Ice, but no fire: a new depositional age for the Rapitan Group, Canada

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The timing and causes of the glacial events associated with the ‘Snowball Earth’ hypothesis remain contentious. The earliest of these events, the Sturtian glaciation, has returned U-Pb zircon and Re-Os black shale ages from 740 Ma to as young as 660 Ma. Recently, strata correlated with the glaciogenic Rapitan Group of NW Canada have been dated at 716.47±0.24 Ma [1]. This supported a genetic correlation of the Sturtian glaciation and the Rapitan Group with the Franklin large igneous province (LIP), suggesting that the Sturtian glaciation may have been triggered by excessive CO_2 drawdown by weathering of this LIP – the ‘fire and ice’ model [1,2]. This model relies on penecontemporaneous emplacement of the LIP, its weathering, and Rapitan Group glacial onset at low latitudes. Here we present a new age for detrital zircon from the Rapitan Group itself. The sample was extracted from cross-bedded sandstone underlying the Rapitan iron formation by 75 m. A large number of zircon were pilot dated by LA-ICP-MS on double-sided tape and the youngest were then dated by high-precision ID-TIMS (see diagram). A coherent population of 8 grains defines a concordia age of 711.34±0.25 Ma. This is the new maximum age for deposition of the Rapitan Group and for the Sturtian glaciation in the region, and is consistent with Re-Os dates from shales overlying other Sturtian glacial deposits [3]. Significantly, it is a full 5 million years younger than the Franklin LIP, a span of time that is too long to support the ‘fire and ice’ model. The Rapitan Group may have been erroneously correlated with similar nearby strata. It is also possible that global ‘Sturtian’ glacial deposits were not the result of a single glacial episode.

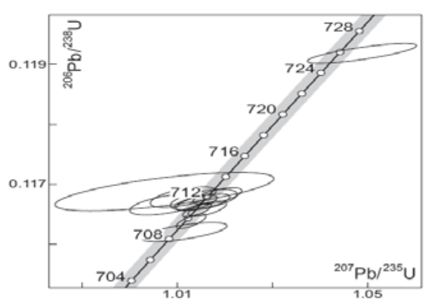

Figure 1: U-Pb concordia diagram for detrital zircon from the Rapitan Group, Canada. N=12, eight grains yielded a mean age of 711.34±0.25 Ma (MSWD = 2.0).

[1] Macdonald *et al.* (2010) *Science* **327**, 1241-1243. [2] Goddéris *et al.* (2003) *Earth Planet. Sci. Lett.* **211**, 1-12. [3] Rooney *et al.* (2011) *Precamb. Res.* **185**, 202-214.

Reconstruction of *P-T* paths in polymetamorphic rocks of the Clearwater core complex, northern Idaho

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Understanding where, when, why, and how metamorphic core complexes form in settings of continental shortening is important because these features are part of the rock record of deformation. Moreover, core complexes provide the most direct observational information about the relationship between the middle and uppermost crust in the late stages of orogenesis, so offer a valuable opportunity to investigate crustal coupling and mass transfer within continental crust.

In the northern U.S. Rockies, core complexes show a prolonged metamorphic history, lie inboard of the $^{87}Sr/^{86}Sr$ 0.706 line, and are spatially associated with major Cordilleran batholiths. Peak metamorphic conditions are amphibolite facies, with maximum crustal depths of around 25-35 km in the most deeply exhumed complexes. Metamorphosed footwall rocks include units within Proterozoic crystalline basement as well as the sediments of the overlying Mesoproterozoic Belt Supergroup. Widespread extension occurred 59-40 Ma, with several core complexes recording an initial rapid phase of extension at *c.* 49-48 Ma followed by more protracted exhumation. The focus of this paper is on characterization of polymetamorphism in the Clearwater metamorphic core complex (CMCC) located in northern Idaho, which contains a history of both Proterozoic and Cretaceous-Eocene tectonometamophic events.

Metamorphic events in rocks within the CMCC range from Paleoproterozoic basement formation, Mesoproterozoic crustal thickening, and Cretaceous convergence, magmatism, and final exhumation in the Eocene. The samples focused on in this study are pelitic and unusual Mg-Al-rich schists from both within the high grade core of the complex, as well as schists that lie west and east of the bounding detachments. Previous work has indentified three major metamorphic events in the area [1]. The first has recently been correlated with Mesoproterozoic (1.3 Ga) crustal thickening based on Lu-Hf garnet dating [2]. Rocks also show evidence for a 1.1 Ga event. Zircon rims indicate Cretaceous to Eocene metamorphism in pulses from 82-80, 74-72, 64, and 59-55 Ma [3]. The younger dates likely correspond to fluid migration during exhumation of the complex. Here we present results of pseudosection modeling and garnet compositional isopleth thermometry to place contrainsts on the complex polymetamorphic history of these rocks. The Cretaceous to Eocene history is best preserved in multi-stage garnet microstructures with diffuse high Ca – low Mn rims, rutile converting to ilmenite, pre-kinematic staurolite, and abundant andalusite and sillimanite after kyanite, particularly in rocks within Eocene shear zones.

[1] Grover et al. (1992) *American Journal of Science*, **292**, 474-507. [2] Nesheim et al. (2012) *Lithos*, **134-135**, 91-107. [3] Doughty et al. (2007) *GSA Special Paper,* **434**, 211-241.