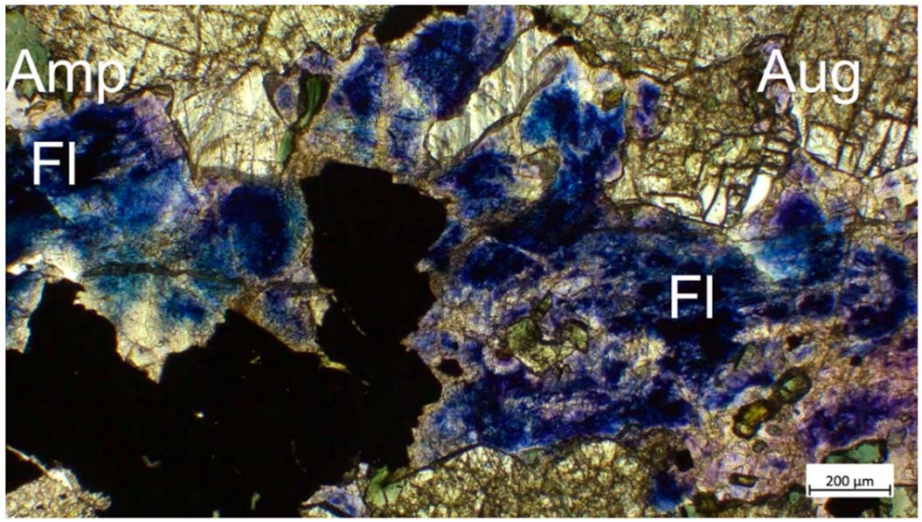
Mary Kathleen Belt Metal Fertility: Constraints from Blue Caesar, Elaine Dorothy and the Mount Philip Breccia.

Ken Collerson

KDC Consulting &

University of Queensland

24th September 2018



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Outline

- Metal association
- Constraints from REE systematics
- Review evidence for post tectonic alkaline magmatism at ~1526 Ma.
  - Feldspathoid- bearing rocks
  - Ultramafic lamprophyres
  - Fenites
- Geochronology and significance of Mt Philip Breccia
- Regional mineral system implications

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Take Home Messages

- Metals in Mary Kathleen Belt - not derived from the Burstall Granite: too old and wrong composition to explain element association.
- Cu, Ni, Co and REEs systematics support derivation of Cu-Au mineralisation from an alkaline magmatic source.
- Mineralisation is orthomagmatic, carbo-fluorothermal and epithermal.
- Metal fertility related to post-tectonic alkaline magmatism at ~1526 Ma.
- Feldspathoid-bearing lithologies and ultramafic lamprophyres confirm this interpretation.
- Mt Philip breccia is an agglomerate related to this event, similar to K-rich agglomerates associated with carbonatites.
- Similar age mineralisation in the Cloncurry Belt likely reflects the same plume magmatic event.

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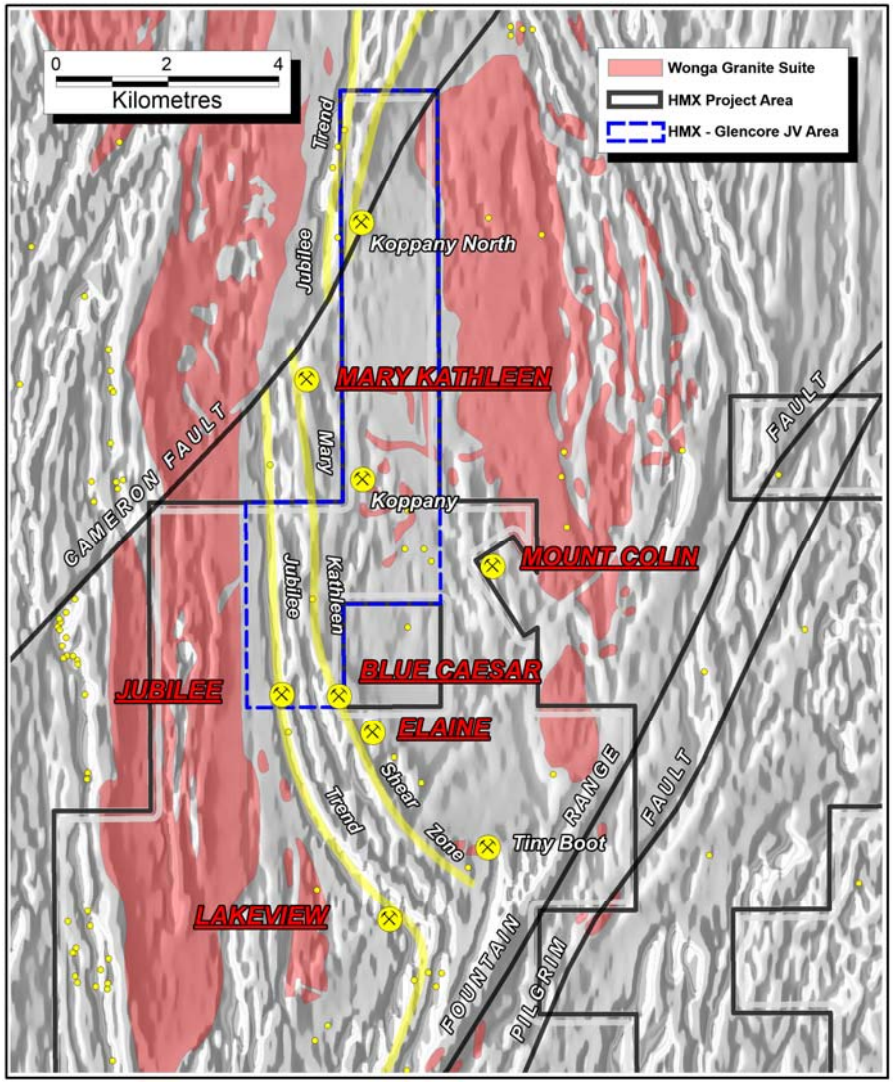

Blue Caesar
Elaine Dorothy
Mary Kathleen and
Koppany

Current Tenure
Hammer Metals & Glencore
Previous Tenure
Chinalco

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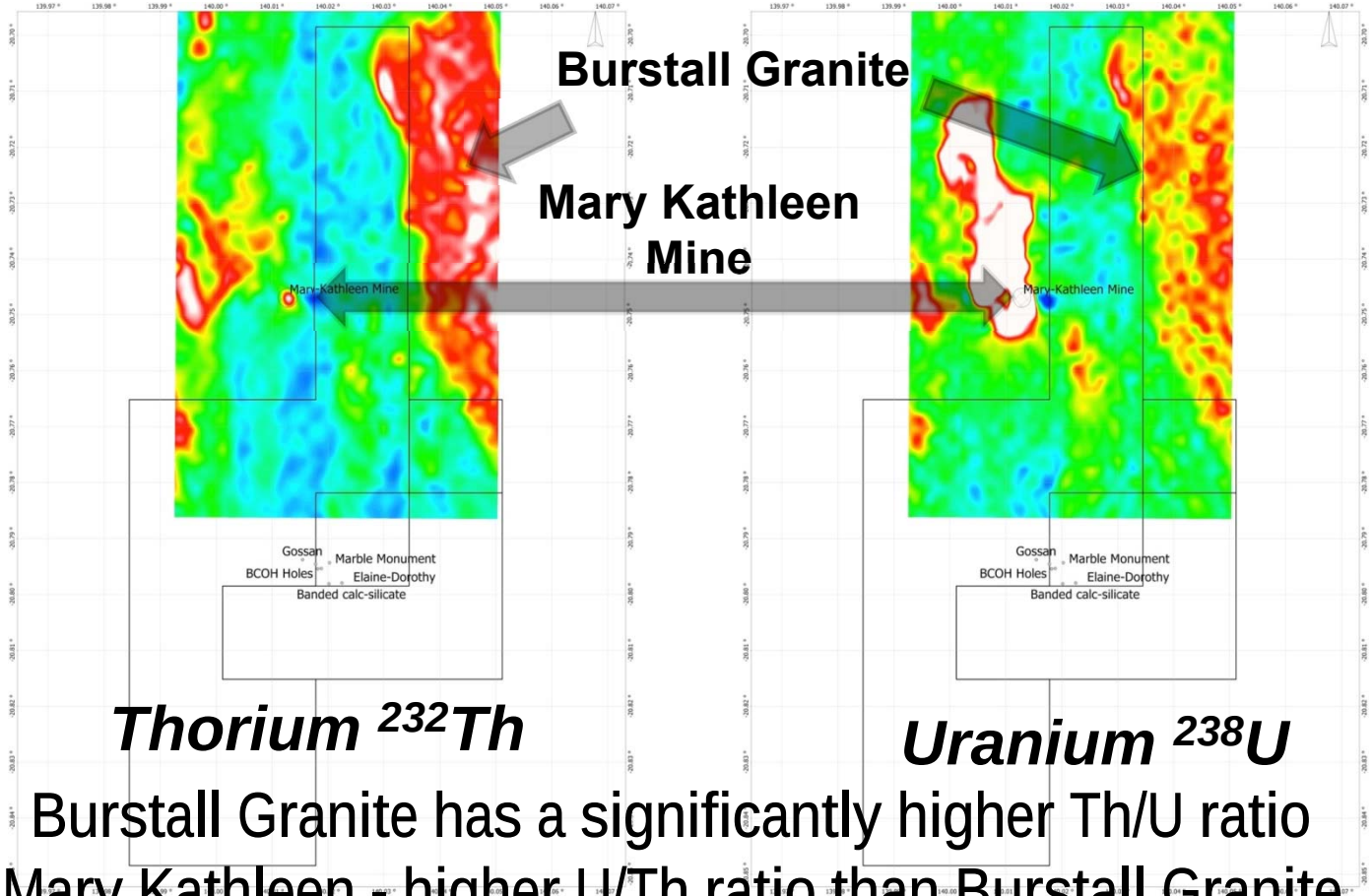
Constraints on the Source of Metals in the Mary Kathleen Belt



Thorium ^{232}Th ***Uranium ^{238}U***

Burstall Granite has a significantly higher Th/U ratio

Mary Kathleen - higher U/Th ratio than Burstall Granite

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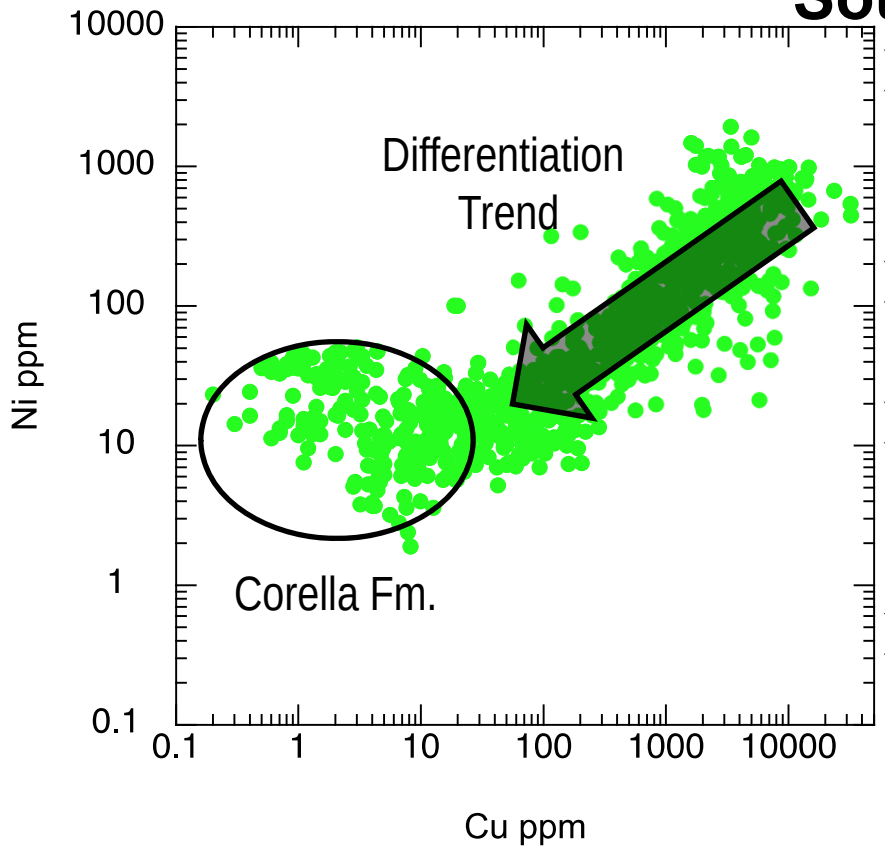
Source of Metals in Mary Kathleen Belt Deposits: Transition Metal Geochemistry indicate a Mafic/Ultramafic Source



- Covariation between Ni & Cu in Mary Elains Dorothy and Blue Caesar cores
- Parent magmas with >100 ppm Ni and 1,000 ppm Cu.
- Cumulates (?) and sulphides have >1000 ppm Ni and 10,000 ppm Cu
- Transition metals were derived from a differentiated mafic igneous source.

