Early to Middle Eocene Thrusting, Outer Foothills Belt, Southern Alberta: Evidence from Apatite Fission Track Data

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Analysis of fission tracks in detrital apatite has been undertaken in association with the Southeastern Cordillera NATMAP project to better constrain the thermal history and, by implication, the timing of thrusting in the outer Foothills of Southern Alberta. Preliminary modelling of our apatite fission track data clearly indicates a rapid cooling event (4-6°C/Myr) in Early to Middle Eocene times, which we interpret as the age of thrusting in this area of the outer Foothills. This timing is significantly later than sometimes assumed, although it is consistent with available stratigraphic constraints (latest deformation must post-date Pakapoo/Porcupine Hills deposition, where the youngest strata are 60-57 Ma, and probably pre-dates motion on the Flathead Fault, constrained by the Middle Eocene to Early Oligocene age of the Kishenehn Formation).

Fission tracks, which are zones of linear crystal damage, form in nature almost solely due to the spontaneous fission decay of 239Pu. These damage zones anneal given sufficient temperatures; apatite annealing occurs between 60°C and 120°C (the "partial annealing window") for geologically reasonable heating and cooling rates: complete annealing occurs at temperatures greater than 120°C. The observed density of fission tracks is an indication of the fission track "age," whereas the track length distribution can be modelled to constrain the time-temperature path of the sample. We use an inverse modelling program to derive a set of statistically acceptable thermal histories for a given observed data set. This solution set yields a mean, or "preferred", thermal history.

Our results are based on samples from Upper Cretaceous rocks exposed in the outer Foothills belt between the international border and the Oldman River. Most sample sites lie in the immediate hanging walls of significant thrusts, including the upper detachment of the triangle zone. Inverse models of the observed fission track data can be constrained to varying degrees, incorporating such factors as the known portion of the sedimentary burial history (and thus an inferred early temperature history), and the degree of thermal maturity, if known (e.g. vitrinite reflectance data). Model results indicate post-depositional heating reflecting sedimentary and/or tectonic burial by thrust sheets, followed by cooling to present-day.

The cooling history commonly shows two segments: the earlier, in Early to Middle Eocene time, is rapid in comparison to the later. We interpret this pattern to indicate the time and duration of thrusting: thrusting produces structural uplift leading to rapid erosion, resulting in relatively rapid cooling rates; later, slower cooling is interpreted to represent regional erosion of the foreland following orogenesis. Regional isostatic uplift due to hinterland extension coincident with foreland thrusting may also factor into the period of rapid erosion rates. The maximum absolute temperatures implied by the fission track data also constrain the thickness of the foreland succession removed by erosion.

Facies and Sequence Stratigraphic Interpretations of Wolfcampian (Early Permian) Strata of the Orogrande Basin: Hueco Mountains, West Texas

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Upper Wolfcampian (Lower Permian) strata exposed in the outcrops west of the Hueco Mountains' main escarpment show an overall shallowing-upward trend with superimposed higher-frequency landward- and seaward-stepping packages. The landward-stepping packages have an erosive base, are characterized by breccias and both coarse and fine grainstones and packstones, with coarse crinoidal lags and channeling. These packages are interpreted as transgressive, continuously cannibalized, high energy, nearshore environment strata. The seaward-stepping packages may show a complete succession with deep-shelf-to-basin (thin-beded, spiculitic wackestones), outer shelf (fusulinid packstones, skeletal packstones), buildups (highly porous, phyllid algal- Tubiphytes-Archaecithophyllum-sponge boundstones), and shallow shelf strata (fine and coarse, well-sorted skeletal and peloidal grainstones). These seaward-stepping packages are interpreted as a southward prograding shelf margin.

Four sequences have been identified within this outcrop. The boundaries of these sequences are recognized by brecciated beds and reworking of lower strata, truncation and toplap, sharp facies changes, and karsting. The lowermost sequence, Sequence 1, is composed of deep-shelf-to-basin strata, sharply overlain by clinoformal shelf strata. No landward-stepping unit is observed. Sequence 2 is composed of a landward-stepping unit consisting of breccias and shallow shelf rocks, forming a mound morphology draped by deep-shelf-to-basin strata. Interfingering of the deep-shelf-to-basin and the landward-stepping strata is shown by turbidite beds traced to the mound. Sequence 2's seaward-stepping package shows an upward succession from deep-shelf-to-basin, to outer shelf, and finally, to shallow shelf strata. Some interfingering of the deep-shelf-to-basin with the outer shelf strata is observed in this sequence. Sequence 3 consists of a thicker landward-stepping package, composed of breccias and shallow shelf strata. This sequence is missing deep-shelf-to-basin strata, and its seaward-stepping unit is composed of only outer shelf and shallow shelf rock types. A landward-stepping succession is not present in Sequence 4, and only buildup and shallow shelf strata compose the seaward-stepping unit. These buildups, exhibiting large paleofores, are a feature unique to this sequence.

As much Wolfcampian strata is subsurface, this outcrop provides an excellent exposure in which stratigraphic relations from this Early Permian pericratonic basin can be revealed. The bounding surfaces identified within this study have been previously unrecognized. The large porosity, associated with the buildup strata, is a valuable feature that can provide more information as to the reservoir possibilities of the subsurface Wolfcampian.