Cones have a point: Using the cone sheets of the Carlingford Igneous Complex to understand deeper crustal architecture and mineralisation in the system.

Trinity College Dublin, The University of Dublin

Laidlaw Foundation

Meabh Ní hÉalaithe, Dr. Michael Stock, Jack Beckwith, Dr. Mark Cooper

Introduction

Platinum Group Elements (PGEs) have been named a Critical Raw Material (CRM) by the European Commission. PGEs are used in catalytic converters and advanced fuel cells, making them essential for green technologies. Understanding how these elements occur in the Earth's crust is essential to enable us to find and extract these resources in a more sustainable manner. The Paleogene Carlingford Igneous Province on the Cooley Peninsula has a history of PGE exploration and offers a unique insight into a subvolcanic magma chamber. Cone sheets – radial injections from deeper reservoirs below the magma chamber – can offer us a glimpse into the deeper processes in Earth's crust. These cone sheets carry clinopyroxenes up from the reservoirs. Clinopyroxene is a magmatic mineral which records the pressure at which it crystallised in its chemistry. Using these minerals, magma storage depths can be constrained to give better picture of subsurface processes involved in PGE mineralisation.

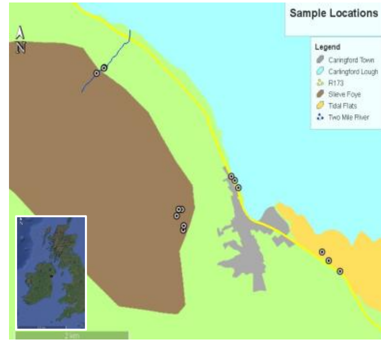


Figure 1. Map of Carlingford and surrounding area showing sample locations (black and white spots) and location of Carlingford in Ireland (Google Earth 2025).

Methods:

Two days of field work were undertaken in Carlingford, Co. Louth. Samples were taken from several locations including the coast of Carlingford Lough, Two-Mile River, and the northeast slope of Slieve Foye. Sample preparation was done on Trinity campus in the Earth Surface Research Laboratory (ESRL) and the Museum Building lab. X-Ray Fluorescence Microscopy (XRF) and bulk rock analysis was also done in the ESRL. Optical microscopy and Scanning Electron Microscopy were done on campus in the Centre for Microscopy and Analysis (CMA) laboratory. Electron Microprobe analysis was undertaken in the Archaeology laboratory in the University of Oxford. Machine learning thermobarometry was used to constrain magma storage depths.

Depth (km), Pressure (kilobar)

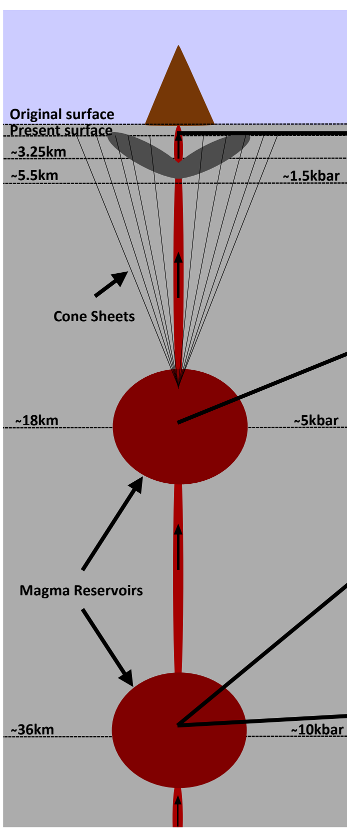
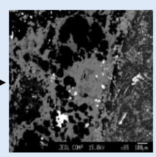
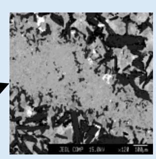


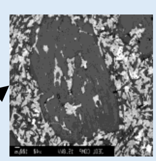
Figure 2. Diagram of deeper magma storage systems at Carlingford.



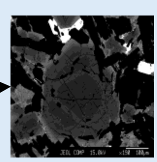
Shallow (0.3kbar): The vent contains crystals that cooled in a shallow environment, they were likely the last to crystallize.



Deeper (5kbar): Clinopyroxene crystals cooled at around 18km depth, forming a mush with a honeycomb patterning before travelling up as cone sheets were emplaced.



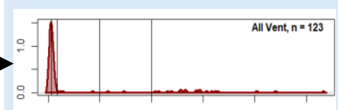
Deepest (10kbar): Clinopyroxene (light grey) in Plagioclase crystal (dark grey). This would have been formed in the deepest chamber.



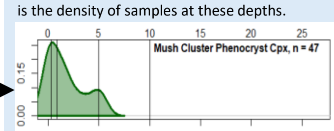
Deepest (10kbar): This Clinopyroxene shows zoning, where it has been chemically altered as it has travelled up from the deeper magma reservoir.

Figure 3. Crystal images corresponding to crystallization depth.

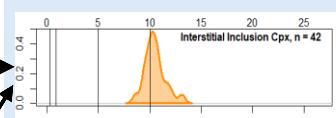
Density plots of crystallization depths measured in kilobars.



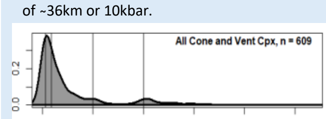
1. Almost all minerals in the vent agglomerate crystallized at a depth of ~1.08km or 0.3kbar. For all plots x-axis is depth in kbar and y-axis is the density of samples at these depths.



2. Minerals in the clinopyroxene 'mush' shows a peak at 5kbar or ~18km depth.



3. Clinopyroxene inclusions in plagioclase crystals show a crystallization depth of ~36km or 10kbar.



4. Combined data from the clinopyroxenes in the cone sheets show peaks at 0.3-1.5kbar, 5kbar, and 10kbar respectively.

Figure 4. Plots showing crystallization depth distribution.

Time

Figure 3. One of the sample locations on the northeast slope of Slieve Foye.

Conclusions

Five separate storage depths were recorded by the cone sheet data, showing evidence of further magma reservoirs. Four separate cone sheet samples contained clinopyroxenes with a crystallization depth of ~10kbar (approx. 36km below the original surface), double the depth of what was originally the deepest reservoir recorded under the complex. Two cone sheets with mineralised PGEs were found and will be analysed further. The deeper processes that occurred underneath the Carlingford Igneous Complex during the Paleogene were instrumental in the emplacement and mineralisation of PGEs, though further research is needed to better understand these dynamic systems.

Acknowledgements

I would like to extend my sincerest thanks to the Laidlaw Foundation, my supervisor Dr. Michael Stock, Jack Beckwith, Dr. Mark Cooper, Dr. Victoria Smith, staff of the ESRL, CMA, and Museum Building, and to the Archaeology laboratory in the University of Oxford.

Meabh Ní hÉalaithe
nihealam@tcd.ie