[PS]Detrital Thermochronologic Lag Times in the Cordilleran Foreland Basin: A New Approach to Assessing Syn-tectonic vs. Anti-tectonic Deposition in Foreland Basins*

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Abstract

The interpretation of coarse-grained deposits in distal foreland basins has varied greatly. Some have interpreted distal coarse sediments as a result of increased tectonic shortening, exhumation, and the resultant increase in source material. In contrast, others attribute these distal coarse sediments to periods of tectonic quiescence, flexural rebound, and reworking of proximal deposits into the distal foreland. We address this question by measuring lag-times of these sediments in the central Cordilleran foreland basin. The time span between source exhumation and sedimentation (i.e., lag time) is measured with the cooling age of the source material through thermochronology and the depositional age of the foreland deposits. Lag times of distal coarse deposits should be relatively long if the sediments accumulated during periods of tectonic quiescence, whereas lag times should be short in the case of syn-thrusting distal deposition. We sampled coarse-grained proximal units in the Sevier thrust belt in Utah and their distal equivalents up to 300 km east of the thrust front, and generated detrital apatite fission track (AFT) and zircon (U-Th)/He (ZHe) ages. We also further constrained the depositional age of the distal coarse sediments through detrital zircon ages (DZ). AFT cooling ages for the proximal upper Campanian Price River Formation are 79.8 ± 6.3 Ma in the lower part of the formation and 74.5 ± 6.4 Ma higher up in the section. DZ ages of the distal equivalent of the Price River Formation (the Sego Sandstone) show a maximum depositional age of circa 76 Ma. The Maastrichtian to Paleocene North Horn Formation, which is separated from the Price River Formation by an angular unconformity, has an AFT age of 66.1 ± 6.2 Ma. This suggests that Paleozoic strata within the Charleston-Nebo salient were exhumed from ~4-5 km depth during the late Cretaceous, recording the timing of active deformation. The depositional ages of these units are within error of the cooling ages, indicating very short (approximating to 0) lag times, rapid exhumation of the Sevier fold-thrust belt, and syntectonic deposition. Ongoing work is focused on measuring lag-times of distal course sediments in the Sevier foreland from the Upper Jurassic to Upper Cretaceous time.

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Abstract:

The interpretation of coarse-grained deposits in distal foreland basins has varied greatly. Some have interpreted distal coarse sediments as a result of increased tectonic shortening, exhumation, and the resultant increase in source material. In contrast, others attribute these distal coarse sediments to periods of tectonic quiescence, flexural rebound, and reworking of proximal deposits into the distal foreland. We address this question by measuring lag-times of these sediments in the central Cordilleran foreland basin. The time span between source exhumation and sedimentation (i.e., lag time) is measured with the cooling age of the source material through thermochronology and the depositional age of the foreland deposits. Lag times of distal coarse deposits should be relatively long if the sediments accumulated during periods of tectonic quiescence, whereas lag times should be short in the case of syn-thrusting distal deposition. We sampled coarse-grained proximal units in the Sevier thrust belt in Utah and their distal equivalents up to 300 km east of the thrust front, and generated detrital apatite fission track (AFT) and zircon (U-Th)/He (ZHe) ages. We also further constrained the depositional age of the distal coarse sediments through detrital zircon ages (DZ). AFT cooling ages for the proximal upper Campanian Price River Formation are 79.8 ± 6.3 Ma in the lower part of the formation and 74.5 ± 6.4 Ma higher up in the section. DZ ages of the distal equivalent of the Price River Formation (the Sego Sandstone) show a maximum depositional age of circa 76 Ma. The Maastrichtian to Paleocene North Horn Formation, which is separated from the Price River Formation by an angular unconformity, has an AFT age of 66.1 ± 6.2 Ma. This suggests that Paleozoic strata within the Charleston-Nebo salient were exhumed from ~4-5 km depth during the late Cretaceous, recording the timing of active deformation. The depositional ages of these units are within error of the cooling ages, indicating very short (approximating to 0) lag times, rapid exhumation of the Sevier fold-thrust belt, and syntectonic deposition. Ongoing work is focused on measuring lag-times of distal course sediments in the Sevier foreland from the Upper Jurassic to Upper Cretaceous time.