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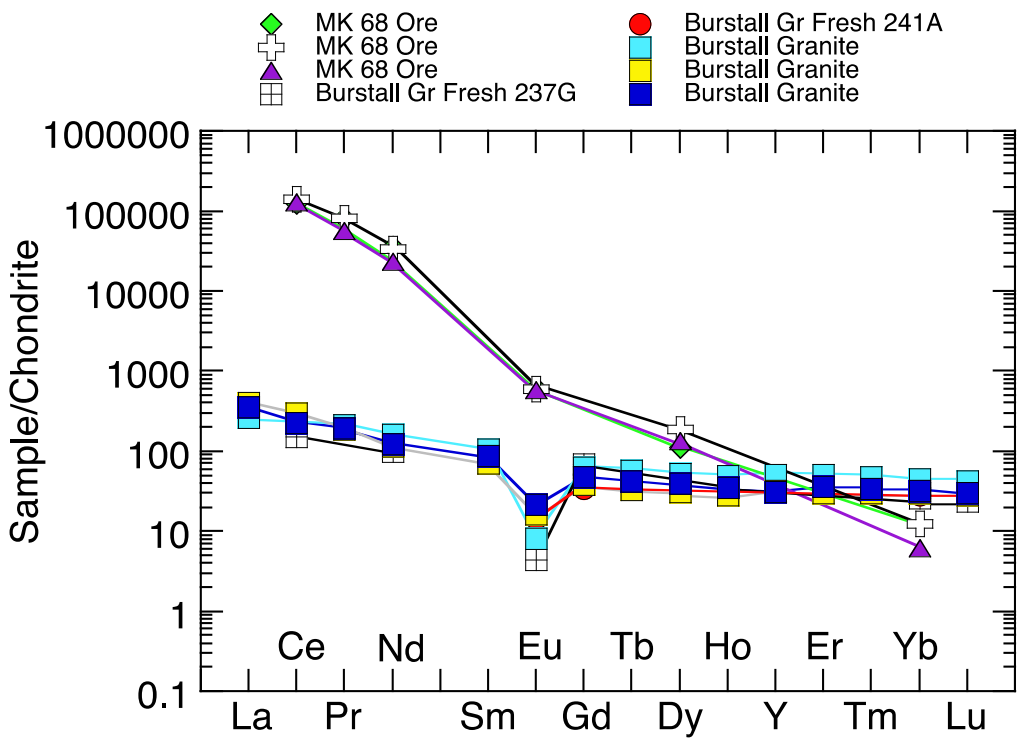
REE Chemistry also Provides Constraints on MKB Mineral System



Data from Maas *et al.*, (1987)

- Mary Kathleen ore strongly LREE enriched and hence a very large La/Yb ratio.
- By contrast, the Burstall granite pattern typical of A-type (alkali) granites.
- Essentially non-fractionated pattern with similar levels of LREE and HREE and a significant negative anomaly indicative of plagioclase fractionation.

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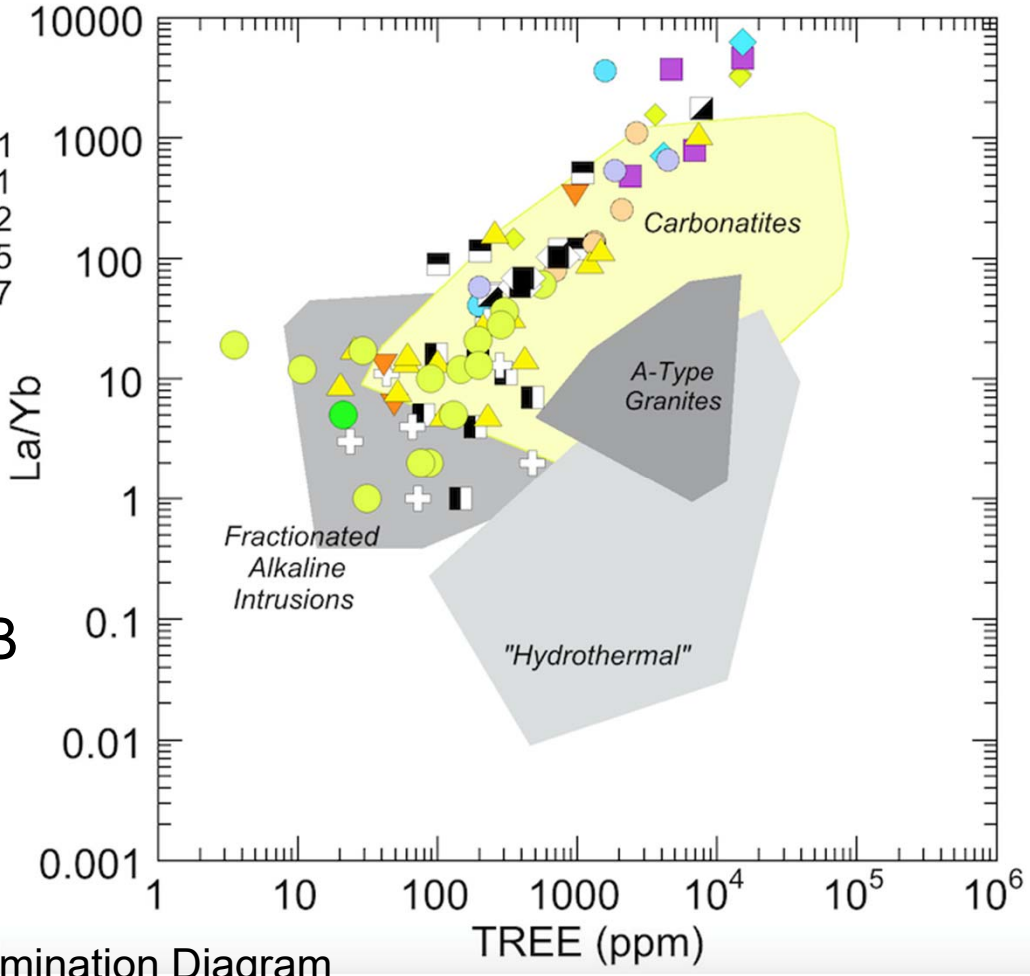
Constraints from REEs

- REEs indicate derivation from from a mafic alkaline magmatic source.
- Conclusion: metals in MKB deposits were not derived from the Burstall Granite



Ammended Loubet et al., (1972) Discrimination Diagram

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Chronology of the MKB Mineral System

- Deposition of calc silicate protoliths of Corella Fm. ~ ***1770 ± 6 Ma***
- Isoclinal folding producing transposed layering with rootless intrafolial folds.
- Intrusion of Lunch Creek Gabbro/ A-type Burstall granite
- Thermotectonism.
- Intrusion of post-tectonic alkaline suite pyroxenites and feldspathoid-bearing units associated with glimmerite and ultramafic lamprophyre dykes.
- Mineralisation associated with these units constrained by titanite U-Pb geochronology: $^{238}U/^{206}Pb$ 1526±11 Ma and $^{207}Pb/^{206}Pb$ 1524±9 Ma (Sha 2012).
- Mt Philip breccia/agglomerate 1500 to 1530 Ma

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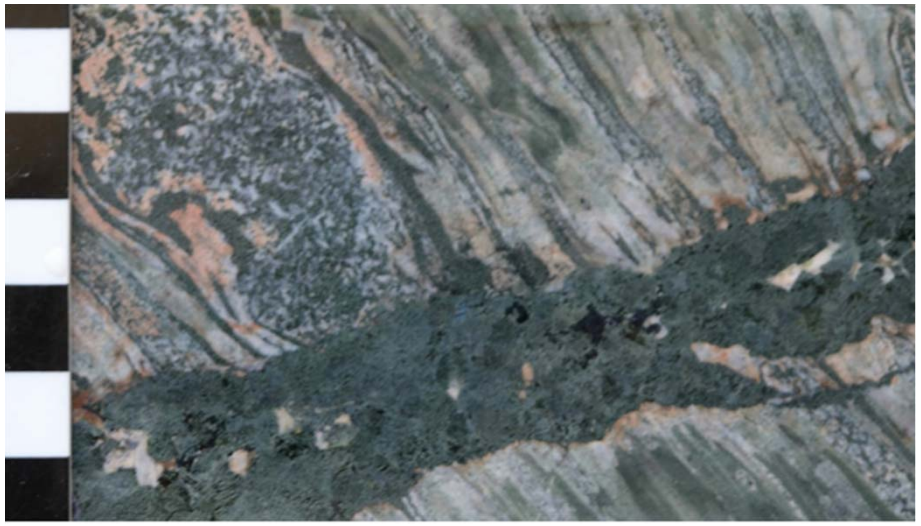

Pyroxenite Dykes Cutting Corella Fm.

- Titanite geochronology **$^{238}U/^{206}Pb$ 1526±11 Ma and $^{207}Pb/^{206}Pb$ 1524±9 Ma** (Sha, 2010).
- Within error of Sm-Nd isochron for Mary Kathleen mineralisation; 1557±40 Ma Maas *et al.,* (1987)
- Cu and U-REE mineralisation in the Mary Kathleen Belt were derived from same igneous source.

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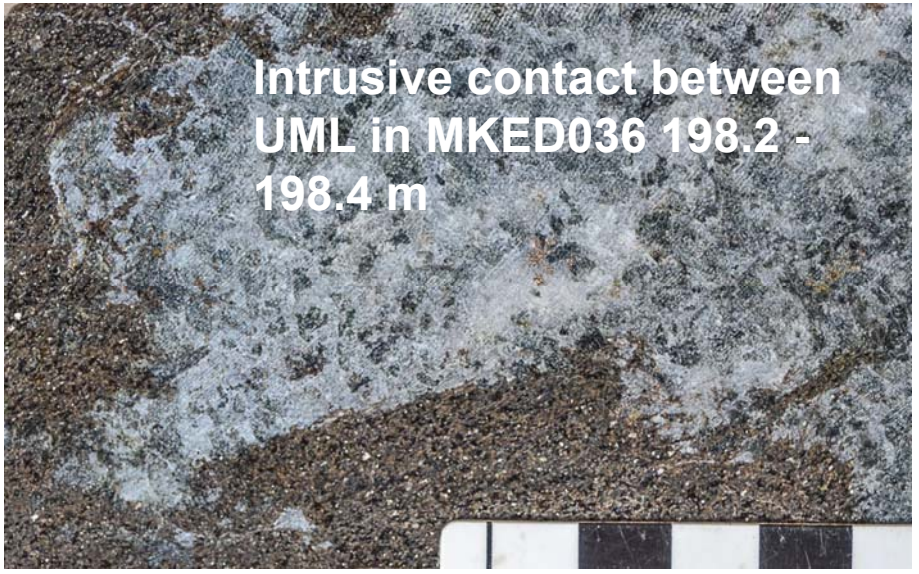
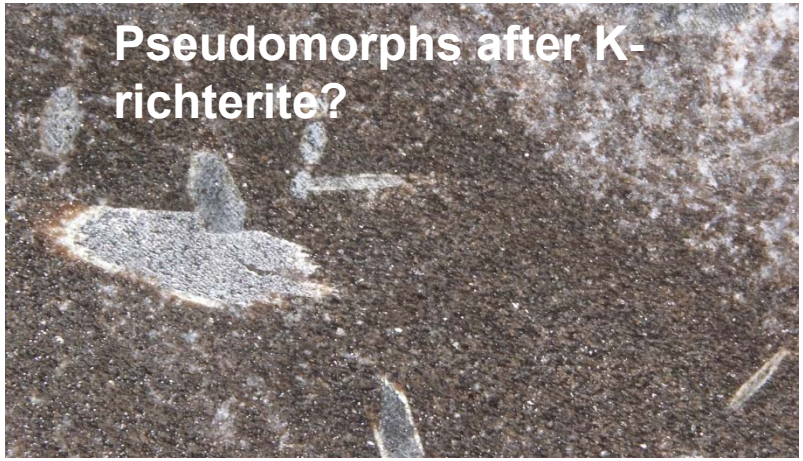
Chronology of the MKB Mineral System
Ultramafic Lamprophyres and Glimmerites

- Post-tectonic ultramafic lamprophyres (glimmerites) in many MK Belt cores.
- Logged as “biotite schists”.





