Using Thermochronology to Determine the Timing and Rates of Tectonic Processes

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The Earth's crustal evolution is preserved in the mineral assemblages, textures and isotopic composition of exhumed rocks. Thermochronology provides a set of tools to determine rates of geologic and tectonic processes. Using a range of minerals with different closure temperatures, integrated with petrologic and fabric analysis, we present three case studies from the obliquely convergent Australia(AUS)-Pacific(PAC) plate boundary zone that constrain rates of subduction, timing of peak metamorphism, and timing/rates of rock exhumation. In each case changes in exhumation rates can be linked to changes in relative plate motions.

The HP terrane of New Caledonia preserves a record of Paleogene subduction and exhumation within the AUS-PAC plate boundary zone. Volcanic and sedimentary protoliths were subducted at rates of 0.6-1.6 cm/yr, and metamorphosed under HP conditions at ~44 Ma. Subsequent rapid cooling from 40-34 Ma occurred at rates of ~ 0.5 cm/yr as the HP terrane was exhumed as a coherent block to relatively shallow crustal levels, via ductile shearing associated with crustal extension. Since the mid Oligocene (<34 Ma) exhumation rates decreased to <0.3 mm/yr as brittle normal faulting and erosional processes continued to exhume blueschists and eclogites from relatively shallow (i.e., cool) crustal depths.

In the South Island of New Zealand oblique AUS-PAC convergence led to formation of the Southern Alps. Thermochronologic studies of the hanging wall (PAC plate) east of the Alpine Fault reveal an asymmetric zone of lower crustal rocks exhumed since ~ 6 Ma at rates of 0.6-0.9 cm/yr. In contrast, thermochronology of the footwall (AUS plate) provides a record of the earlier (since 23–25 Ma) development of the plate boundary not preserved elsewhere in the Southern Alps. The data set records the evolution of the AUS-PAC boundary from a strike-slip to obliquely convergent plate boundary.

The most rapid exhumation rates within the obliquely convergent PAC-AUS plate boundary zone, occur in an extending region located west of the Woodlark Basin seafloor spreading rift tip in eastern Papua New Guinea. There, 8-2 Ma eclogites have been exhumed at plate tectonic rates (>1 cm/yr) within the lower plates of metamorphic core complexes. Counter-clockwise rotation of the Woodlark plate relative to the Australian plate led to reactivation of a former subduction thrust, and resulted in extensional eversion of the youngest known HP and UHP rocks on Earth.