Background:

Syntectonic vs. Anti-tectonic deposition -

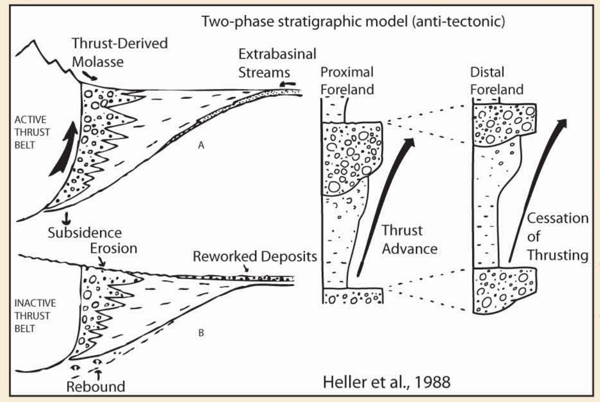


Figure 1 The two-phase stratigraphic model, and example of an anti-tectonic basin filling model, was proposed by Heller et al. (1988) and Beck et al. (1988) and has been used by many to interpret coarse grained sediments in the distal foreland system. The model predicts that upward coarsening strata in the proximal foreland represent thrust advance, whereas upward coarsening strata in the distal foreland represent a cessation of thrusting, flexural rebound and a reworking of proximal deposits. In contrast, others interpret coarsening upward strata in the distal foreland as evidence for rapid exhumation and shortening within thrust belt (i.e., syntectonic).

Using lag time to test these basin filling models -

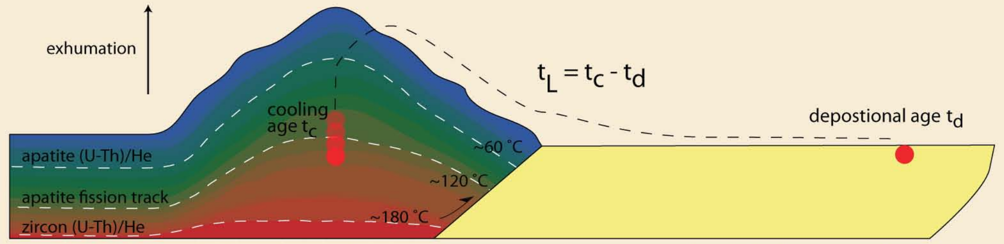


Figure 2 Lag-time t_L is the difference between the source cooling age t_c and and the depositional age in the of the foreland basin deposit t_d (after Brandon et al. 1988; Brandon and Vance, 1992; Garver et al., 1999; Reiners and Shuster, 2009).

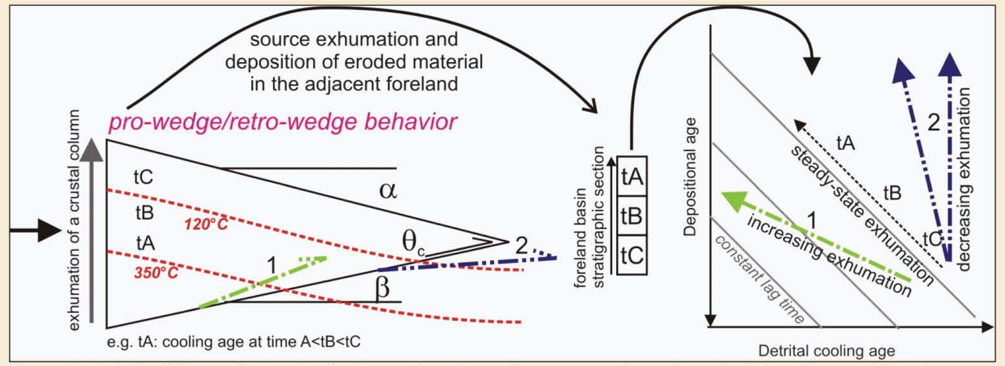


Figure 3 At left - Schematic sketh of exhumation through an orogenic wedge. At right - Constant lag times represent steady state exhumation, lag times that decrease up-section represent an increase in exhumation, and lag times that increase up-section represent an decrease in exhumation (Carrapa, 2009).