- Lamprophyres contain abundant Cu sulphides
- They are fluorine (~1.5% rich) and have high REE contents
- **High U/Th ratios like Mary Kathleen**

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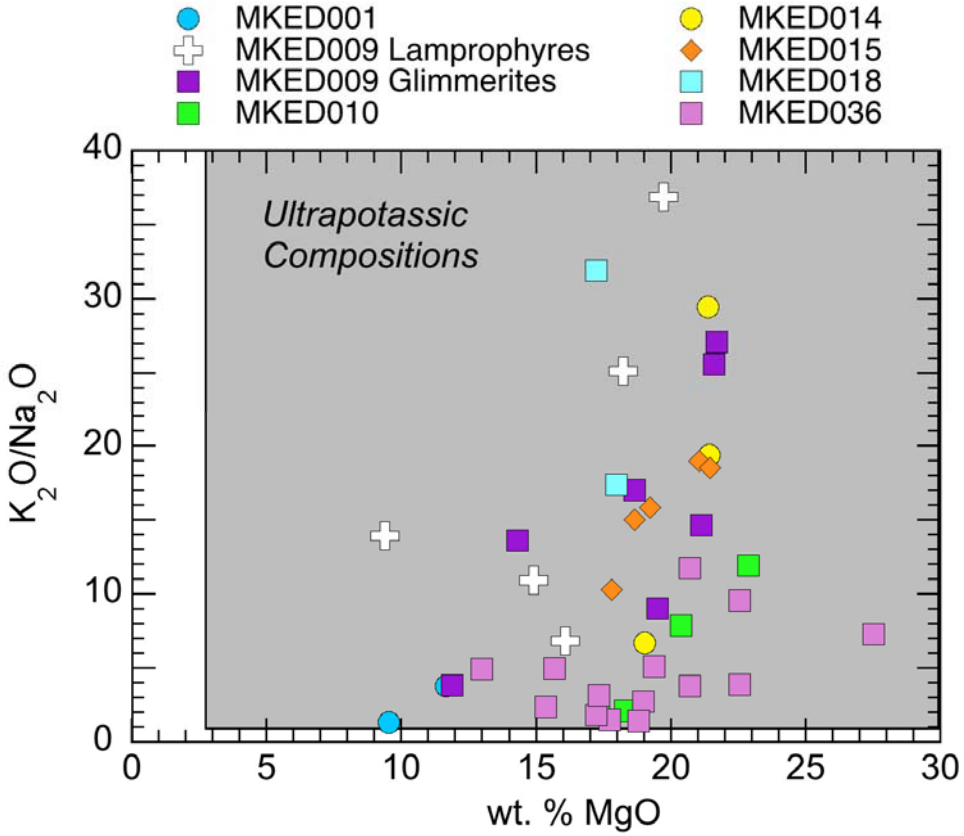
Chemistry of Ultramafic Lamprophyres and Glimmerites



These are rare ultra-potassic mantle-derived lithologies.

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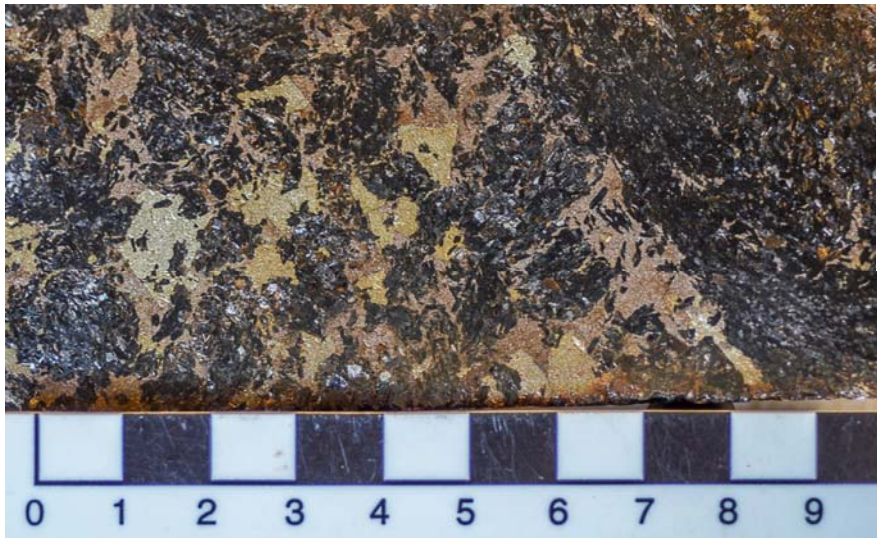
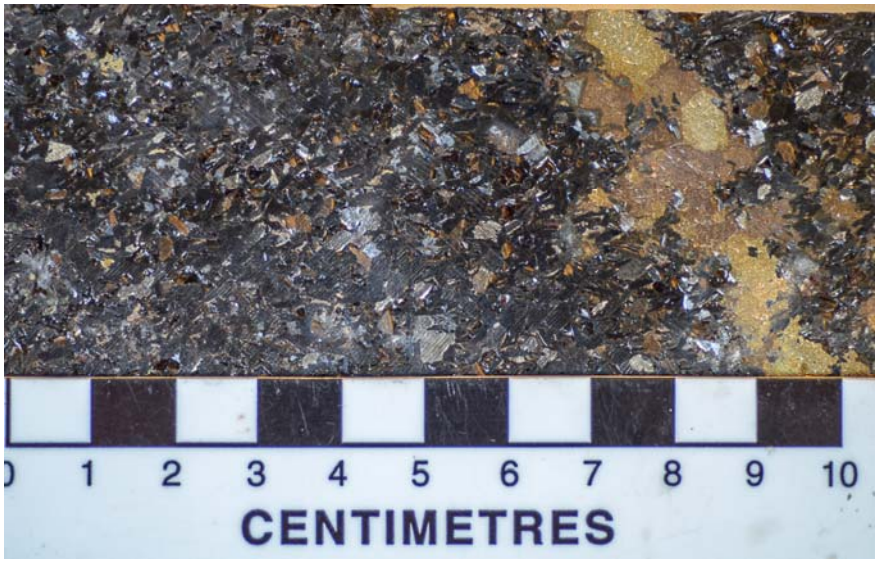
Ultramafic Lamprophyres and Glimmerites are Sulphide-rich





- Orthomagmatic chalcopyrite, pyrhhotite and pyrite in ultramafic lamprophyre MKED009 328.23-329.93 m.
- Exsolution of fluorine-rich fluids from these alkaline magmas explains the mineral system responsible for MKB deposits .

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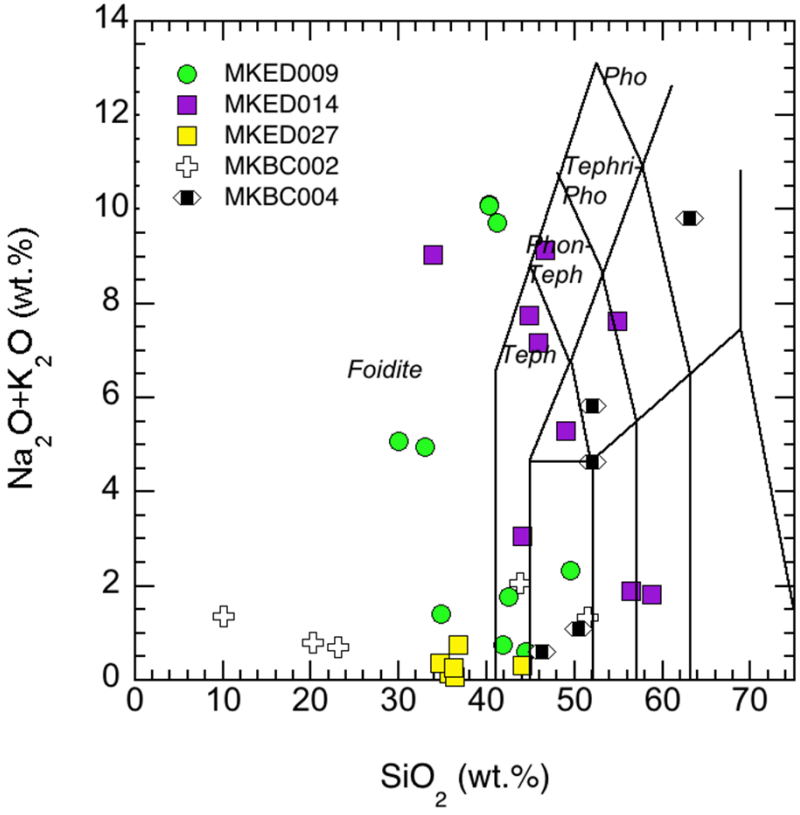
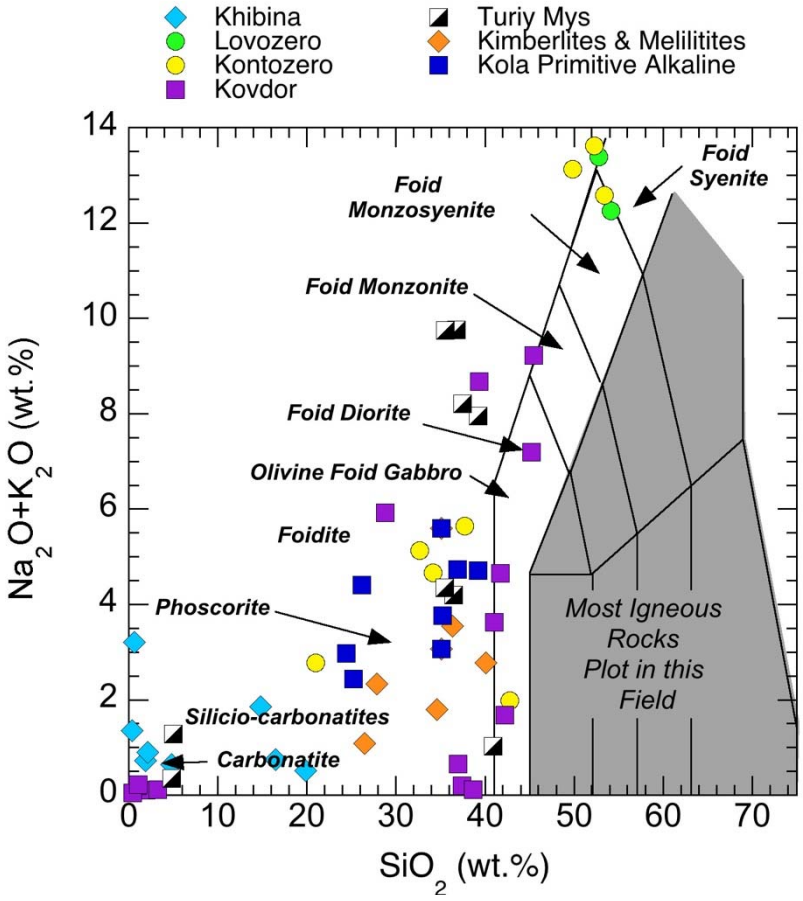
TAS Projection of MKB Alkaline Lithogies

