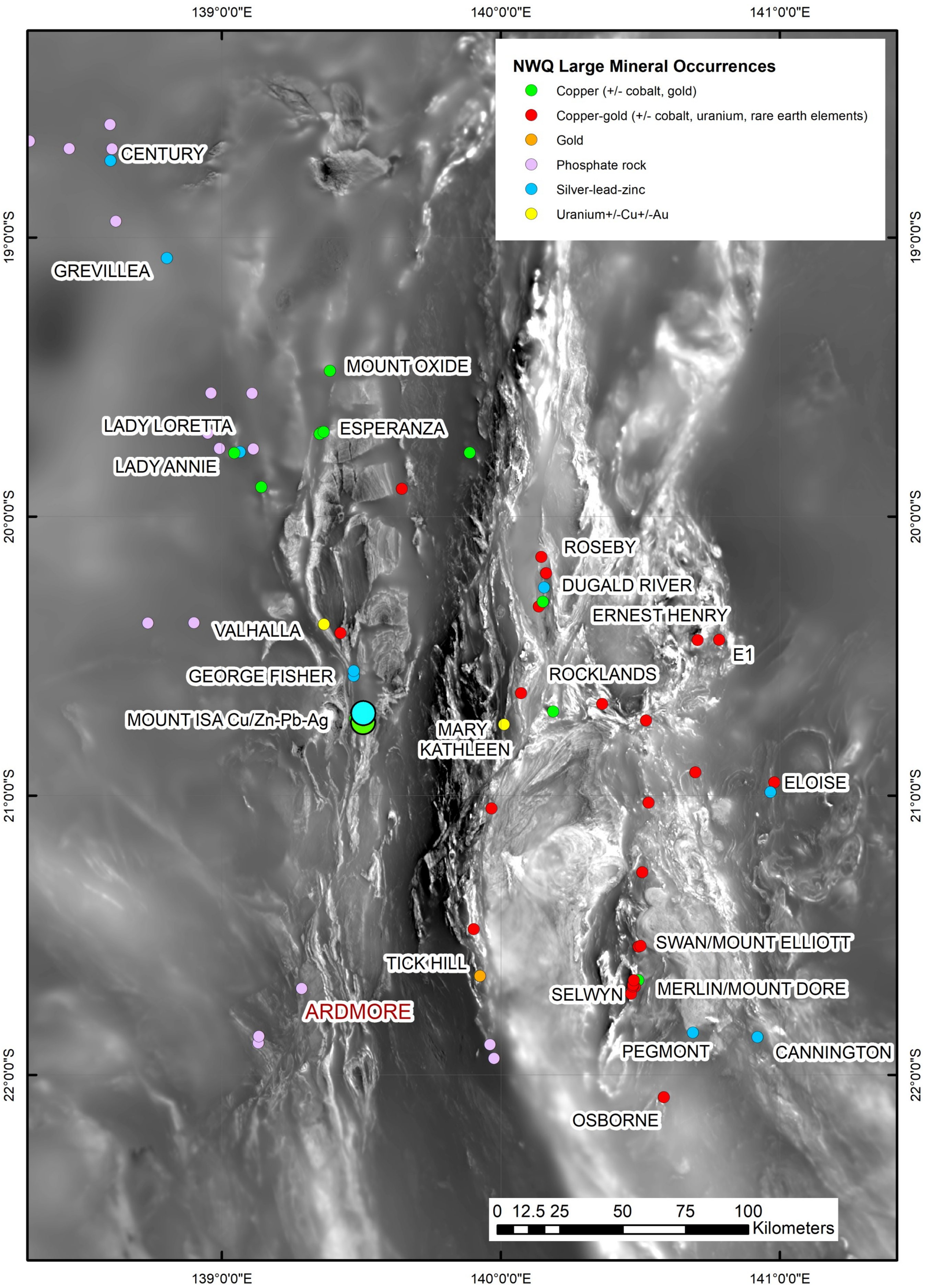
In the Devonian-Carboniferous, contractional and extensional movements were associated with the Alice Springs Orogeny (~400-350 Ma), influencing the deformation of the Georgina Basin, and still influencing the present-day stress regime of the Georgina Basin (Rajabi et al., 2017). The present-day shape of the basin is the result of erosion of some of the Paleoproterozoic and Palaeozoic sediments, together with tectonic segmentation of the basement.

The Ardmore Outlier, host to the Ardmore deposit, is interpreted as a small graben in the Rufus Fault Zone (Bultitude, 1982). The Cambrian rocks are mainly flat-lying to gently dipping, and have a faulted contact with the Sybella Granite (Pgs) and the Sulieman Gneiss (Pgs) to the east and the Saint Ronans Metamorphics (Ps) package to the west, as well as an unconformable contact with the Saint Ronans Metamorphics on the western boundary of the northern Ardmore Outlier (Figure 20.8). The Cambrian units form a concordant sequence, which is unconformably overlain by pebbly and conglomeratic sandstone of probable Mesozoic age (Bultitude, 1982).

HOST ROCKS

The Cambrian units in the Ardmore Outlier comprise a concordant sequence that contains several unconformities and hiatuses in

Figure 20.2: Location of the Walford Creek deposit overlain on an image of total magnetic intensity from the GADDS data for the region



deposition (Figure 20.7). The units comprise from base to top (Bultitude, 1982):

- **Riversdale Formation**: red-brown ferruginous, gritty to pebbly, quartzose and feldspathic sandstones, with some conglomerate in the lower part.
- **Thorntonia Limestone**: calcareous and dolomitic beds, overlain by a regionally extensive layer of rubbly black to white banded and convoluted chert and chert breccia up to 15m thick
- **Beetle Creek Formation**: phosphorites (mainly pelletal) interbedded with chert and siliceous shale. The Beetle Creek Formation is subdivided by Hamilton (1975) into the Lower Siltstone Member, which comprises black shales and cherts, and the upper Simpson Creek Phosphorite Member, which hosts the phosphate deposits.
- **Blazan Shale**: siltstone, shale, thenbeded chert, fine-grained sandstone and scarce thin bands of bituminous limestone. Typically 40-50m thick.
- **Quita Formation**: The Blazan Shale interfingers with the Quita Formation, which is a sequence up to 70m thick of thin-bedded to laminated bituminous limestone.
- **Steamboat Sandstone**: a cross-stratified ripple-marked sandstone with interbeds of silty sandstone and siltstone.

Mine Stratigraphy

Within the Ardmore Outlier, the single phosphate bed occurs within the Simpson Creek Phosphorite Member (SCPM) of the Cambrian Beetle Creek Formation.

The SCPM is essentially flat-lying with a gentle-to-moderate dip (<20°) to the east, and occurs spatially within two main separate areas: the Northern Zone and the Southern Zone.

The SCPM has an approximate average thickness of 5 m in the Southern Zone and is located from surface to greater than 15 m depth.

The Northern Zone has an approximate average thickness of 3 m and is deeper than the Southern Zone, with depths starting from near-surface in the west before dipping away to the east and extending to depths greater than 20 m.

Major Host Rock

The Cambrian-aged sedimentary phosphate deposit consists predominantly of pelletal phosphorites with small bands of collophane mudstone. The small (approx. 100-200 micron) sized pellets of carbonate-fluorapatite are thought to have formed in a shallow shelf environment with a warm climate (Hamilton, 1975).