Research:

Study Area: spatial and temporal distribution -

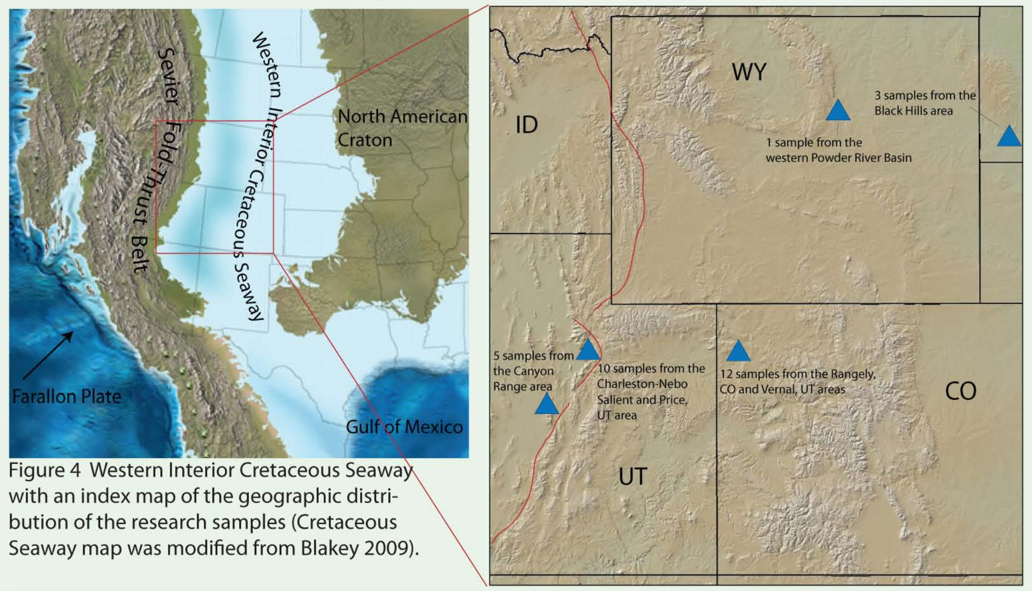


Figure 4 Western Interior Cretaceous Seaway with an index map of the geographic distribution of the research samples (Cretaceous Seaway map was modified from Blakey 2009).

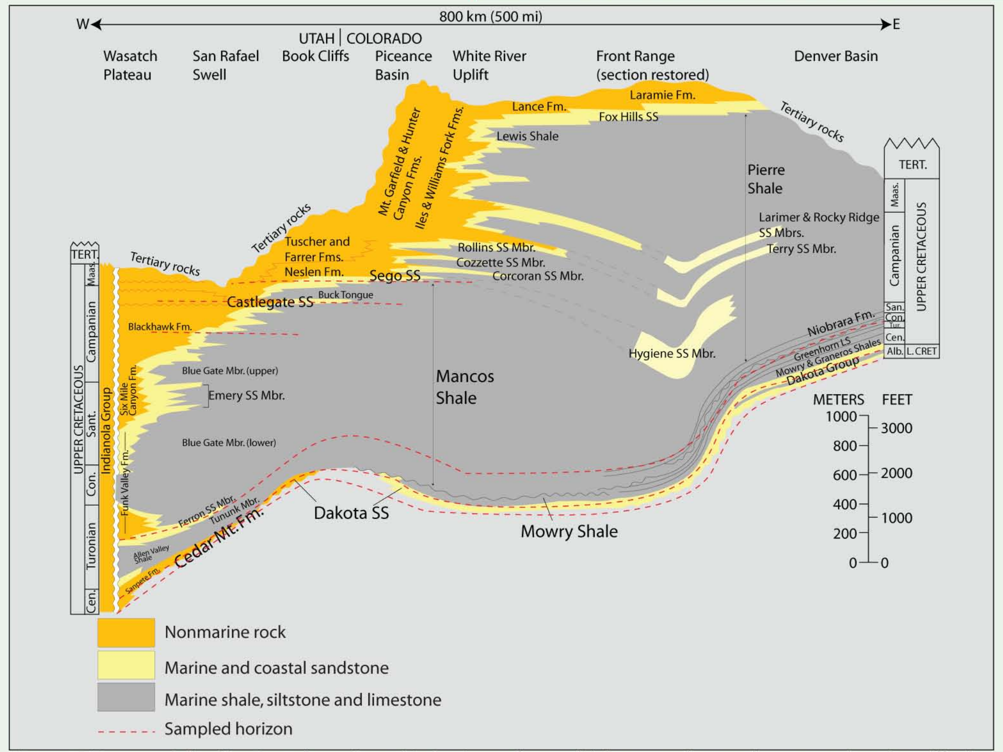


Figure 5 Temporal distribution of stratigraphic horizons from which research samples were taken (modified from Franczyk et al., 1992; Cobban et al., 2006).