Mary Kathleen ~1526 Ma Intrusive Phases



Kola Peninsular



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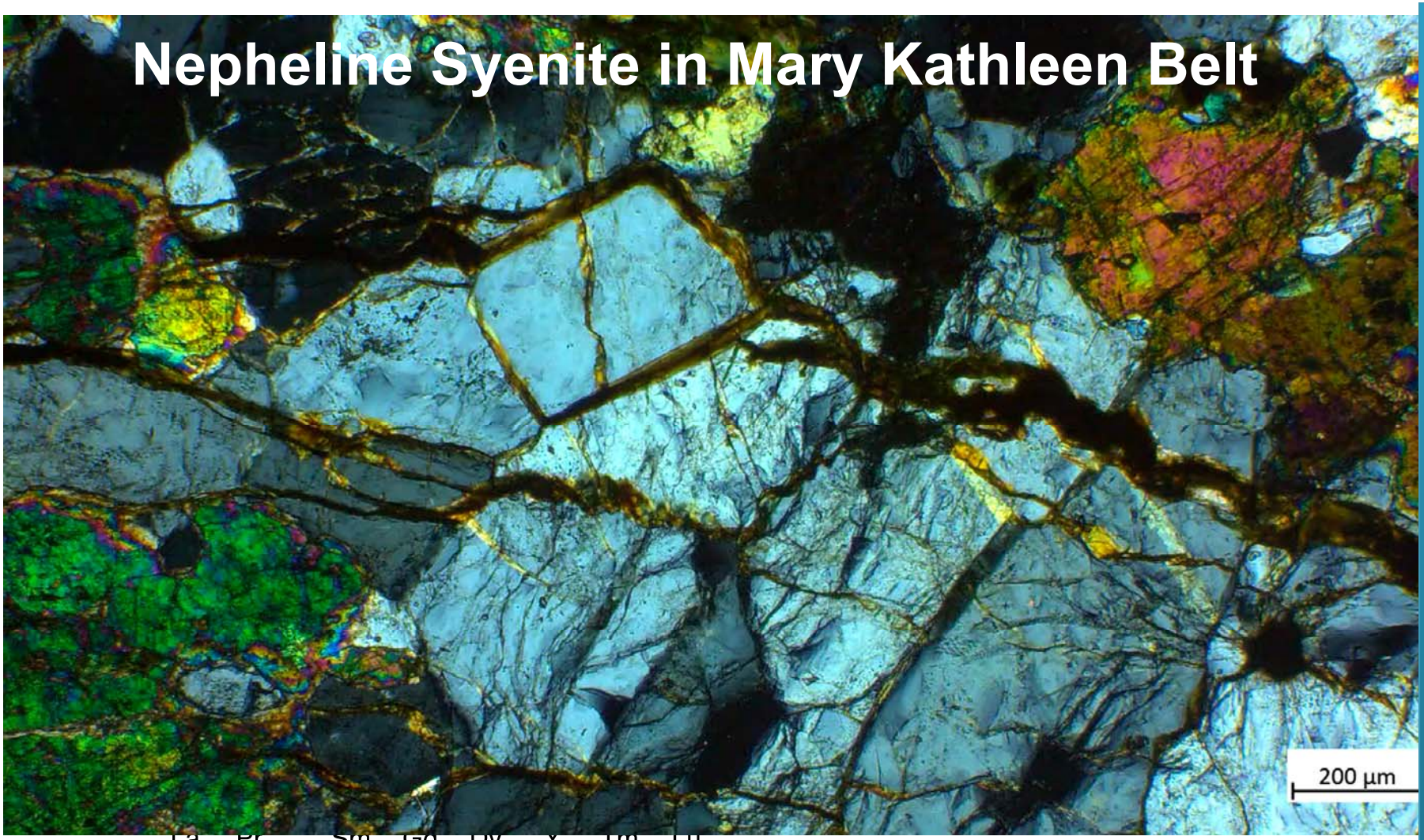
Nepheline Syenite in Mary Kathleen Belt



La Pr Sm Gd Dy Y Tm Lu

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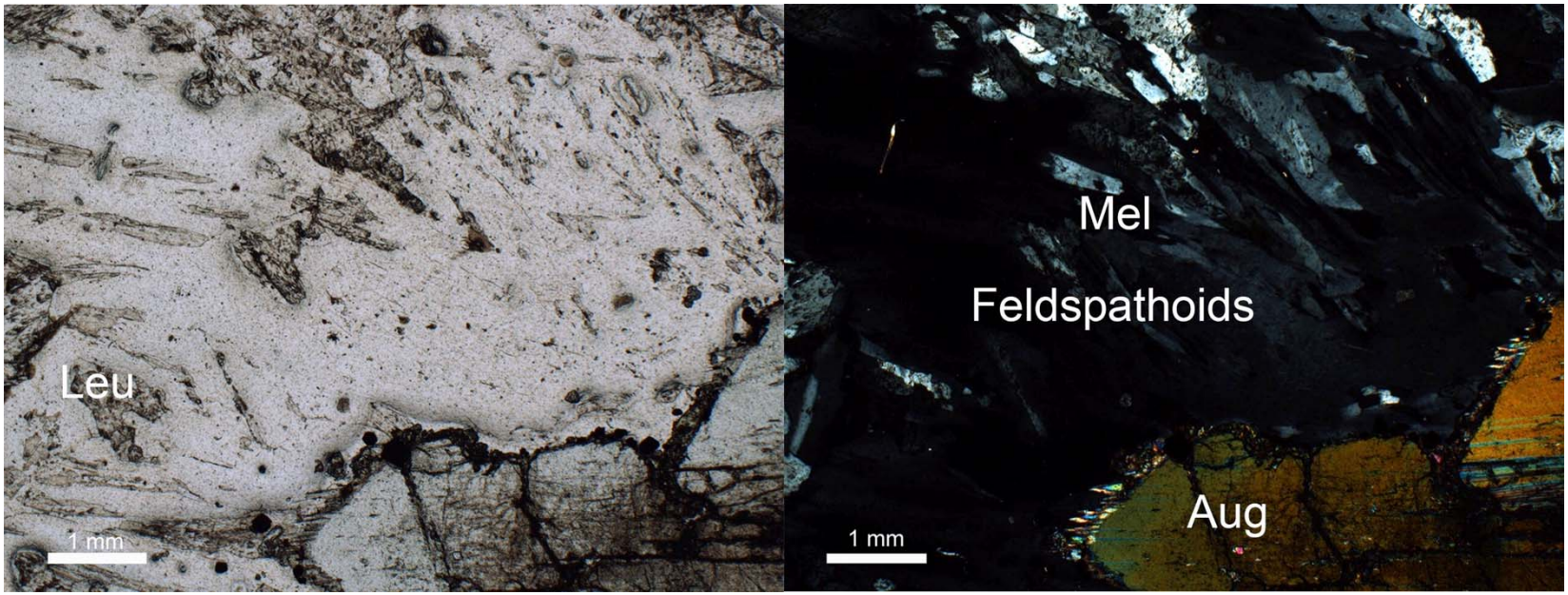
1526 Ma Alkaline Suite – Mary Kathleen Belt
Feldspathoidal Syenite



Plane Polarised Light

Cross Polarised Light

Leucite and melilite-bearing syenite

MKED 014 – 260 m

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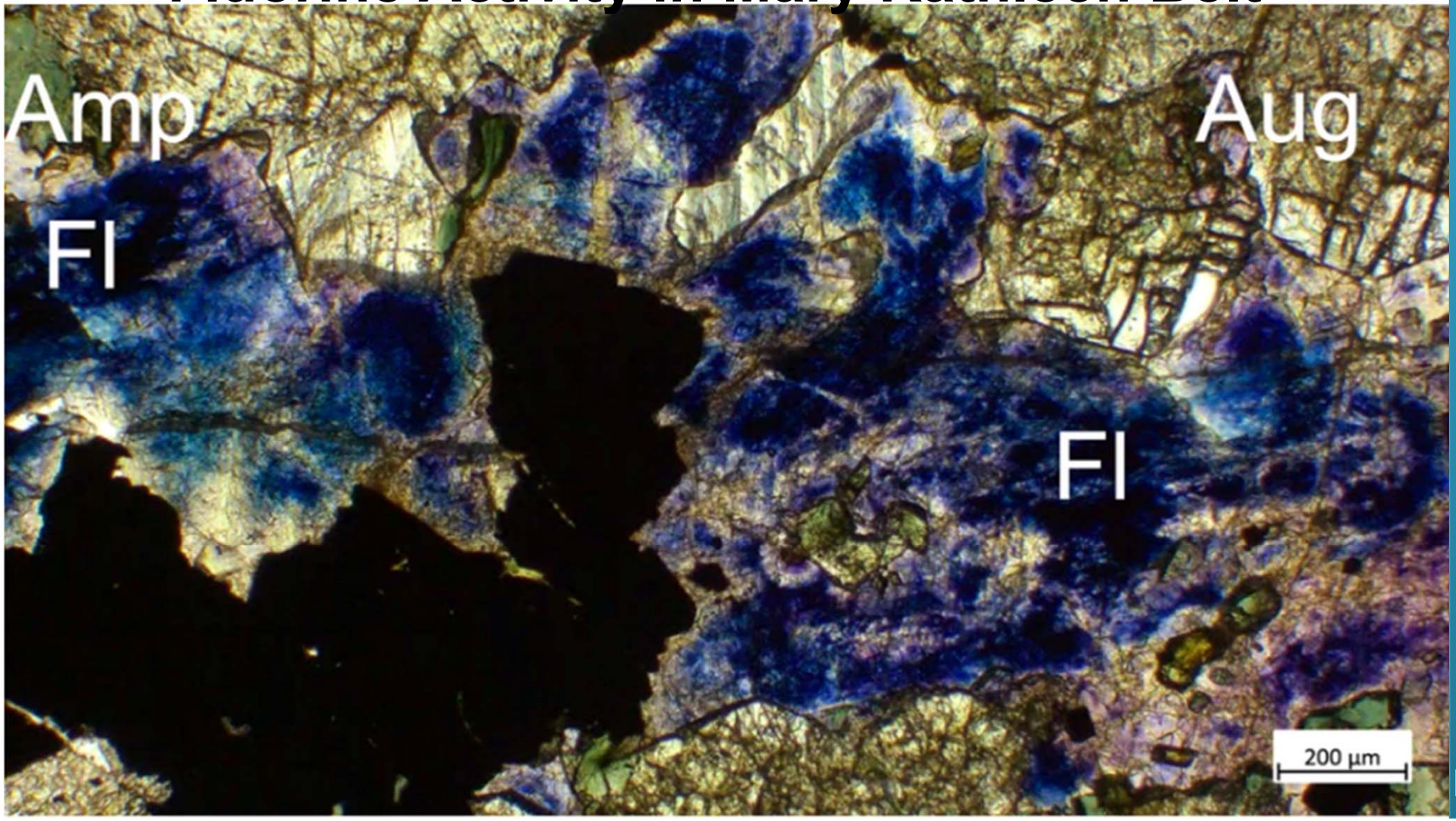
Fluorine Activity in Mary Kathleen Belt