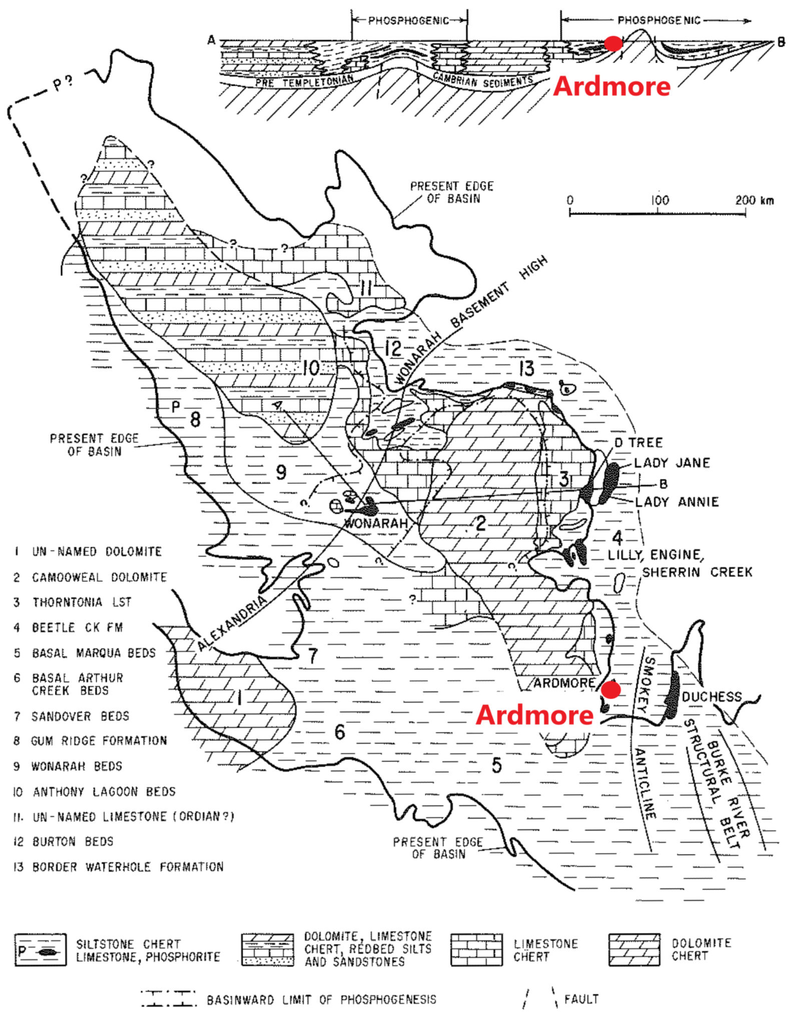


Figure 20.3: Location of the Ardmore deposit in the southeast of the Cambrian Georgina Basin. A set of phosphate deposits were developed on the eastern margin of the Georgina Basin during the Cambrian. The approximate location of the Ardmore deposit is shown on the schematic section in the phosphogenic zone adjacent to a basement high.

From Howard, (1986).

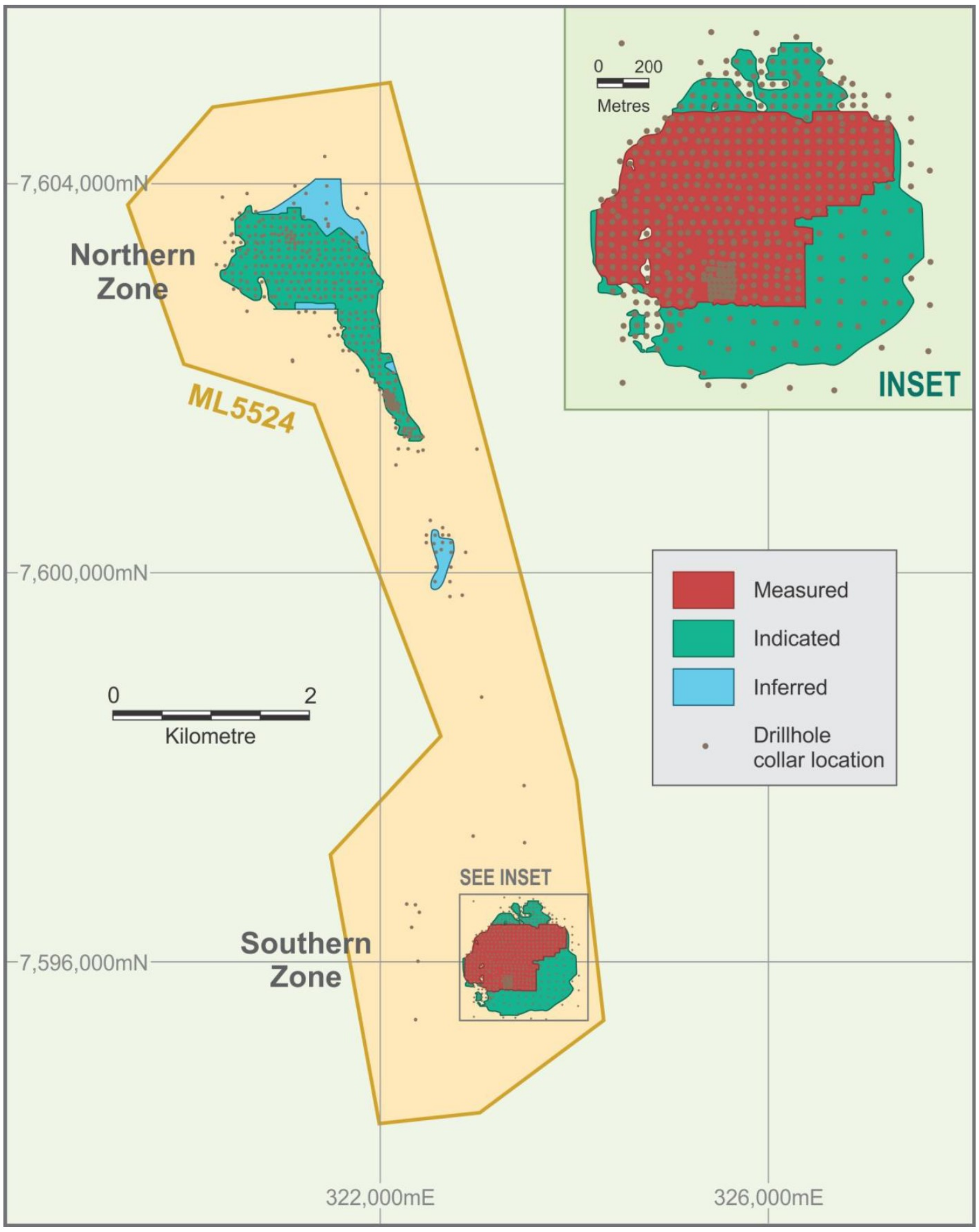


Figure 20.4 (left): Plan of the location of the Mineral Resource, which comprises two main zones separated by approximately 5km. From Centrex Metals Limited, 2018a.

INTRUSIVE ROCKS

There are significant granitic bodies of Proterozoic age in the vicinity of the Ardmore Outlier, with much of the southern Ardmore Outlier juxtaposed against a Sybella Granite body by the Rufus Fault Zone.

However, the presence of intrusive rocks is not thought to have had any direct bearing on development of phosphate mineralisation.

METAMORPHISM

The Cambrian sedimentary rocks of the Ardmore Outlier are not metamorphosed. The underlying and fault juxtaposed Proterozoic rocks are typically metamorphosed to amphibolite facies.

STRUCTURAL CHARACTERISTICS

Structural Setting

The Ardmore Outlier is interpreted as a small downfaulted graben of Cambrian rocks in the Rufus Fault Zone (Bultitude, 1982). The Rufus Fault Fault Zone is a regionally extensive, broadly NNE-trending, fault zone, that swings into a NNW orientation in the vicinity of the Ardmore Outlier. It is interpreted as an extension of the Mount Annable Fault to the north. The Mount Rufus Fault, and the Wonomo Fault further to the east, are interpreted as deep crustal discontinuities (Bultitude, 1982), which display long-lived movement during the Proterozoic and post-Cambrian.

Structural History

Northeast and northwest-trending faults cross-cut the Cambrian rocks in the Ardmore area, with a northeast trending fault inferred as crosscutting the northern Ardmore Outlier. These faults are in turn crosscut by the Rufus Fault Zone. Minor folding of the Cambrian sequence and steepening of dips close to fault zones are interpreted as related to late fault movement.

Major Structural Styles

Typically the Cambrian sedimentary rocks throughout the Ardmore district show broad fold flexures, with dips of less than 5° except adjacent to some faults where the beds are moderately to steeply dipping. In the immediate deposit environs that dip shallowly to the east, with localised small-scale folding of the phosphorite horizon (Figure 20.5).

