Scottish Highlands Caledonian Granites: A fresh look at Hot Zone Origins, Emplacement and their relationship to Pb-Zn-Carbonate Mineralisation

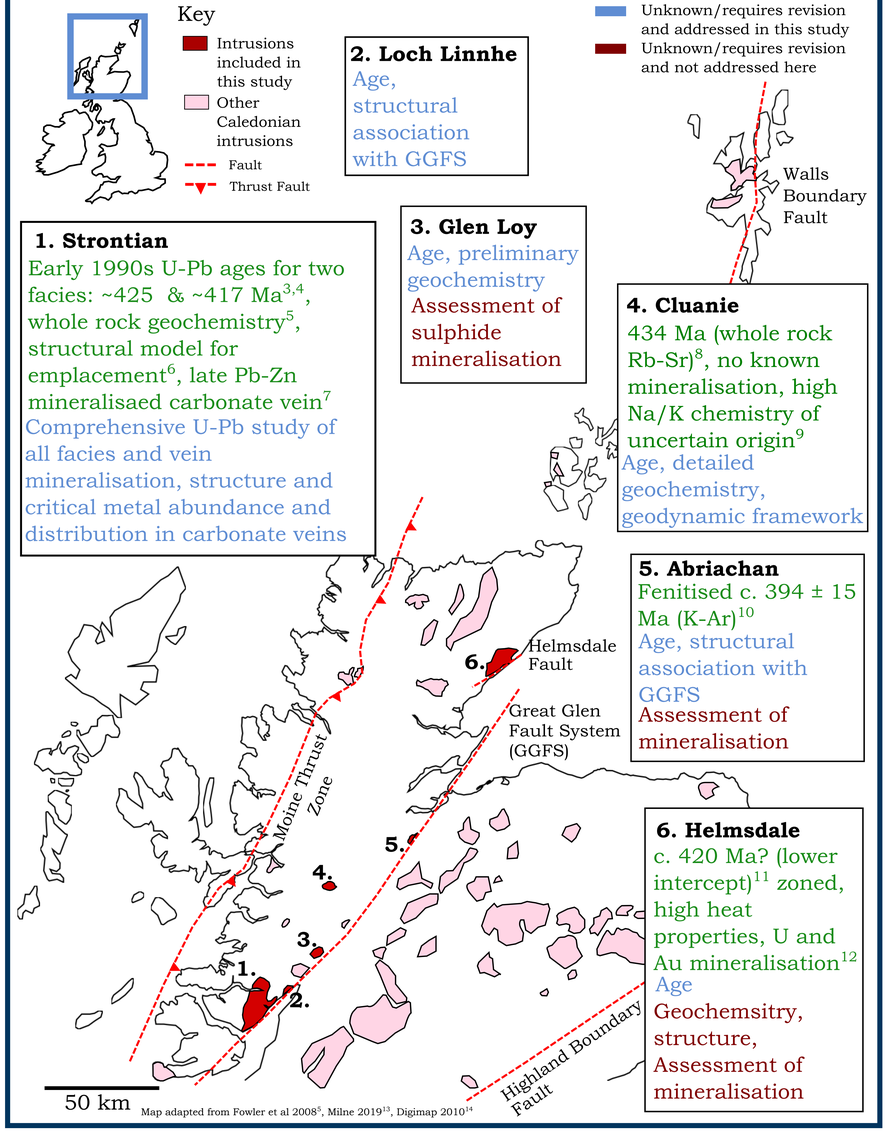
Careen MacRae, Iain Neill, Joshua Einsle, Edward Dempsey, Anna Bird, Eilidh Milne, David Currie, Chloe Gemmell

School of Geographical and Earth Sciences, University of Glasgow | 2386309m@student.gla.ac.uk

1. Aims & Motivations

- Develop a **cost effective strategy** to investigate intrusions and mineral deposits in line with new BGS and UK government focus on a secure **UK critical metal supply**[1,2]
- **Caledonian intrusions lack modern knowledge** of geochemistry and geochronology, and application of the recognised **lower crustal hot zone** model to geological understanding of the Northern Highlands
- Focus on the **Strontian pluton** and Northern Highlands where there is **known mineralisation**, but geological **framework unclear**

2. Regional Background



Map adapted from Fowler et al 2008[8], Milne 2019[13], Digimap 2010[14]

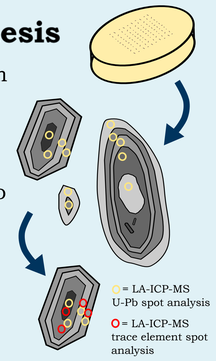
3. Strategy

Testing the Hot Zone Hypothesis

The Hypothesis: A lower crustal hot zone existed from c. 450 - 430 Ma beneath the Northern Highlands