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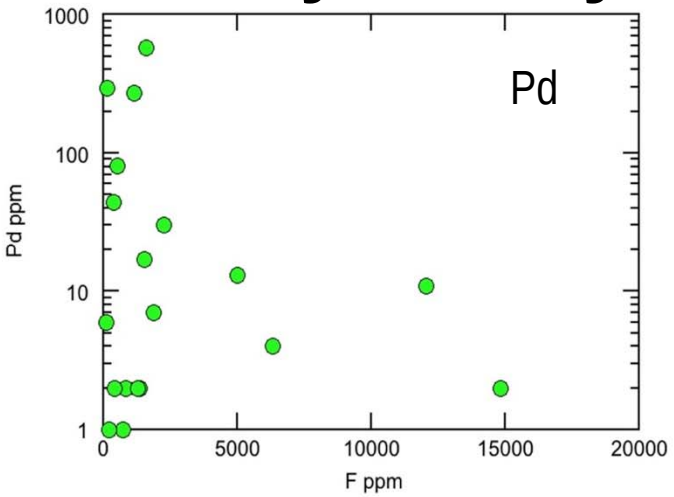
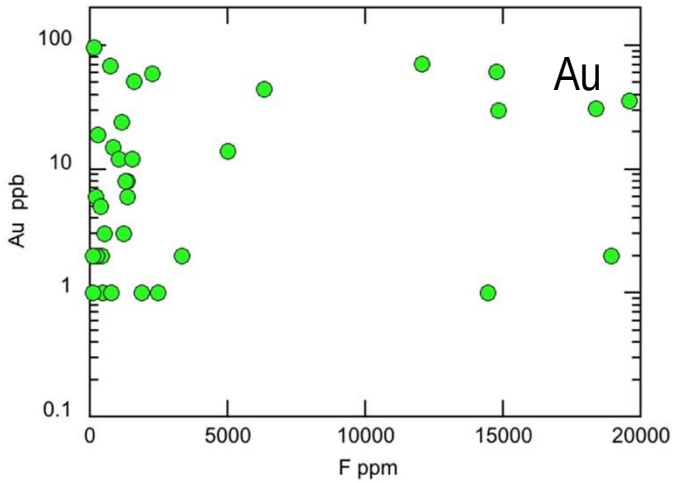
Fluorine Activity in Mary Kathleen Belt

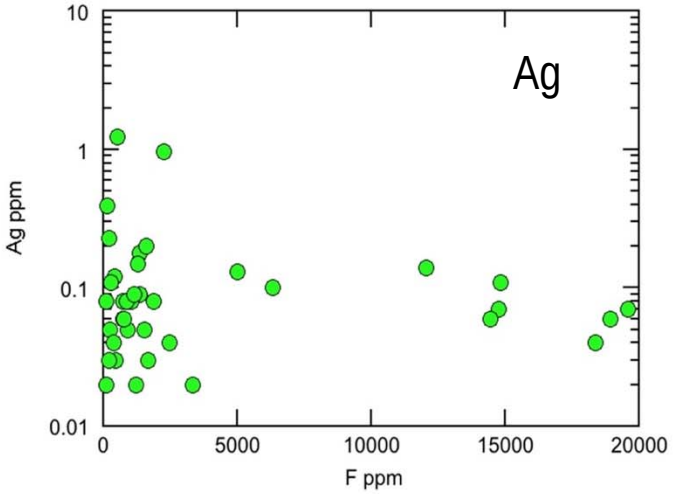
Fluorite is present in many samples - also visible in the open cut at Mary Kathleen.

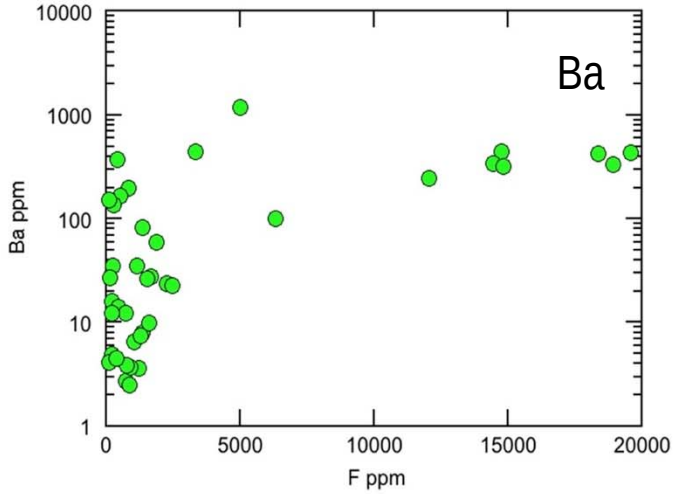
Ultramafic lamprophyres, av. 1.5 wt % F.

Fluids responsible for mineralisation were likely derived from this alkaline suite









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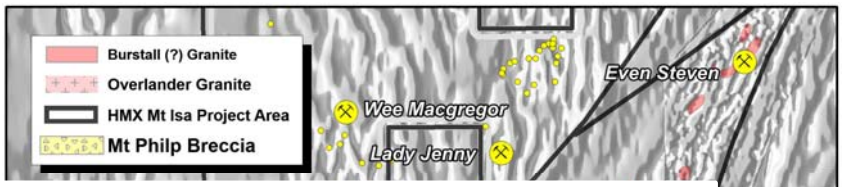
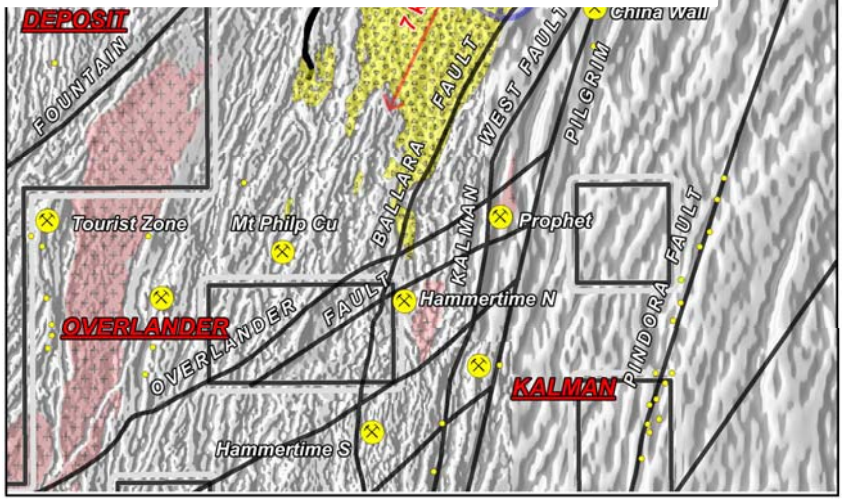
Is the Mount Philip Breccia the Smoking Gun?

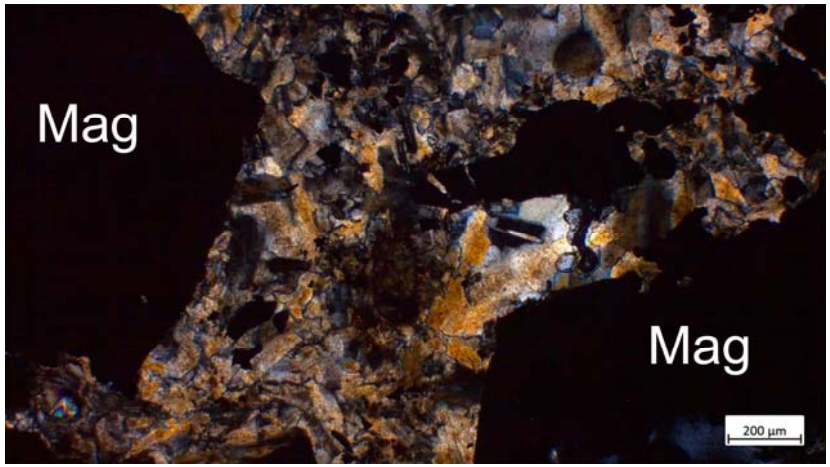


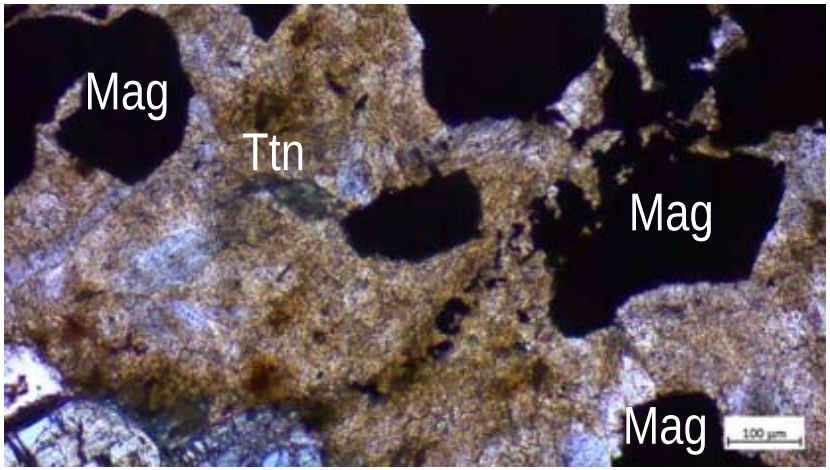
- U-Pb titianite dates for intrusives and Mt Philp Breccia 200 Ma younger than expected.
- Breccia event constrained to between 1550 Ma and 1500 Ma

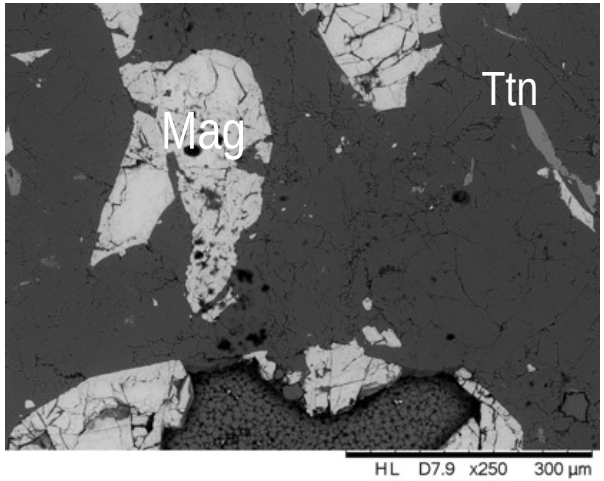
- Mount Philp Breccia an area >19 km^{2,} east of Prince of Wales and the Mt Philp Hematite Deposit.
- Breccia also occurs at Kalman 10km to the south.
- Breccia is non-foliated and postdates regional metamorphism of the Corella Formation and intrusion of the Wonga Granite).



