Directly dating fluid flow, faulting and mineralisation using U-Pb carbonate geochronology - opportunities and challenges

Dr. Catherine Mottram

Associate Professor in Geology, University of Portsmouth, UK

catherine.mottram@port.ac.uk

Deformation in the upper crust is commonly accommodated by brittle fracturing and faulting. These events are coupled with fluid flow resulting in pervasive calcite/quartz veining in these geological settings. These rapid, low temperature processes are notoriously difficult to date as the minerals usually used to record geological time (such as zircon) typically do not crystallise or record any deformation under these conditions. In the last decade advances in in-situ laser ablation mass spectrometry techniques mean it is now possible to directly-date calcite associated with brittle structures using the U-Pb carbonate geochronology method (e.g. Roberts et al., 2020). This has opened up a whole new realm of tectonic investigation in the upper crust.

This talk will explore the effectiveness of the U-Pb calcite dating technique for providing timing constraints for orogenic crustal deformation, fluid flow and mineralisation events. In similarity with other unconventional geochronometers that have low U content and incorporate common Pb into their structures (such as titanite), calcite is not always straightforward to date and results can therefore be ambiguous to interpret. This talk will explore examples of the 'good, bad and ugly' in the world of calcite U-Pb dating.

Despite these challenges, this talk will highlight the use of in-situ U-Pb carbonate geochronology to successfully date a variety of fault material and mineralised and unmineralised veins within a major fault-controlled Cu-Au-Mo porphyry system in the central Yukon, Canadian Cordillera (e.g. Mottram et al., 2020; 2024). I will also explore other case studies where this method has provided helpful constraints for brittle deformation including the Main Boundary Thrust in the Himalaya, and the North Anatolian Fault in Greece. This will demonstrate how U-Pb carbonate dating can be used to reconstruct the displacement history of these various first-order structures. The results can be used to examine how orogenic stress is spatially and temporally accommodated along major seismically-active, continental-scale faults. Furthermore, this talk will highlight the power of carbonate geochronology for dating many previously un-dateable processes and for highlighting the complexity of fluid flow in the upper crust.

References

Mottram, C. M., Kellett, D. A., Barresi, T., Zwingmann, H., Friend, M., Todd, A., & Percival, J. B. (2020). Syncing fault rock clocks: Direct comparison of U-Pb carbonate and K-Ar illite fault dating methods. *Geology*, *48*(12), 1179-1183.

Mottram, C. M., Kellett, D. A., Barresi, T., Chapman, G. G., & Halle, J. (2024). Tracking the porphyry-epithermal mineralization transition using U-Pb carbonate dating. *Geology*, *52*(9), 723-728.

Roberts, N. M., Drost, K., Horstwood, M. S., Condon, D. J., Chew, D., Drake, H., ... & Lee, J. K. (2020). Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) U–Pb carbonate geochronology: strategies, progress, and limitations. *Geochronology*, *2*(1), 33-61.