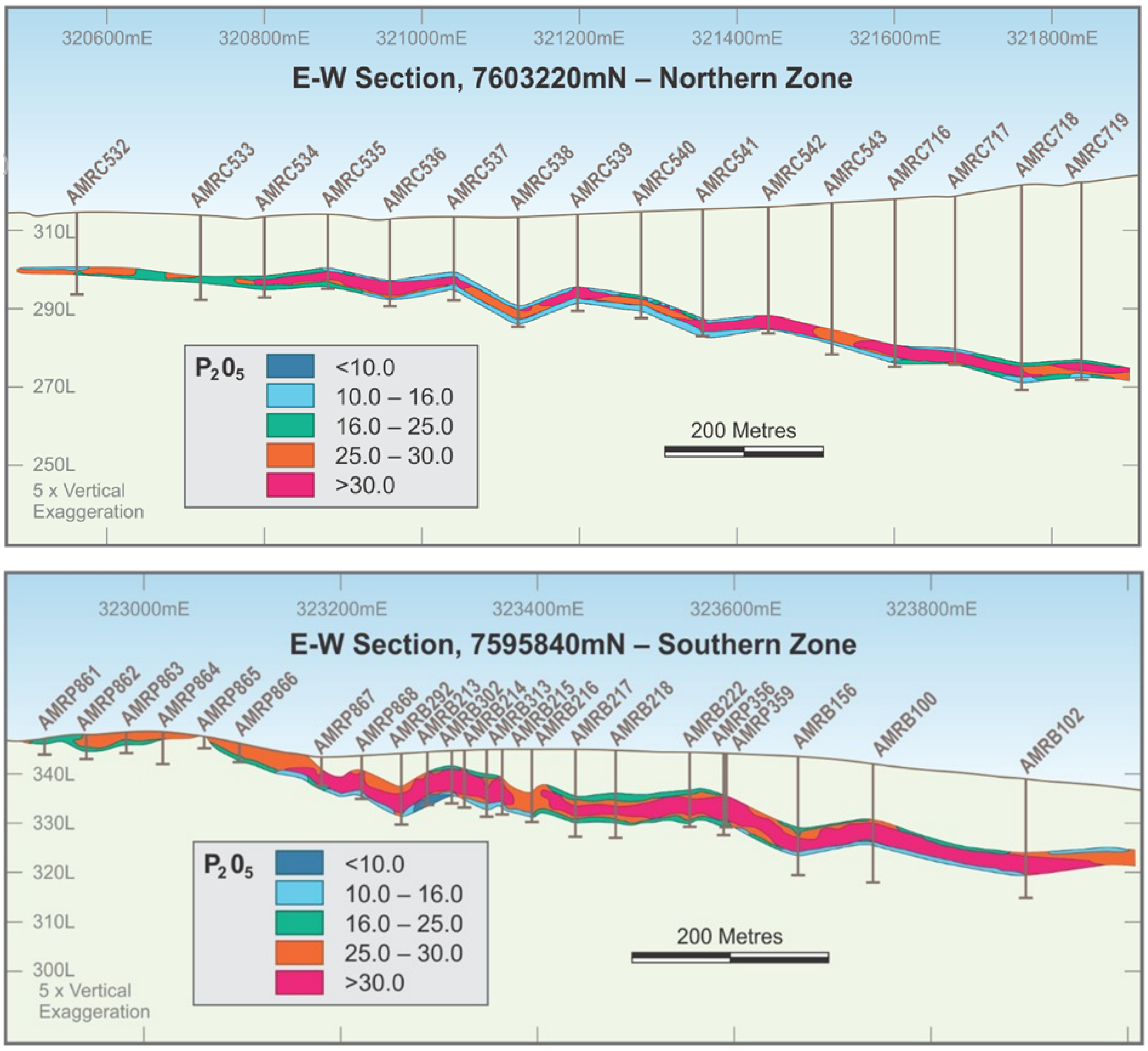


Figure 20.5 (left): East-west grade cross-sections through the Northern and Southern Zones. Both zones dip shallowly to the east and have east-west extents of +1000m. Note 5x vertical exaggeration. From Centrex Metals Limited, 2018a.

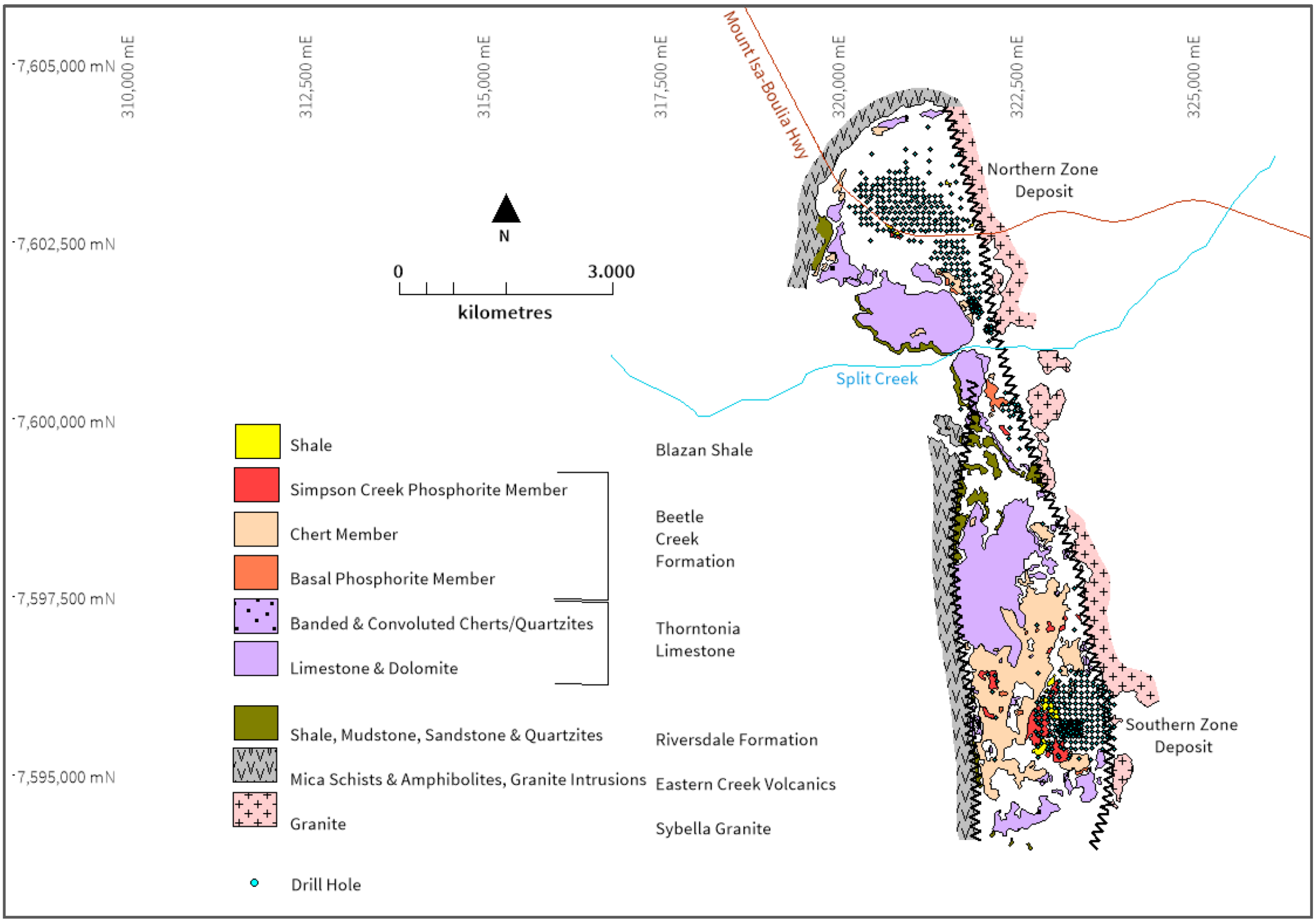


Figure 20.6 (above): Geological map of the Ardmore Outlier and Phosphate deposit. The main phosphate host, the Simpson Creek Phosphorite Member does not outcrop over the entire deposit, being locally overlain by the Blazan Shale. From Centrex Metals Ltd, 2018b).

