Low-temperature thermochronology of fundamental structures in the Gulf Extensional Province, Baja California, Mexico

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The 1300 km long Baja California (BC) Peninsula has been undergoing transfer from the North American to the Pacific Plate since the Miocene. This motion has mainly occurred across the Gulf Extensional Province (GEP), which is spatially and kinematically partitioned between embryonic spreading centres linked by an en-echelon array of right stepping transform faults and a broader network of N-NW striking normal faults along the margins of the Gulf of California. Low-temperature thermochronology of apatites by the fission track (AFT) and (U-Th)/He methods (AHe) are used to characterize the 3-D cooling and denudation patterns in two of the best developed east-directed normal faults on the rifted margin of BC: the fault array cutting the Los Cabos block in the south, and the escarpment of the Sierra San Pedro Mártir in the north.

The San José del Cabo (SJC) fault in the Los Cabos block, a massif of Mesozoic crystalline basement, is a major east-dipping fault with a strike length of ~150 km. The fault forms a topographic escarpment >1 km high and defines the eastern limit of the block. The footwall records rapid cooling related to tectonic exhumation between ~10-6 Ma. The fault accommodated ~5-6.5 km of exhumation at rates as high as ~1.5-2 mm/yr, but much less since the late Pliocene. A similar exhumation history is discerned to the east of the SJC for the clockwise-rotated Sierra La Trinidad block, the deepest levels of which are inferred to lie offshore.

The Sierra San Pedro Martír in northern BC, comprises middle Cretaceous granitoids and forms a prominent escarpment rising to an elevation of 3 km. AFT and AHe ages decrease from 54-65 Ma along the range crest to 34-38 Ma at the base of the escarpment accompanied, by shortening of track lengths, suggesting exhumation of less than ~2.5 km. AHe ages along the base are much younger at 11-13 Ma representing cooling related to tectonic denudation on the fault system. In rotated blocks of the hanging wall complex, east of the escarpment, AFT ages range from 15-47 Ma and AHe ages from 7-11 Ma indicating cooling from slightly deeper crustal levels.

Extended blocks in both areas show progressively deeper crustal levels and more rotation (about both horizontal and vertical axes) toward the east in the direction of transport. The combination of AFT and AHe thermochronology in both cases has proved much more powerful than either method applied separately.

Synthetic seismic signature of thermal mantle plumes

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The first seismic images of mantle plumes have been a source of significant debate. To interpret these plume images, it is useful to have an idea of the expected seismic signature of a mantle plume. We perform a set of numerical experiments to obtain dynamic thermal whole mantle plumes, with temperature contrasts below the lithosphere that are consistent with those inferred from surface observations. The plume thermal structures are converted to seismic structure taking into account the effect of temperature, pressure, an average mantle composition including phase transitions, and anelasticity. Models with depth-dependent expansivity and conductivity and temperature and depth-dependent viscosity predict plumes that are 500-800 km wide in the lower mantle. A lowering of the viscosity above 660 km by at least a factor 30 can narrow upper mantle plumes to the 100-200 km inferred from surface observations and tomography. All model plumes had buoyancy fluxes ≥ 4 Mg/s and it seems difficult to generate whole mantle thermal plumes with much lower buoyancy fluxes. Due to the varying sensitivity of seismic velocities to temperature with depth and mineralogy, variations in amplitude and width of the seismic plume do not coincide with the variations in the thermal structure of the plume. Anomalies of 2-4% are predicted in the uppermost mantle. Reduced sensitivity in the transition zone, as well as complexities due to phase boundary topography, may hamper imaging continuous whole mantle plumes. Lower mantle plumes that are consistent with temperature constrasts of 100-300°C below the lithosphere have seismic amplitudes of only 0.5-1%. Seismic anelasticity structure follows the thermal structure more closely and yields plume anomalies of 50-100% in $dln(1/Q_S)$.