Long-lived zircon growth in trapped eclogite

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The residence time of rocks within subduction channels provides a narrative on the physical processes that reflect the interplay between subduction rate and angle, coupling between the lower and upper plate and hydration of the mantle wedge. In oceanic subduction systems, it is now recognised that rocks can reside within subduction channels for 10’s of millions of years. These apparently long-lived durations of entrainment in the subduction channel probably require circulatory motions that recover material from terminal subduction and simple one-cycle exhumation. In turn, these residence times can plausibly be used to deduce geodynamic variables that control the subduction system.

Establishing the duration a rock has been stored within a subduction environment typically requires application of multi-mineral geochronology coupled with considerations of closure systematics. However because subduction environments are commonly fluid-rich, a mineral with great potential to reveal durations rocks can reside within subduction channels is zircon. In subduction environments, several studies have documented apparently long-lived records of zircon growth, but seemingly have not recognised the potential for zircon to extract information on the duration a rock experienced subduction channel metamorphism.

Lawsonite-bearing eclogite in eastern Australia has a remarkable microstructural record of zircon growth. Thin section-scale 1-3 micron resolution synchrotron mapping by X-ray Fluorescence (XFM) reveals the presence of 1000’s of micron-sized zircons which occasionally range up to 15 microns in size. Zircon: (1) defines inclusion trails in garnets, (2) is a foliation defining matrix mineral and (3) occurs in retrograde chlorite-bearing veins that formed during post-eclogite blueschist paragenesis. In-situ U-Pb geochronology shows that zircon growth occurred over the interval c. 520-400 Ma. The zircons have hydrothermal characteristics with elevated LREE and simple tetragonal morphologies. The apparently long duration of zircon growth is generally consistent with other geochronology from the eclogite: garnet Sm-Nd and Lu-Hf ages between 530-490 Ma, matrix foliation titanite U-Pb c. 450 Ma, and matrix foliation phengite Ar-Ar and Rb-Sr ages of 460-450 Ma.

The small size of the zircons means they cannot be readily extracted using bulk rock methods. Instead, fast, high-resolution imaging methods such as synchrotron XFM mapping coupled with spatially precise U-Pb-trace element analysis reveal a long history of HFSE element mobility resulting in microstructurally organised zircon growth that allows rock residence time in a
subduction channel to be determined.

If lawsonite eclogite from eastern Australia records more than 100 Ma of zircon growth at eclogite-blueschist facies conditions, the single eclogite sample reflects around 5000-7000 km of consumption of the palaeo-pacific plate under the east Gondwana margin while remaining trapped in the subduction channel.