Figure 20.7 (below): Stratigraphic column showing the Cambrian stratigraphy in the Ardmore Outlier. From Bultitude, 1982).

Structural Controls on Mineralisation

Other phosphate deposits in the eastern Georgina Basin have well documented relationships with broadly north-south trending fault systems that have been active during phosphorite deposition and acted to localise the phosphate mineralisation. Examples include the Phosphate Hill (Russell and Trueman, 1971) and Lady Annie deposits (Cook and Elgueta, 1986).

It is not clear if any such controlling structure was active at the Ardmore deposit, although approximate north-south trending faults occur on either side of the Ardmore Outlier. The slight thickening to the east of the phosphorite horizon in the Northern Zone (Figure 20.5) perhaps hints at a fault on the eastern margin, part of the Rufus Fault Zone, with syn-depositional normal movement.

MINERALISATION

General Characteristics

The phosphorite composition is well documented by Hamilton (1975), with the following based on excerpts from this thesis. The phosphorites comprise both pelletal and collophane mudstone, with the collophane mudstone dividing the pelletal phosphorites into two sub-horizons with differing dominant lithologies.

Upper Pelletal Unit

The upper pelletal layer is a white, off-white, tan to khaki, blocky think to thin bedded indurated phosphorite with loose pelletal material. The pellets in this upper layer are well sorted (0.1 – 0.2mm) and there is a distinct lack of smaller pellets. Large-scale crossbedding is present in the beds of this upper pelletal sequence. The cement in the indurated beds is usually cryptocrystalline silica although phosphatic and calcareous cement may occur.

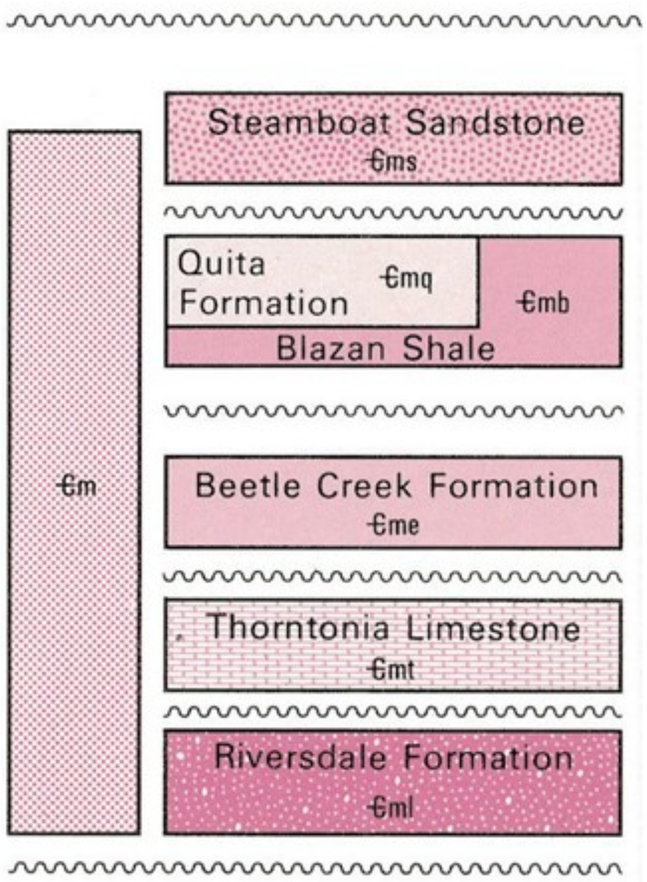
Calcareous fragments may be present which have been partially phosphatised indicating that replacement of calcareous material by phosphate has occurred.

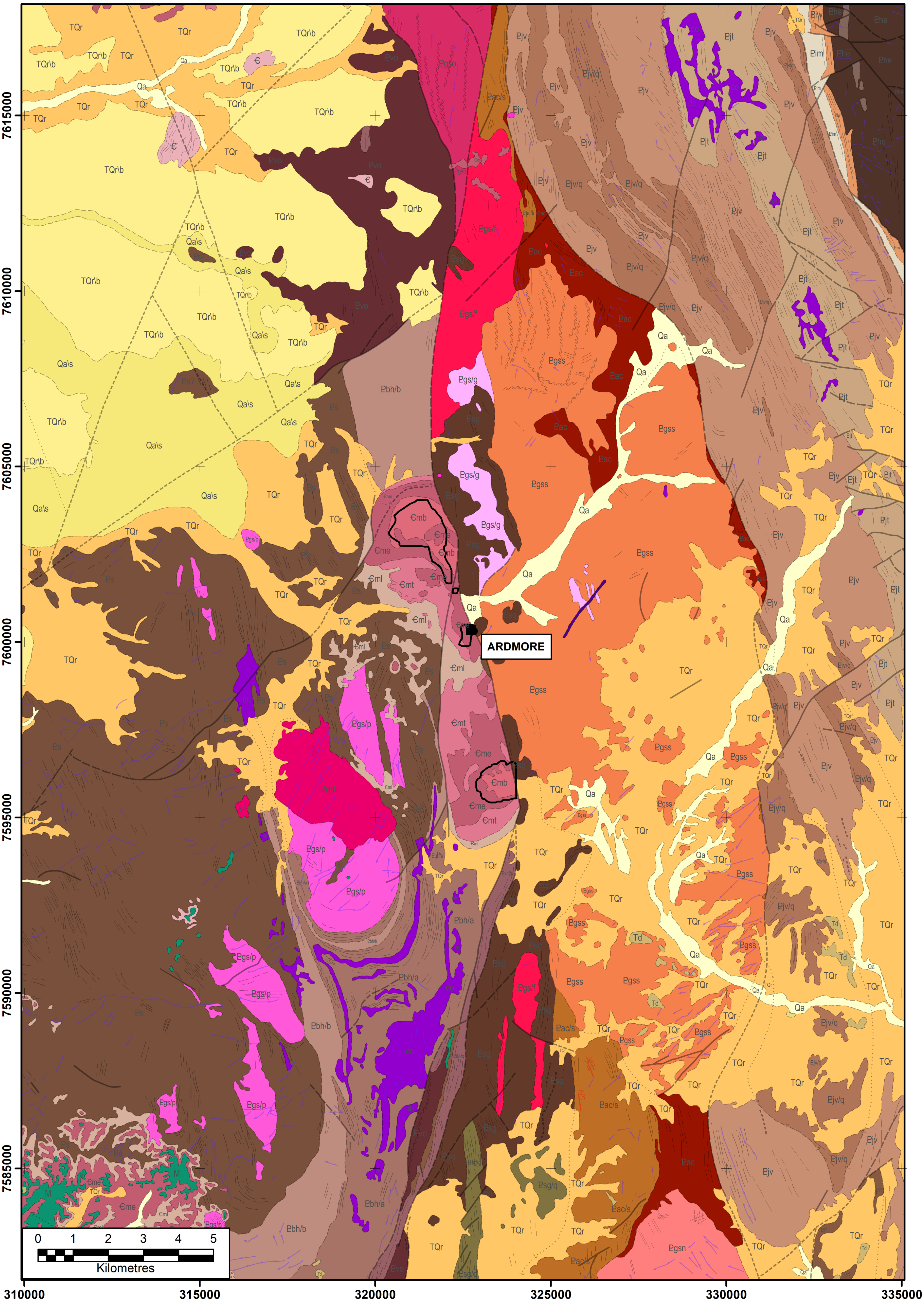
Collophane Mudstone

The collophane mudstone is a fine grained, brown to milky white well fractured layer. In hand specimen the bed is chert like in appearance. The layers vary in thickness from 65mm to 180mm, and the beds within these layers vary in thickness from 1mm to 40mm. The collophane layers contain over 31% P2O5 and are composed almost entirely of carbonate fluorapatite. In thin section the beds consist dominantly of very fine grains of phosphate with minor grains of quartz, calcite and sericite.