Groundmass Mount Philip Breccia #154







- Groundmass - interlocking laths of turbid albite
- Matrix texture hydrothermal not cataclastic
- Similar to “fenite” microstructures seen in MKB lithologies

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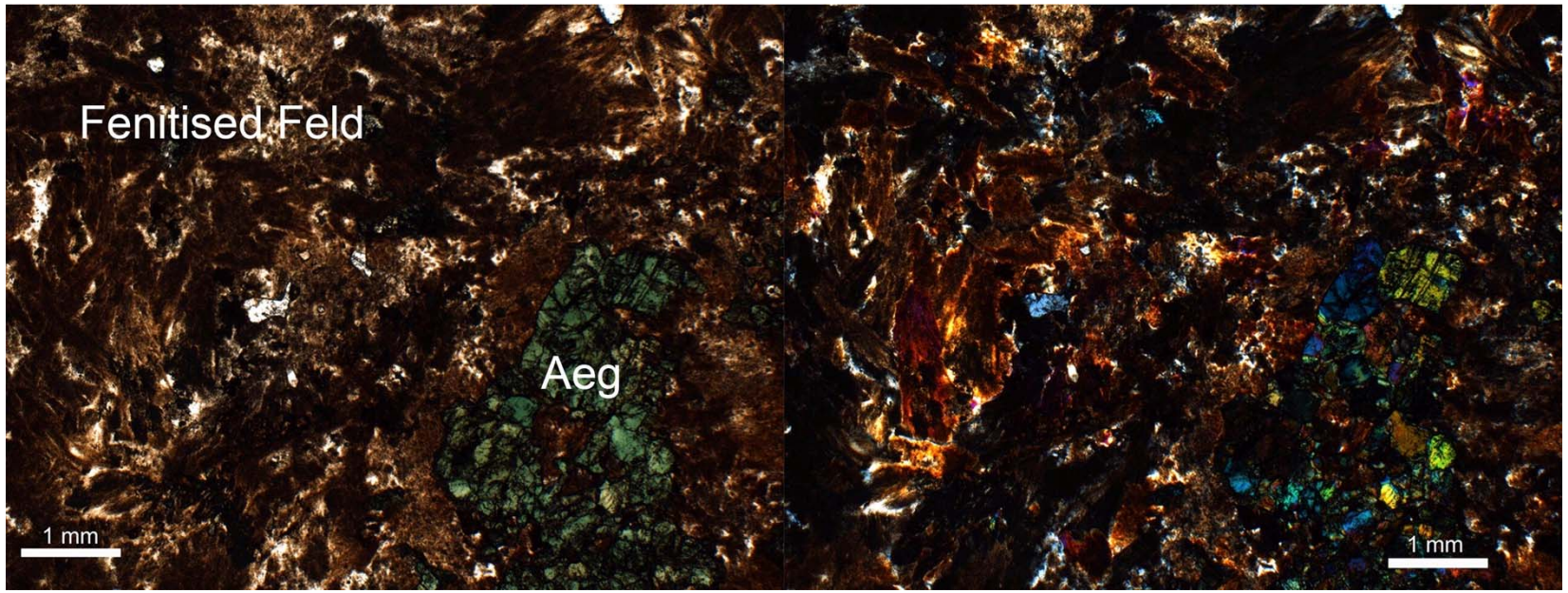
Fenites in the Mary Kathleen Belt

1526 Ma Alkaline Suite – Mary Kathleen Belt

Aegirine Syenite Resembles Mt Philip Breccia Matrix



Plane Polarised Light

Cross Polarised Light

Panidiomorphic granular feldspars showing pervasive alteration by fluoro-carbothermal fluids

MKBC 004 – 143.5 m

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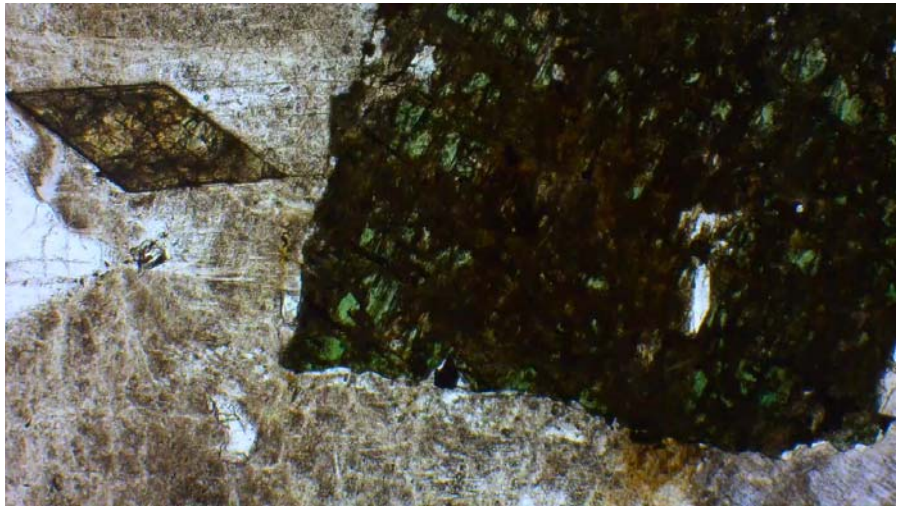
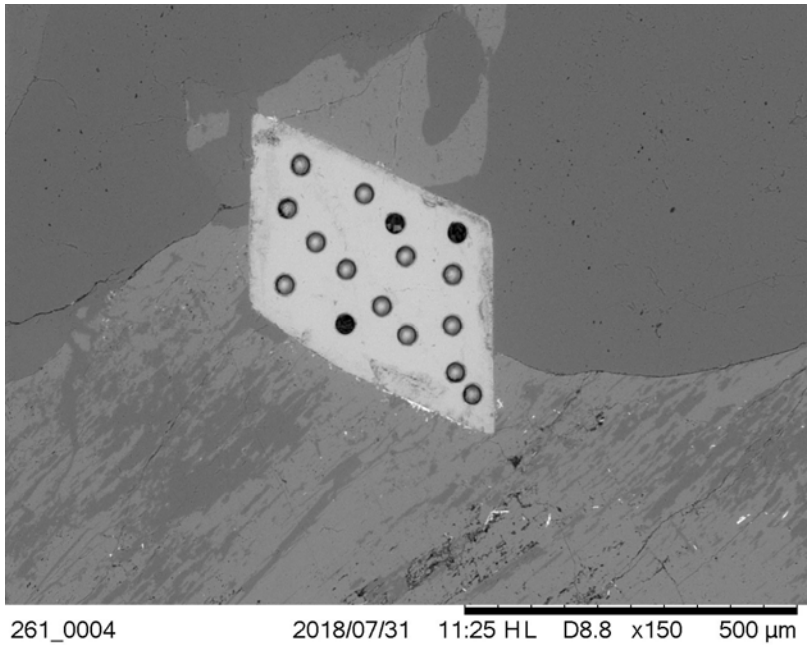
LA-ICPMS Geochronology

#261 – A type Granite - Syenite

- Aegirine-bearing granite-syenite



Laser Ablation Craters



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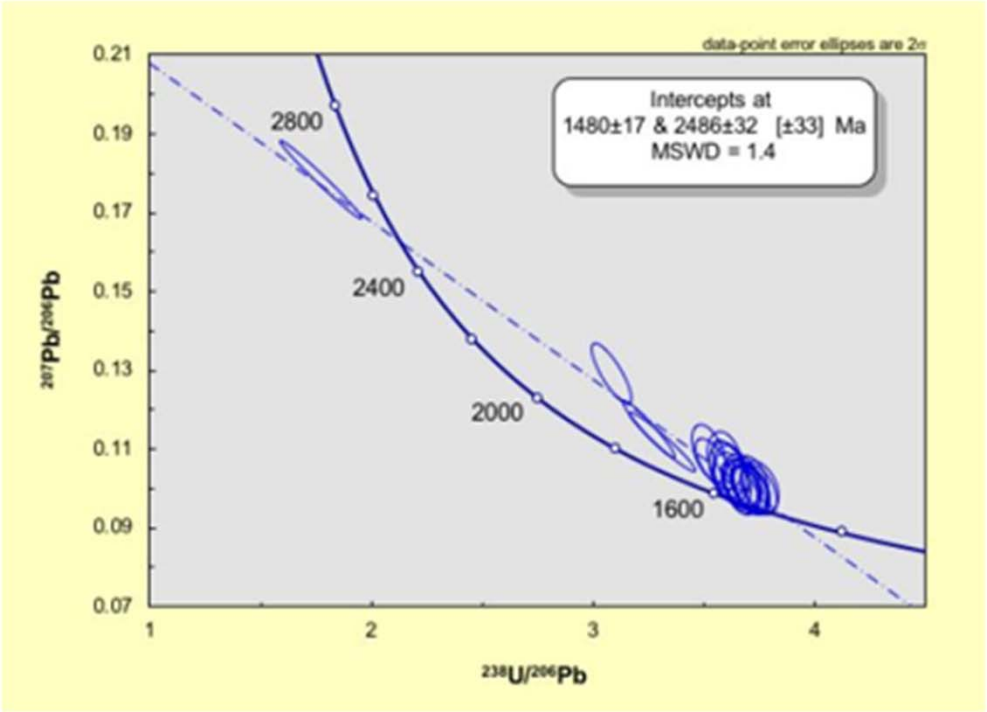
#261 – A type Granite - Syenite

- Previously identified as Burstall Granite
- Brecciated by Mt Philp Breccia
- 1480 ±17 Ma – 1548 ± 1.8 Ma



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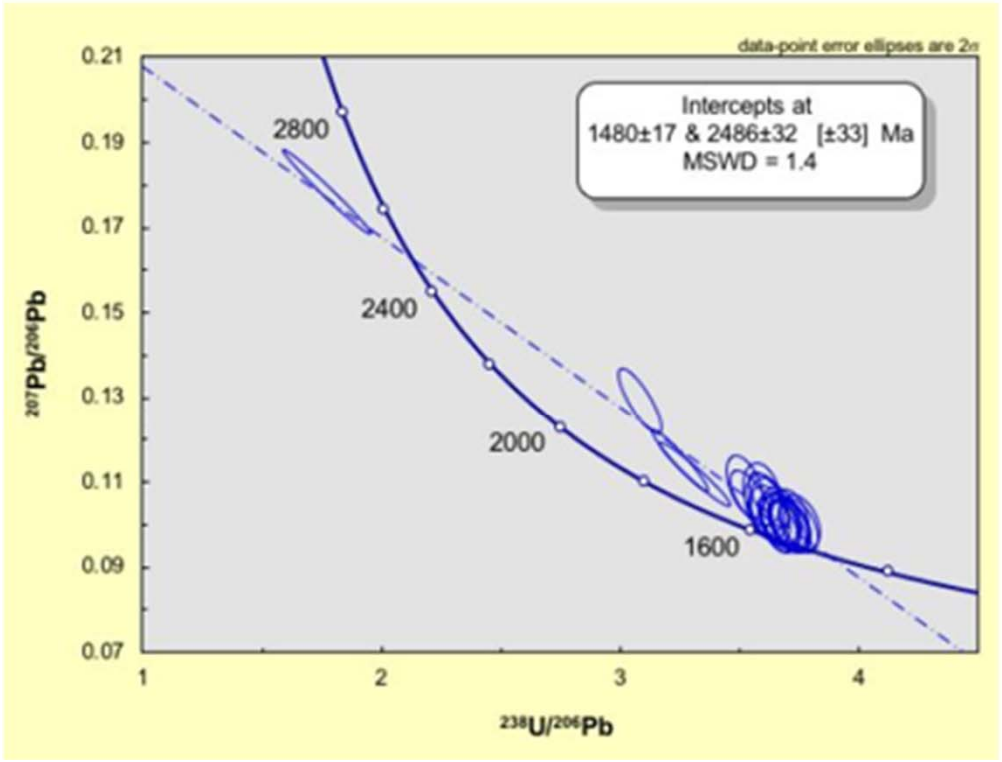
#162 – Gabbro clast/raft in Mt Philp Breccia

- Defines age of 1480± 17 Ma
- Interpreted to reflect the time of emplacement



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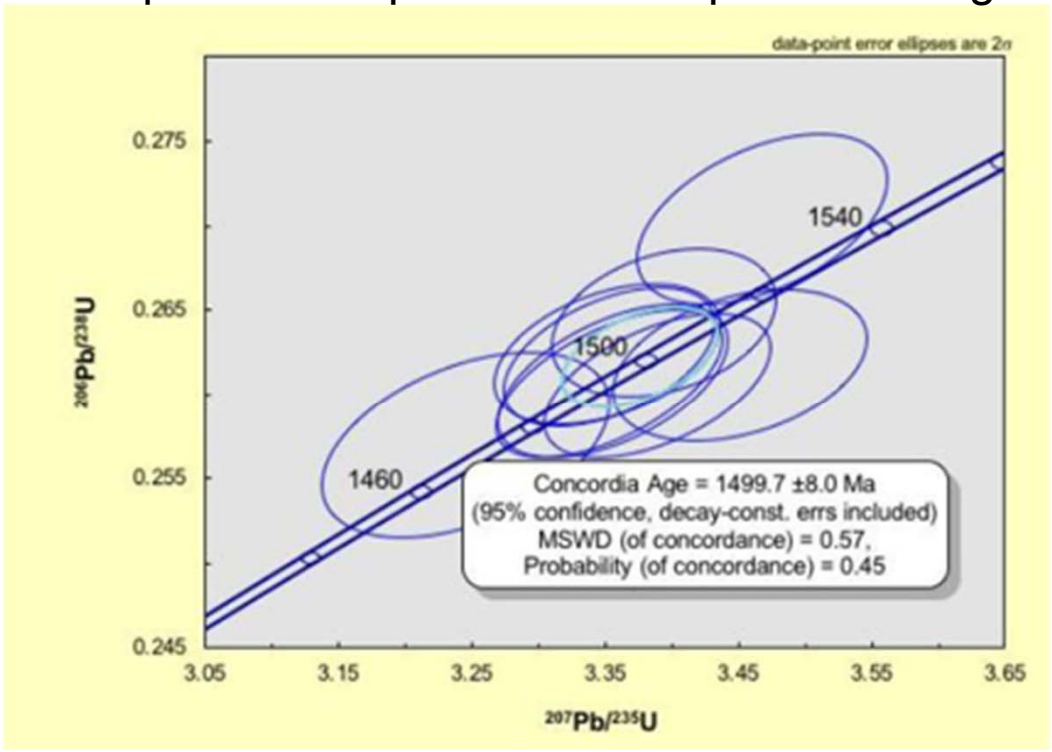
#116 – Mt Philp Breccia titanite in matrix