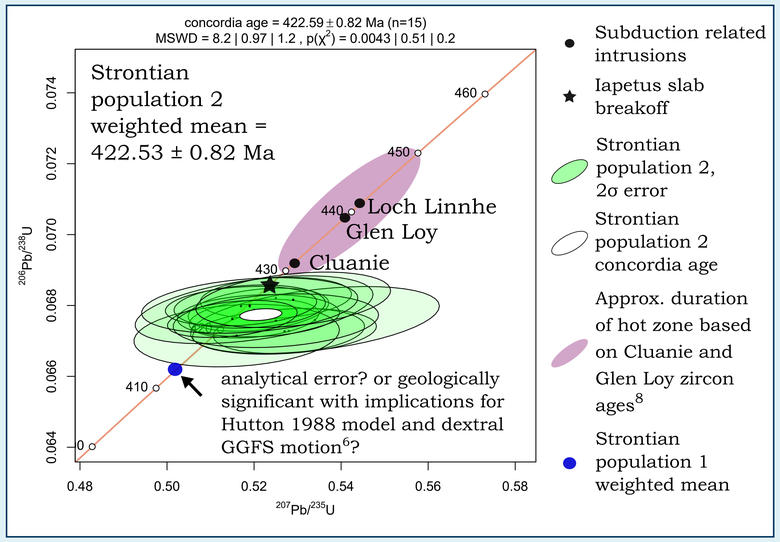
LA-ICP-MS on ≤ ~100 grains per sample, multiple spots per grain + targeted ID-TIMS and titanite dating if necessary: prevents reliance on few grains to date emplacement as in previous CA-ID-TIMS work

Standard picking and cathodoluminescence, U-Pb and adjacent trace element spots targeting growth zones to minimise bias and identify metal enrichment at deep crust vs emplacement depths

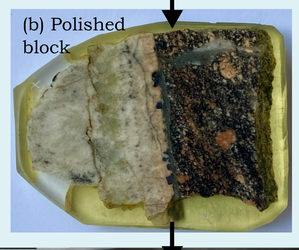


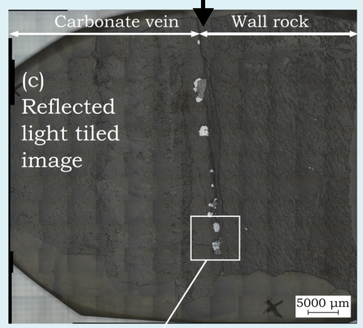
Current Results	
Intrusion	LA-ICP-MS zircon $^{206}Pb/^{238}U$ weighted mean
Glen Loy	439.4 ± 3.1 Ma
Loch Linnhe	441.3 ± 2 Ma
Cluanie	431.6 ± 1.3 Ma
Strontian (outer)	zircon population 1: 413.3 ± 1.3 Ma
	Zircon population 2: 422.53 ± 0.82 Ma

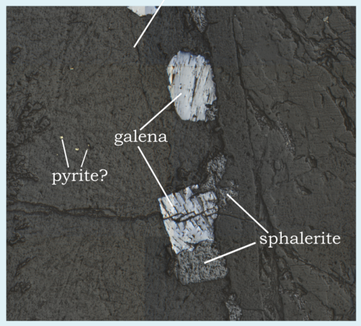
Results to Follow	
Intrusion	Justification
Strontian (outer, inner)	Clarification of current result
Abriachan	REE potential?
Helmsdale	Geothermal potential



Dating and Analysis of Mineralisation







1. Dating:
U-Pb calcite of main vein
U-Pb apatite of associated sub-volcanic dyke (Permian-Carboniferous?)

2. Collect large optical data sets via stitching image tiles (c)

3. Machine learning: clustering and quantitative criteria to segment images, identify regions of interest

4. EDX + LA-ICP-MS of regions of interest, correlate info to sample scale;
focused ion beam tomography for grain morphology (3D) and mineralisation processes

5. Results dependent + geological framework, further focus on e.g., Ge and In, known in galena/ sphalerite but untested at Strontian

4. Future Work

- Embed workflow between Glasgow and Hull Universities and the BGS Critical Minerals Intelligence Centre
- Use the workflow to rapidly assess baseline geology in understudied plutons, quantify the pluton-mineralisation association and determine critical metal load and distribution in previously identified mineralised sites
- Combine analytical approaches with modelling of 3D structure and deformation history of plutons to further constrain their potential as geothermal energy sources

References: 1. HM Government., 2022. Resilience for the Future: The United Kingdom's Critical Minerals Strategy. 2. Deady, E. et al., 2023, Potential for Critical Raw Material Prospectivity in the UK. British Geological Survey CR/23/024. 3. Rogers and Dunning, 1991, Journal of the Geological Society, 148(1), pp.17-27. 4. Paterson et al., 1993. GSA Abstarcts with Programs, 25. 5. Fowler et al., 2008, Lithos, 105, pp.129-148. 6. Hutton, 1988, GSA Bulletin, 100, pp.1392-1399. 7. Ineson and Mitchell, 1974, Transactions of the Institution of Mining and Metallurgy, 83, pp.13-19. 8. Milne et al., 2023 Geological Society of London, 180 (2), pp.1-14. 9. Neill and Stephens, 2009, Scottish Journal of Geology, 45(2), pp. 117-130. 10. Deans et al., 1971, Nature Physical Science, 234(51), pp.145-147. 11. Pidgeon and Aftalion, 1978, Geological Journal Special Issue, 10. 12. Tweedie, 1981, Thesis, University of Aberdeen. 13. Milne 2019, Thesis, University of G;asgow. 14. Digimap, 2010, DiGMapGB-250 Rock Units.