Lower Pelletal Unit

The pelletal sequence below the collophane mudstone consists of a white, tan,




ARDMORE
Kilometres
0 1 2 3 4 5
310000
315000
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Legend

Mesozoic - Cenozoic

- Qa-QLD
- Qa\s-QLD
- TQr-QLD
- TQr\b-QLD
- Td-QLD
- Td\q-QLD
- M-MI

Cambrian

- **Cmb** Blazan Shale
- **Cme** Beetle Creek Formation
- **Cmt** Thorntonia Limestone
- **Cml** Riversdale Formation

Mount Isa Group

- **Pi** Mount Isa Group?
- **Pim** Moondarra Siltstone
- **Piw** Warrina Park Quartzite

Intrusive Rocks Sybella dominant

- **Pbk** Lakeview Dolerite
- **Pgsb** Briar Granite
- **Pgso** Kahko Granodiorite
- **Pgss** Steeles Granite
- **Pgsn** Wonomo Granite

Pgs

- Sybella Granite
- Sybella Granite/f
- Sybella Granite/g
- Sybella Granite/p

Pvo

- Oroopo Metabasalt
- Oroopo Metabasalt/q

Phe

- Eastern Creek Volcanics
- Eastern Creek Volcanics/q

Phg Mount Guide Quartzite

Pjv/q Jayah Creek Metabasalt/q

Pjt Timothy Creek Sandstone Member

Pjv Jayah Creek Metabasalt

do-MI

Pbh

- Bucket Hole Metavolcanics/a
- Bucket Hole Metavolcanics/b

Pac

- Alpha Centauri Metamorphics
- Alpha Centauri Metamorphics/s

Ps

- Saint Ronans Metamorphics
- Saint Ronans Metamorphics?

Psg

- Sulieman Gneiss
- Sulieman Gneiss/q

Figure 20.8: Geological map (previous page) and stratigraphic legend (right) from the 1:100,000 mapping from the Geological Survey of Queensland of the Ardmore area.

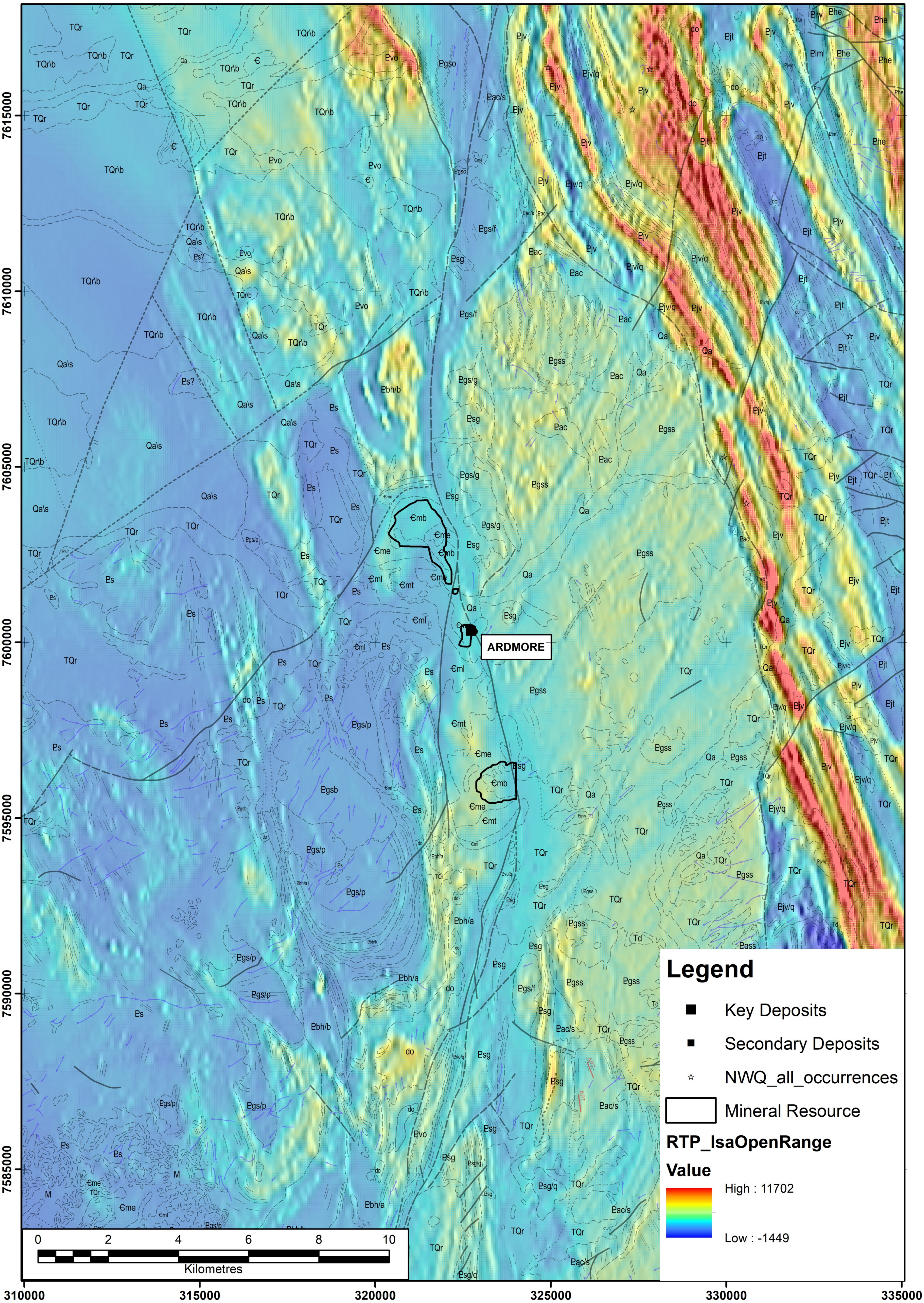

Figure 20.9: Reduced-to-pole aeromagnetic image with 1st vertical derivative sharpening (Mount Isa Open Range survey dataset sourced from QDEX Data https://qdexdata.dnrme.qld.gov.au/GDP/Search).

khaki to grey, thin bedded, often laminated phosphorite. The beds here are poorly cemented and friable. The sorting of this sequence is inferior to that in the upper pelletal unit, with the grain size ranging from 0.066mm to 0.6mm. Some beds here have a slight shale content.

The pellets are roughly spherical in shape but in thin section they show no concentric structures.

XRD analysis of indurated pelletal phosphorite from the southern zone suggests the mineralogy is carbonate fluorapatite (francolite). As well as the carbonate fluorapatite there is a fibrous phosphatic material present (Hamilton, 1975) that occupies the pore spaces in the pelletal phosphorite, and is interpreted by Hamilton (1975) as the secondary phosphate mineral dahlite. The pelletal phosphorites also contain grains of detrital quartz and glauconite. The quartz and glauconite grains in some specimens are replaced by phosphate.

GEOPHYSICAL EXPRESSION

Little information is available regarding geophysical work on the Ardmore deposit, or indeed any of the phosphate deposits in the North West Mineral Province. A set of images of aeromagnetic, bouguer gravity, airborne EM and radiometric data are provided in Figures 20.9 to 20.14.

Of note is the high uranium concentration in the Beetle Creek Formation, which was used as an early prospecting tool in the 1960's. The Southern Zone also appears to be anomalous in the thorium data, but potassium anomalism is not notable in either the southern or northern deposits at Ardmore.

Airborne EM

VTEM airborne EM data was acquired in 2008 (QDEX survey number 1197). The airborne TEM data (Figure 20.11) shows strong conductivity anomalism over the Ardmore deposits, especially the northern deposit. The source of the conductivity is likely either the Blazan Shale, or the Lower Siltstone Member of the Beetle Creek Formation, from which black shales have been reported (Hamilton, 1975).

TIMING OF MINERALIZATION

Absolute Age

The creation of phosphate mineralisation is well known to occur during sedimentation. The Beetle Creek Formation, which hosts the bulk of the phosphorites in the southeastern Georgina Basin is early Middle Cambrian in age, from approximately Templetonian time at approximately 505 Ma (Withnall and Hutton, 2013).