- Defines age of 1499 ± 8 Ma
- Titanites occur in an “igneous” groundmass
- Interpreted to represent the emplacement age



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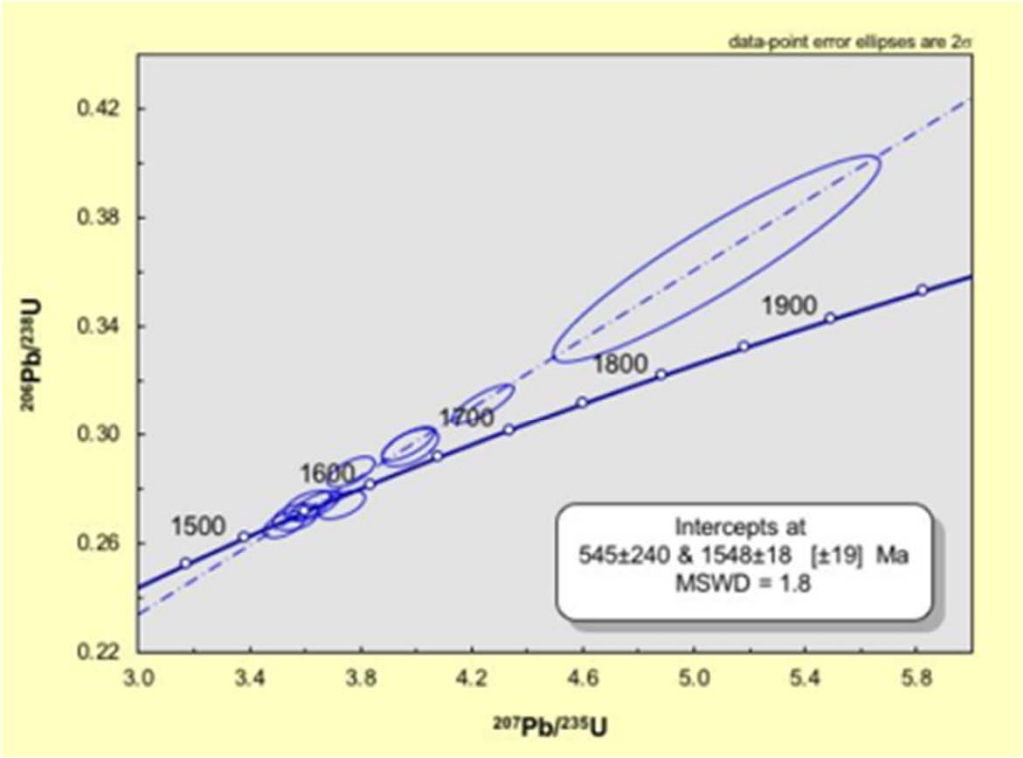
#125 – Carbonate groundmass Mt Philp Breccia

- Defines age of 1548±18 Ma
- Interpreted to reflect the time of emplacement



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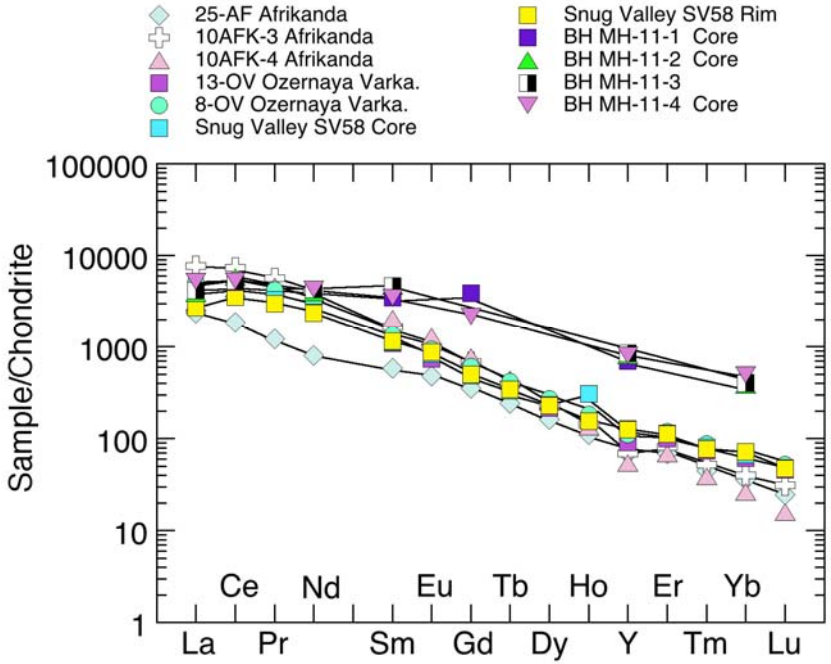
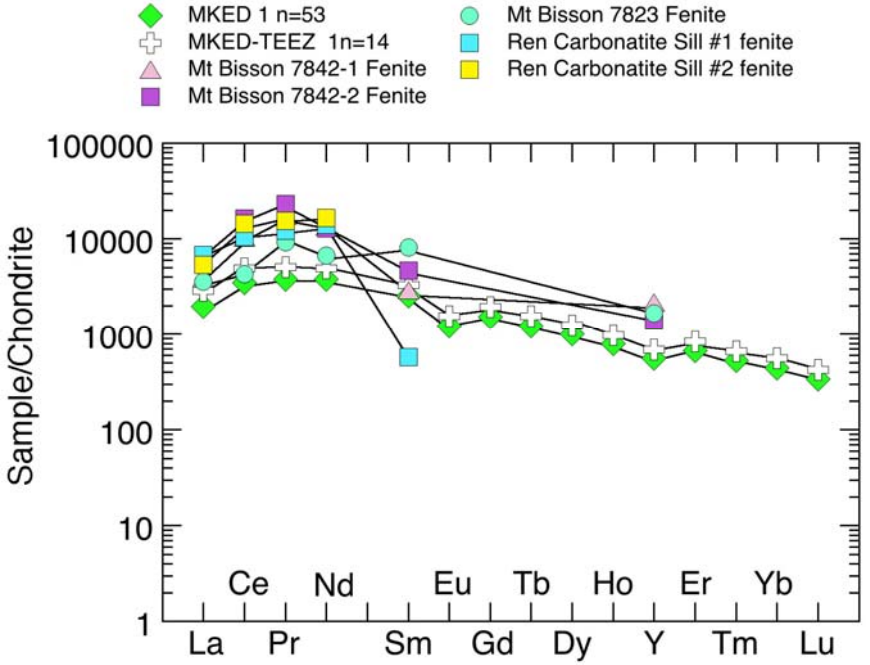
REE Chemistry of Igneous Titanite

- Igneous titanite - no Ce*/Ce anomaly



REE Chemistry of Fenite Titanite

- Fenite titanite



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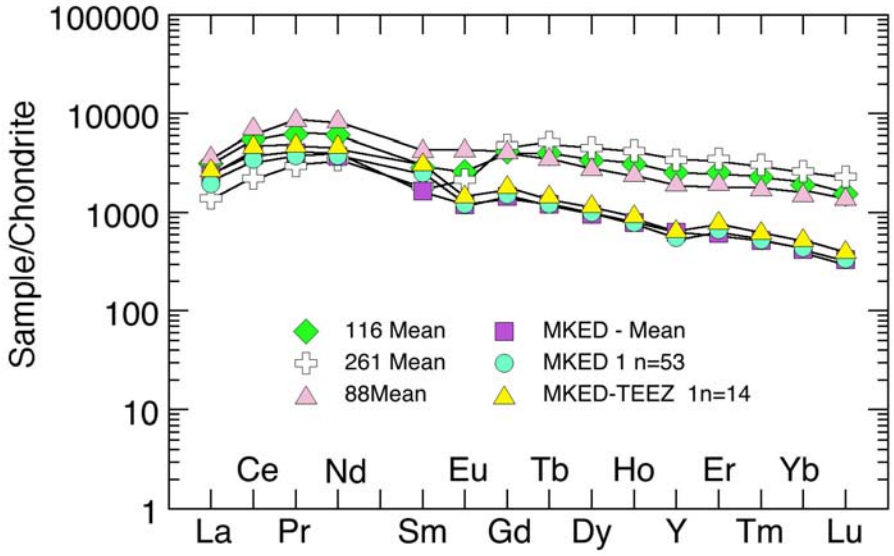
REE Chemistry of Mt Philip Breccia Titanite



