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Orogen-scale anticline revealed in the Southern Alps of New Zealand by structural thermochronology

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A dense set of cooling ages from the Southern Alps reveals an orogen-scale anticline of cooling-age isosurfaces (isochrones) and provides an interesting example of structural thermochronology, where isochrones are used as structural markers. The isochrone concept is an integral aspect of the age-elevation method, but the latter implicitly assumes that all isochrones are horizontal. Our experience in New Zeland and elsewhere is that isochrones are commonly tilted after formation. We use a more general approach that solves for orientation of the isochrone surfaces, and also the slope of the age-elevation trend, where "elevation" is measured normal to the isochrone surfaces.

In New Zealand, collision and convergence between the Pacific and Australian plates have resulted in the formation and continuing growth of the Southern Alps, a prototypical orogenic wedge. In the western side, the Southern Alps is bounded by the Alpine fault, along with deeply exhumed rocks from depths up to ∼25 km. There are 150 apatite and 200 zircon fission-track (AFT, ZFT) ages that cover the vast region of the South Island of New Zealand from Lake Summer to Lake Wanaka. The AFT ages range from <0.5 to ∼140 Ma, and the ZFT ages, from <0.5 to ∼400 Ma. Our approach was initiated by McPhillips and Brandon (Earth and Planetary Science Letters, 2010, doi: 10.1016/j.epsl.2010.05.022). We use a least-squares method to solve for a best-fit sequence of dipping isochrone surfaces. The solution specifies the strike, dip and spacing of the parallel isochrones, the last of which indicates the velocity of the isochrones passing through the closure depth.

We find that the calculation of the entire dataset failed to yield reasonable results, implying nonplanar structures at the regional scale. Using subsets of data, we observed three distinct zones of isochrones from E to W across the South Island. 1) The large area east of the Southern Alps in the central South Island contains ZFT isochrones that dip shallowly (< 1-5 degrees) to the east, with ages of ∼100 Ma and older. The spacing of the isochrones is narrow and indicates low (∼10-100 m/Ma) velocity crossing the closure depth of the samples. 2) In the eastern flank of the Southern Alps, the isochrone dip increases to ∼5-20 degrees with younger ages, ∼50 to < 5 Ma, and a much wide spacing of ∼1000-2000 m/Ma. 3) In the western flank of the Southern Alps around the Mount Cook, the isochrones have a similarly young age and spacing, but dip ∼10-30 degrees to the west.

Collectively, these observations indicate an anticlinal structure across the Southern Alps. We have shown previously that cooling ages provide a kind of upside-down stratigraphy, with age surfaces (isochrones) formed at the closure isotherm and becoming older above that horizon. The isochrones first form as nearly horizontal surfaces and then serve as passive markers of deformation above the closure isotherm. We suggest that the isochrones exposed in the east flank of Southern Alps were formed and tilted to the east as they were advected through the large east-dipping retroshear zone that underlies the Southern Alps. In contrast, the west-dipping isochrones exposed in the west flank of the Southern Alps were formed within the retroshear zone, and their west dip is probably due to shear-induced rotation.