GENETIC MODEL

The genetic model for sedimentary phosphate deposits in the Georgina Basin is generally well established. Within a sedimentary setting, phosphogenesis produces phosphorous (P), enriching the sediments with francolite, apatite or wavellite (phosphate minerals). The sedimentary environments suitable for phosphogenesis are usually marine settings related to P-rich upwelling currents, lagoonal restricted settings related to organic-rich sediments, or coastal settings related to large sediment supply from active river systems. In the eastern Georgina Basin the upwelling currents are interpreted to have come from the deeper waters to the west with deposition in small embayments in shallow water.

POST-FORMATION MODIFICATION

Hamilton (1975) reports that the layers of phosphate at the deposit are folded into the form of a small syncline with an eastward dip. Small faults are also present in the Simpson Creek Phosphorite Member.

EXPLORATION

Discovery Method

The key phosphate deposits of the eastern Georgina Basin were discovered in the mid -1960's by Broken Hill South Limited. The first discoveries were made in Beetle Creek Formation of the Duchess and Ardmore regions in early 1966, followed by the discovery of the suite of deposits in the Highland Plains area including localities referred to as Mount O'Connor and Babbling Brooke Hill in early 1967, and Mount Jennifer, Phantom Hills and Riversleigh later in the year. Lady Annie was discovered further to the south in late 1967, with the discovery of the nearby Lady Jane deposit (a northern extension to Lady Annie, under Mesozoic cover) approximately one year later.

The key exploration tool was field mapping and semi-quantitative chemical testing carried out on outcrop and float. This was followed by trenching and vertical rotary-percussion drilling (Rogers, 1986).

REFERENCES

Bultitude, R.J., 1982. ARDMORE, Queensland 1:100,000 Geological Map Commentary. Geological Survey of Queensland.

Centrex Metals Limited, 2018a. Ardmore Phosphate Rock Project: Definitive Feasibility Study Resuilts & Maiden Ore Reserve. ASX Press Release dated 8 October, 2018.

Centrex Metals Limited, 2018b. Ardmore Phosphate Rock Project: Scoping Study shows strong returns. ASX Press Release dated 15 January, 2018.

Cook, P. J. and S. Elgueta (1986). Proterozoic and Cambrian phosphorites - deposits: Lady Annie, Queensland, Australia. Phosphate deposits of the world. P. J. Cook and J. H. Shergold, Cambridge University Press. 1: 132 -148.

Hamilton, K.W., 1975. The geology of the southern Ardmore Outlier and its associated phosphorites. B.Sc. (Hons.) thesis, James Cook University, Townsville, Australia.

Howard, P. F., 1986. Proterozoic and Cambrian phosphorites - regional review: Australia. In P. J. Cook, & J. H. Shergold (Eds.), Phosphate deposits of the world: Proterozoic and Cambrian phosphorites (Vol. 1, pp. 20-41). (Cambridge Earth Science Series). Cambridge: Cambridge University Press.

Rajabi, M., Tingay, M., Heidbach, O., Hillis, R. and Reynolds, S., (2017). The present-day stress field of Australia. Earth-Science Reviews, 168, pp.165-189.

Rogers, J.K. 1986. Report on area relinquished – April, 1985. Authority to Prospect 903M, Northwest Queensland, Open file company exploration report, CR15312.

Russell, R.T. and Trueman, N.A. 1971. The geology of the Duchess phosphate deposits, northwestern Queensland, Australia, Economic Geology, 66, pp. 1186-1214.

Teasdale, J. and Pryer, L. (2002). Georgina Basin SEEBASE Project, NTGS Record 2002 -004.

Withnall, I. W., and Hutton, L. J., 2013, Chapter 2: North Australian Craton, in Jell, P. A., ed., Geology of Queensland: Brisbane, Geological Survey of Queensland, p. 23-112

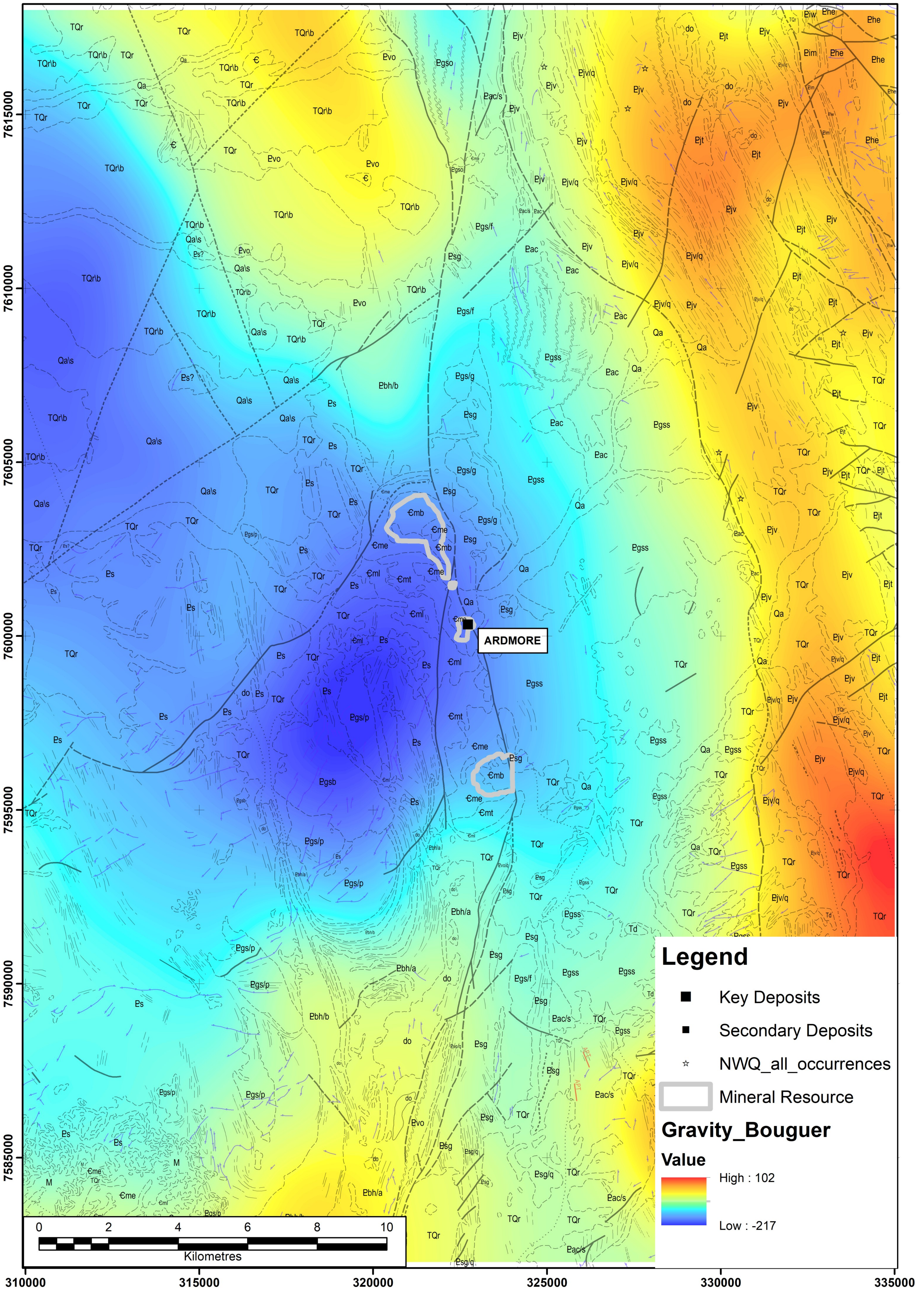

Figure 20.10: Bouguer (infinite slab model) gravity image (dataset sourced from QDEX Data https://qdexdata.dnrme.qld.gov.au/GDP/Search). Contours of 10 µm/s2. The granites I the area are notable in their low density signature, particularly where in contact with the high-density contrasting Jayah Creek Metabasalt (Pjv).