Evidence for fenitisation: Mt. Philip Breccia

- Blue arfvedsonite (Na amphibole)
- Turbid alteration - albite and K feldspar

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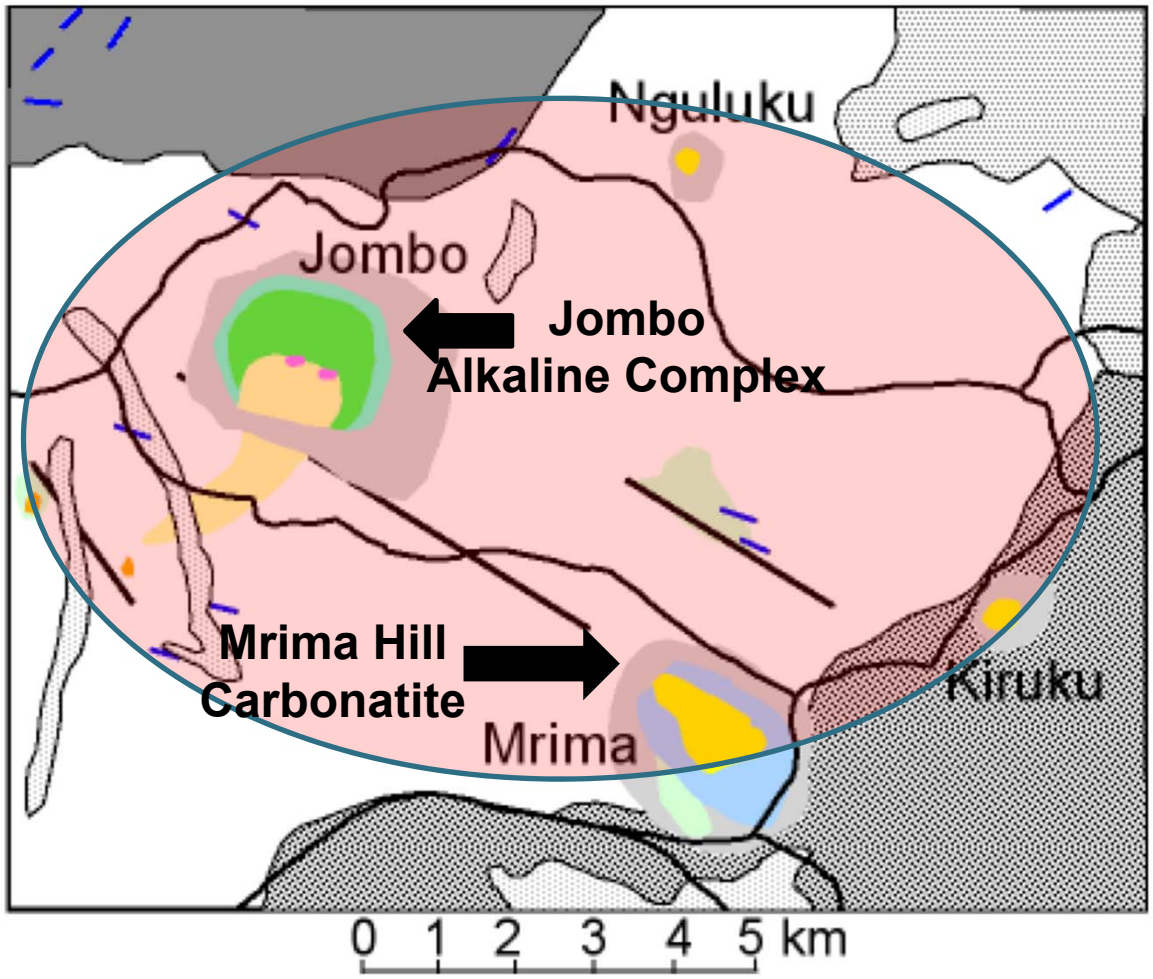
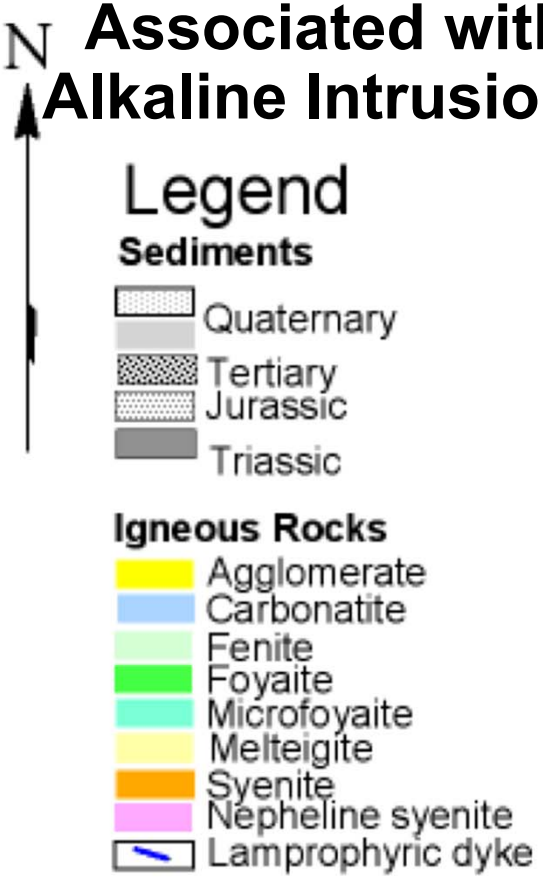
Gravity and Magnetic Anomaly



Agglomerate Associated with Alkaline Intrusions



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Nguluku Agglomerate – Mrima Hill Carbonatite, SE Kenya

Photo Ken Collerson for Pacific Wildcat Resources

Mt Philip Agglomerate

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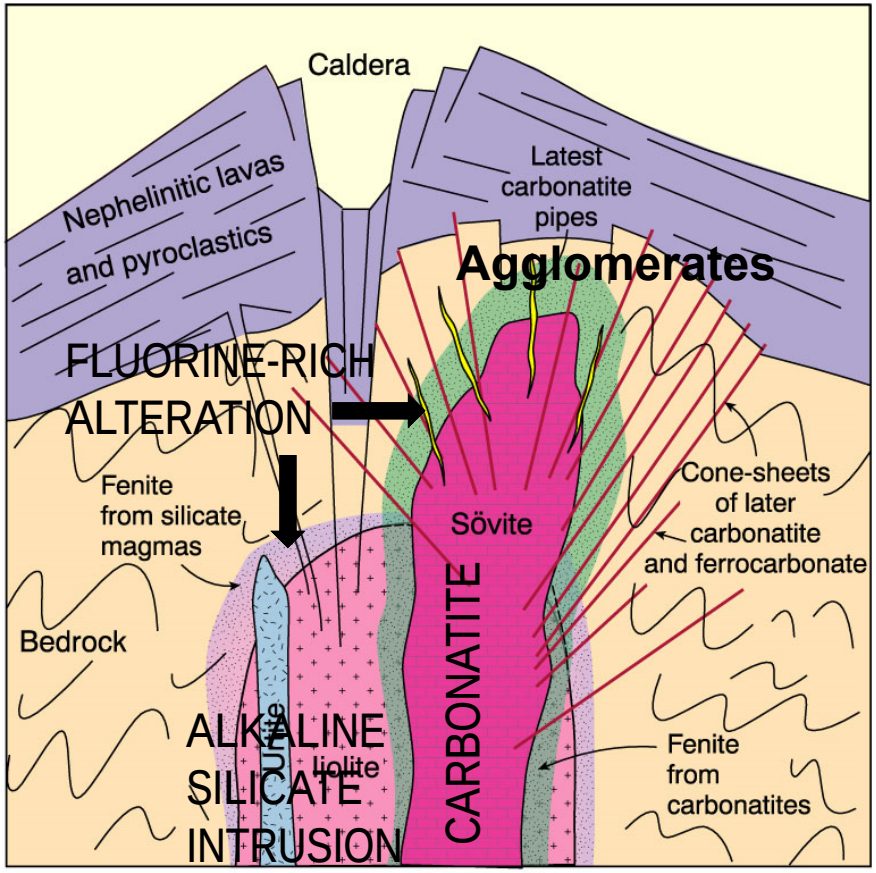
Mineral System Model for Mary Kathleen Belt

- Plume generated alkaline magmatism
- Silicate alkaline magmas (UM's to foid syenites - diorites and ultramafic lamprophyres
- Possibly intruded by carbonatite plug, dikes or cone sheets.
- Carbo- and fluoro-thermal fenite is enriched in REE and HFSE.
- **These alteration zones are excellent exploration targets.**



After Le Bas (1987) *Mineral. Mag.*, 44, 133-40

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Conclusions

- Cu-Au-Co-PGE-REE mineralisation in the MKB are not related to the Burstall Granite or Lunch Creek Gabbro.
- Mineralisation caused by potassic alkaline magmatism at ~1500 Ma to 1530 Ma
- Lithologies include Ijolite-syenite-pyroxenite (phoscorite)-syenite-lamprophyre (glimmerite)
- Alkaline magmas provide the exotic metal assemblage (Cu, Au, Sc, U, REEs, Co, V) seen in the MKB.
- They have high F contents, evidenced from fluorite in comagmatic lithologies.
- Fluorine-rich fluids transported metals along regional fault systems and via fractures into massive calc silicate Corella Fm. lithologies.

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Conclusions - Mount Philip Breccia

- Mount Philp Breccia postdates Corella Fm. and Overlander Granite
- Subsequently breccia matrix preferentially altered to haematite dusted albite leaving igneous clast/rafts largely unaltered.
- MPB resembles agglomerates associated with alkaline intrusive complexes
- Could explain fenitised matrix containing Na amphibole.
- Breccia clasts embayed margins, indicative of interaction with F-rich fluids
- Breccia event is 200 Ma younger than previously thought.
- Similar age mineralisation in Cloncurry Belt IOCGs may indicate genetic relationship between MKB and CB (IOCG) mineral systems.

Disclosures

- Initial work on Blue Caesar funded by Chinalco
- Subsequent investigation undertaken and funded as part of Hammer Metals – Glencore JV
- **Dating and mapping of the Mt. Philip Breccia commissioned and funded by Hammer Metals Limited**

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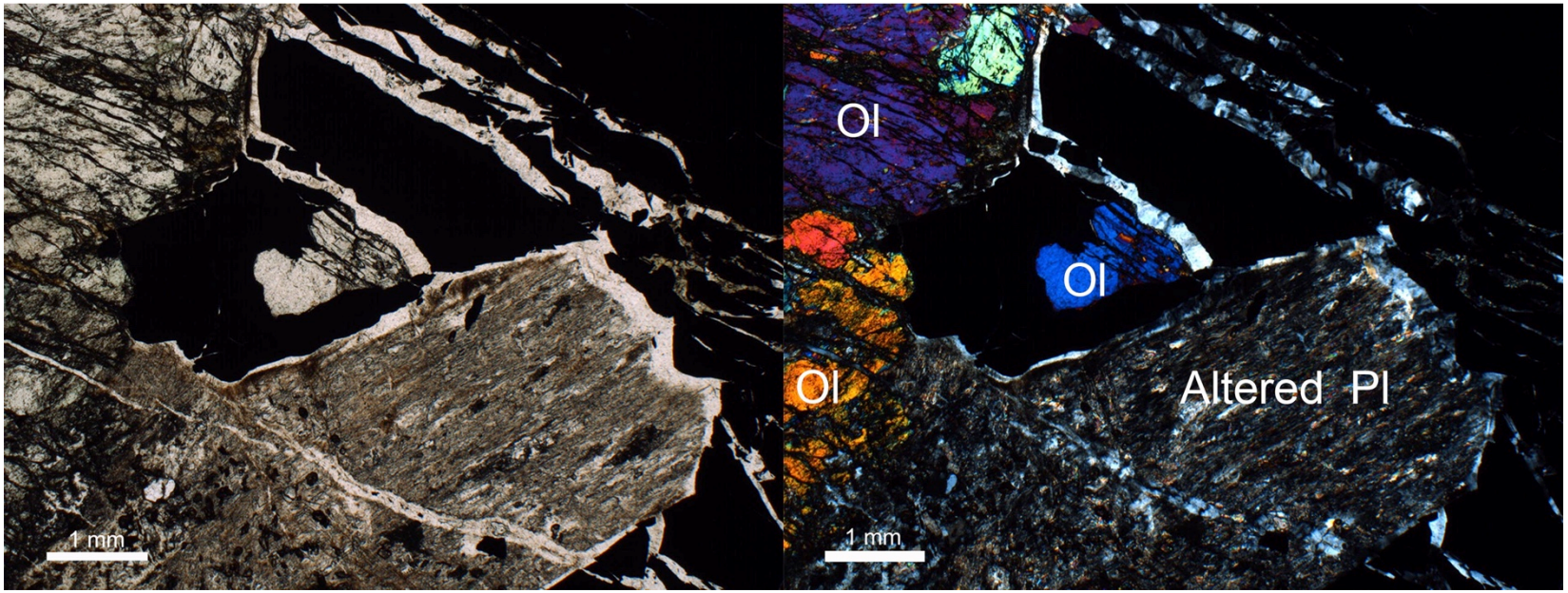
1526 Ma Alkaline Suite – Mary Kathleen Belt
Ijolite - Phoscorite



Plane Polarised Light

Cross Polarised Light

MKED 014 – 268.7 m

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Mount Philip Breccia Mapped by Nick Tate

- Bedding trends
- QZV Quartz vein
- GOS Gossan (after sulphide)
- SAR Strongly altered rock. Lithology unrecognisable.
- BXH Hydrothermal breccia
- BXP Mount Philp Breccia. Includes mafic intrusive rafts.
- MQ Magnetite hematite quartz (ironstone)
- PEG Pegmatite (includes some leucogranite)
- GRN Leucogranite
- RHY Rhyolite
- GAB Gabbro
- DOL Dolerite
- CS Calcsilicates
- CSC Calcsilicates with interbedded limestones.
- CSS Sandy Calcsilicates
- AMP Amphibolite. Weak to modrate folation.
- LST Limestone (marble)
- SSV feldspathic sandstone
- SCH Micaceous schist