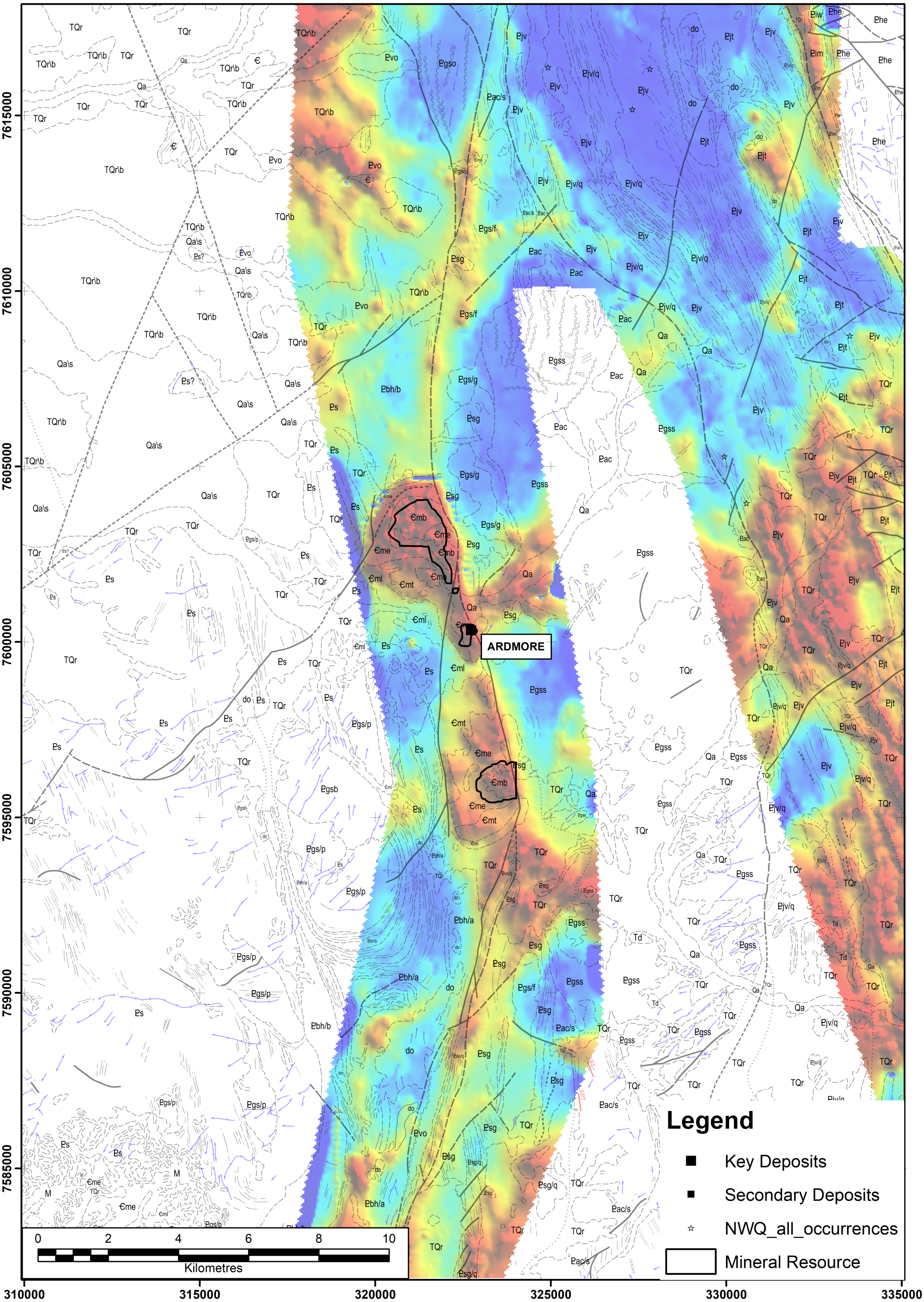

Figure 20.11: Pseudocolour image of VTEM data (dB/dt channel 15, red = higher conductivity) over the Ardmore deposit. The Northern and Southern Zones, which host the mineral resources, are anomalously conductive, presumably related to either the presence of black shales in the Lower Siltstone unit of he Beetle Creek Formation.

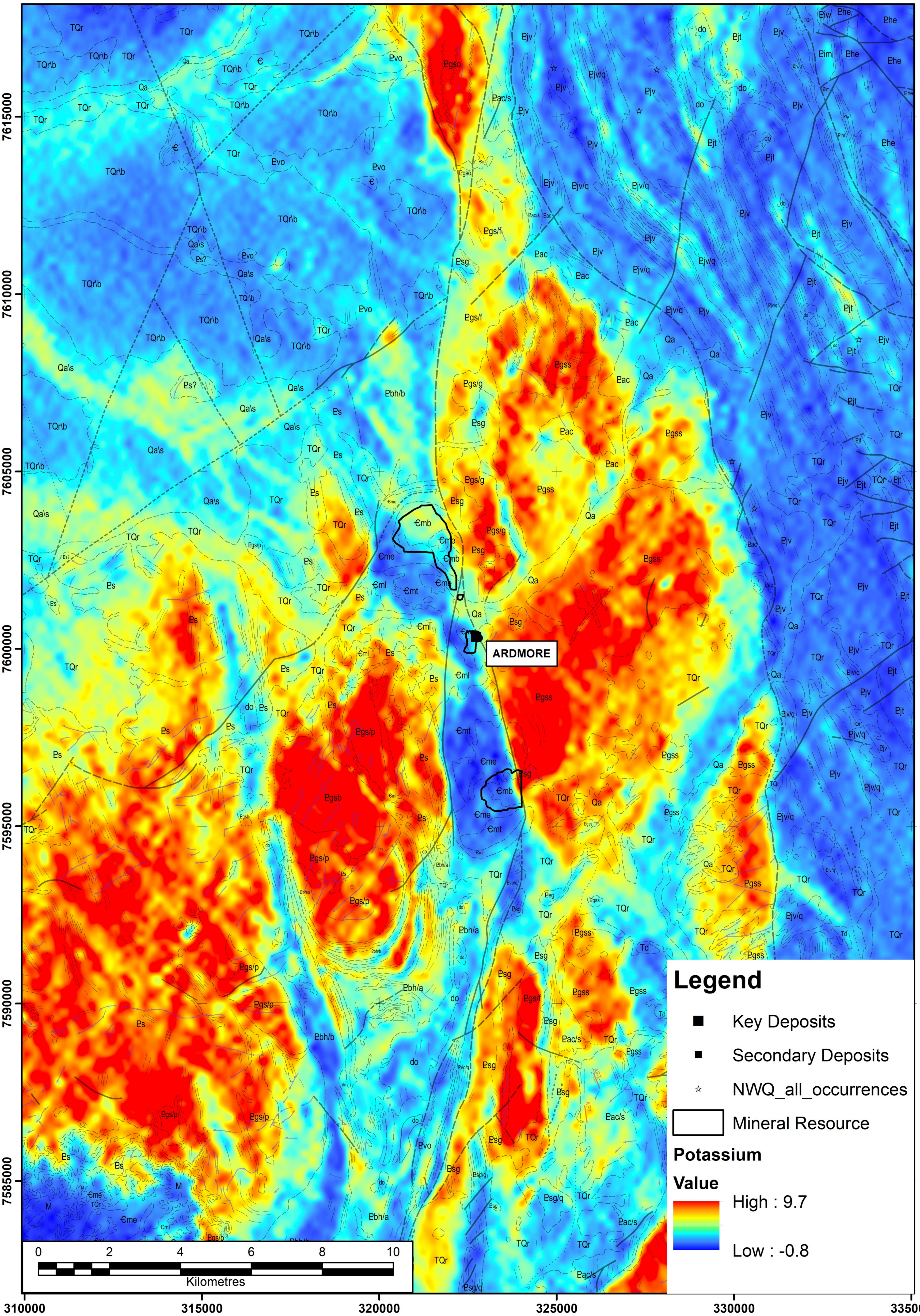

Figure 20.12: Potassium image (from QDEX Data). The high zones are dominated by the Sybella-aged Briar (Pgsb) and Steeles (Pgss) Granites, and to a lesser extent the Saint Ronans Metamorphics. The Cambrian sequence of the Ardmore Outlier displays a distinctly potassium-poor signature.

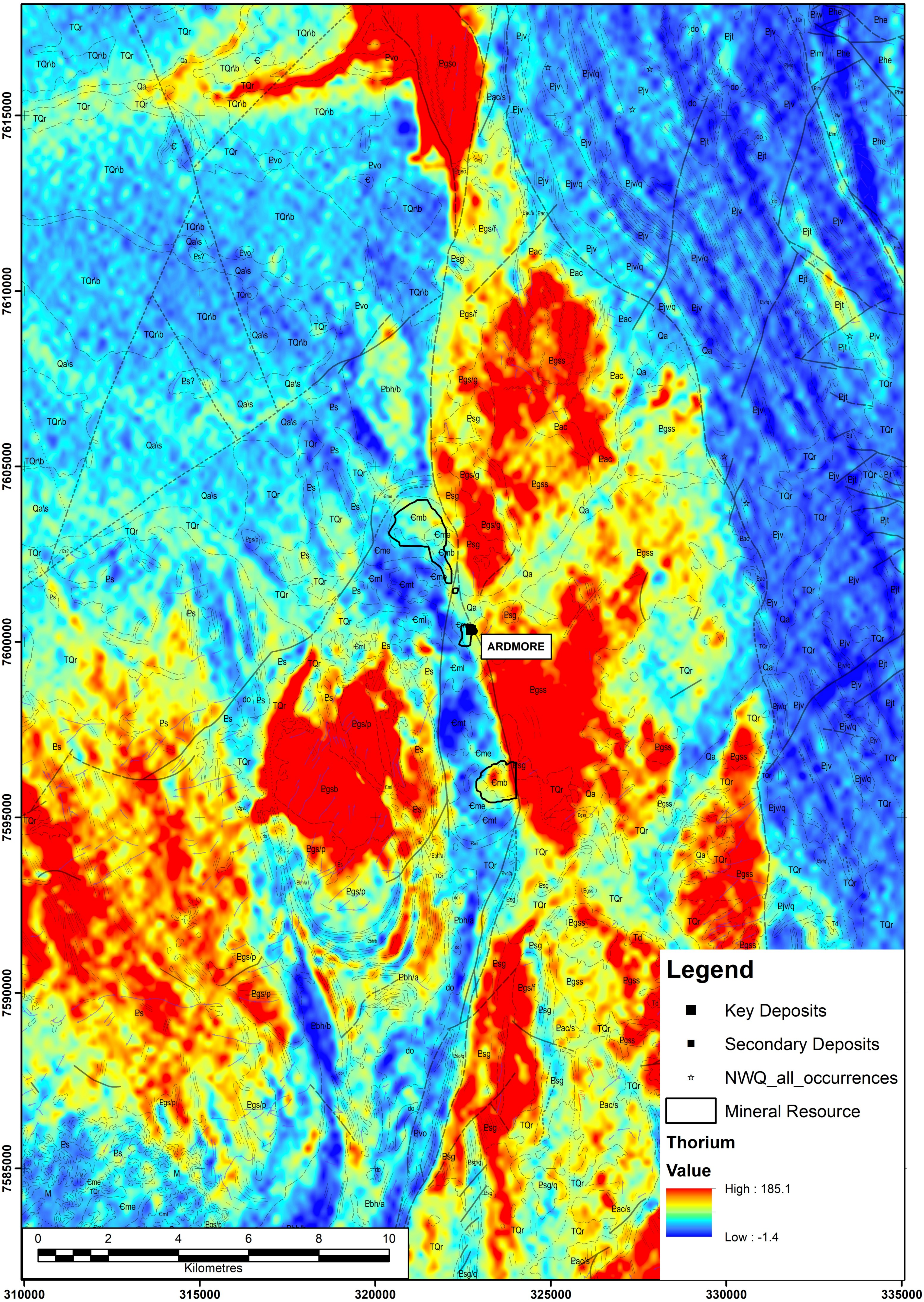

Figure 20.13: Thorium image (from QDEX Data). The high zones are dominated by the Sybella-aged Briar (Pgsb) and Steeles (Pgss) Granites. The Blazan Shale outcrops (Cmb) display a moderate thorium signature, but otherwise the Cambrian rocks display a thorium-poor signature.

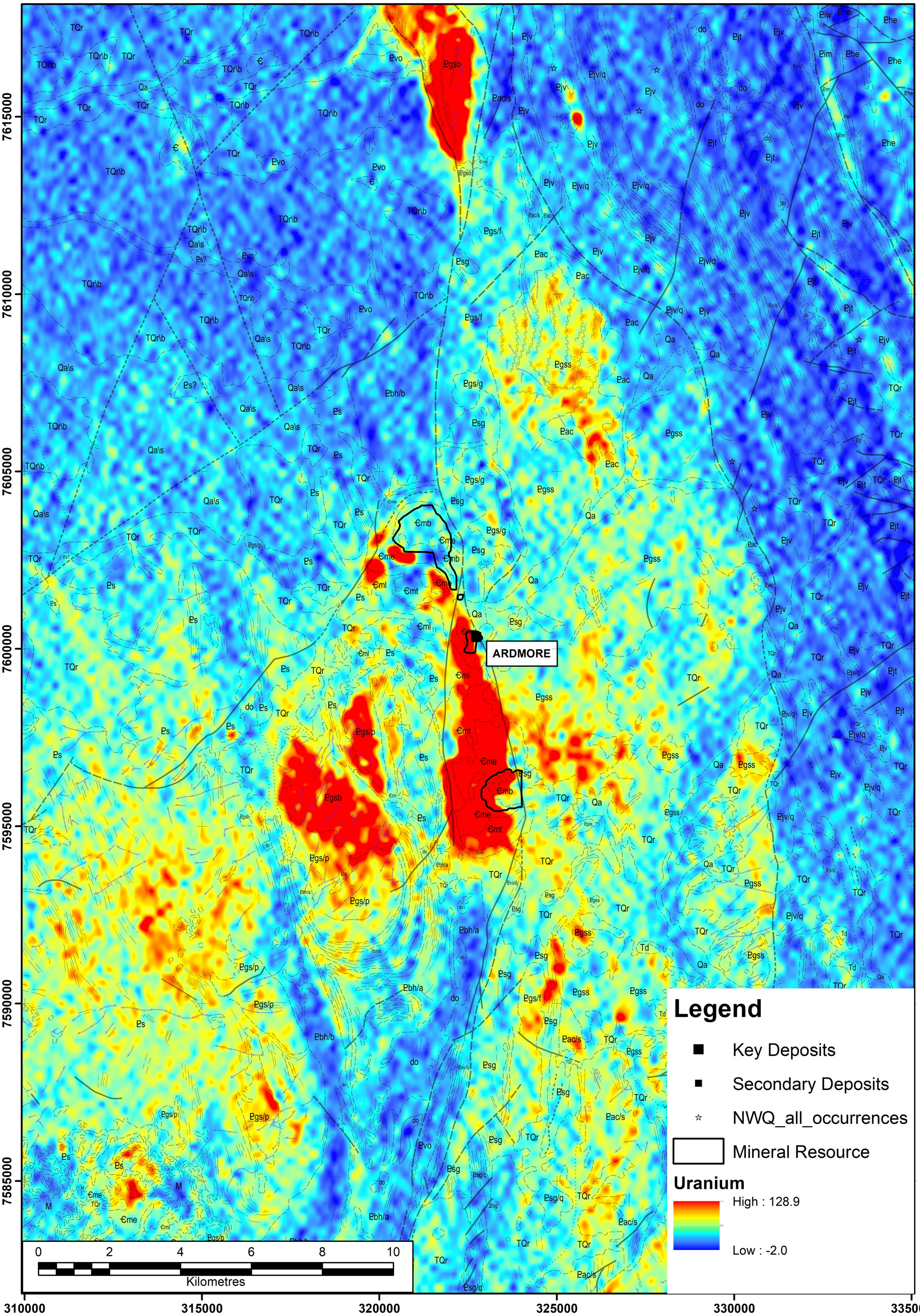

Figure 20.14: Uranium image (from QDEX Data). The high uranium zones are strongly dominated by the Cambrian units of the Ardmore Outlier, although the northern zone is not uranium anomalous, perhaps because the Blazan Shale, which covers much of the area, is uranium-poor. The Briar Granite (Pgsb) is also uranium anomalous.