Finding the right thermochronometer to measure source exhumation -

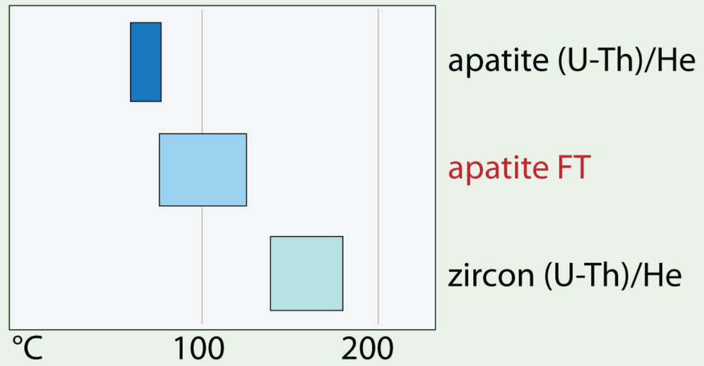


Figure 6 There are numerous low temperature thermochronometers, three of which are apatite (U-Th)/He, apatite fission track, and zircon (U-Th)/He. Each of these records different thermal histories. For our purposes, apatite fission track has proved to be the most effective (modified from Dodson, 1972; Naeser, 1981; Gleadow and Duddy, 1981).

Thermochronologic Data -

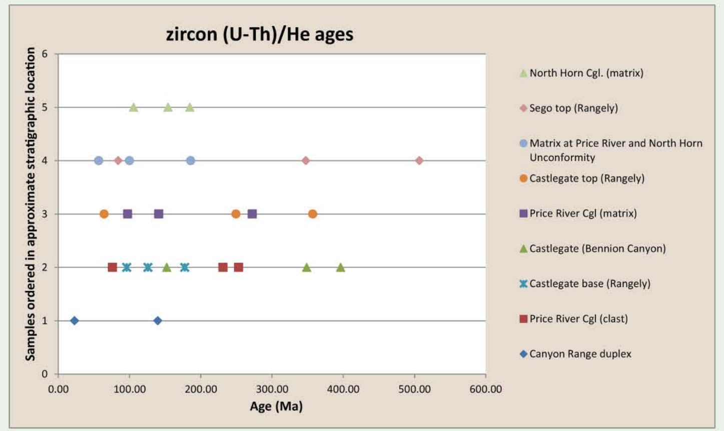


Figure 7 To constrain which thermochronometer is most effective, we first attempted to use zircon (U-Th)/He, which has a closure temperature of ~180 °C. All of these samples displayed discordant ages, showing that the source material never reached temperatures higher than ~180 °C, making it likely that they were never buried deeper than 9 km.

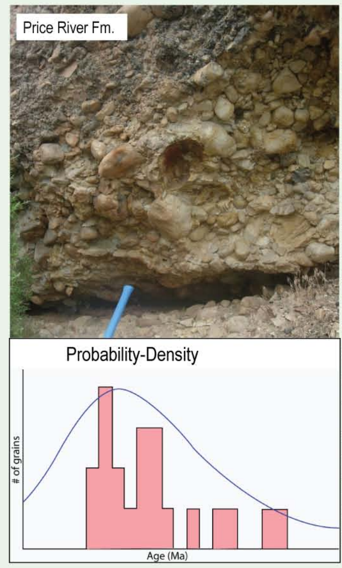
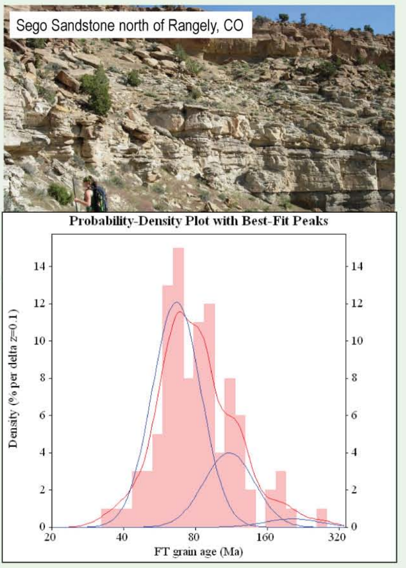


Figure 8 Two types of samples were taken, cobble clasts and detrital samples. In both cases apatites are extracted from the sample. Because cobble clasts are a cohesive piece of strata, they can be treated as a basement sample, analyzing 20 apatites per sample and fitting them with a probability density curve. To be considered as a single age population, X^2 must be greater than 5%. Because detrital samples are sourced from a large catchment, 100 grains need to be analyzed and a binomial fit must be done to identify different age populations; the youngest is assumed to be a source exhumation signal.



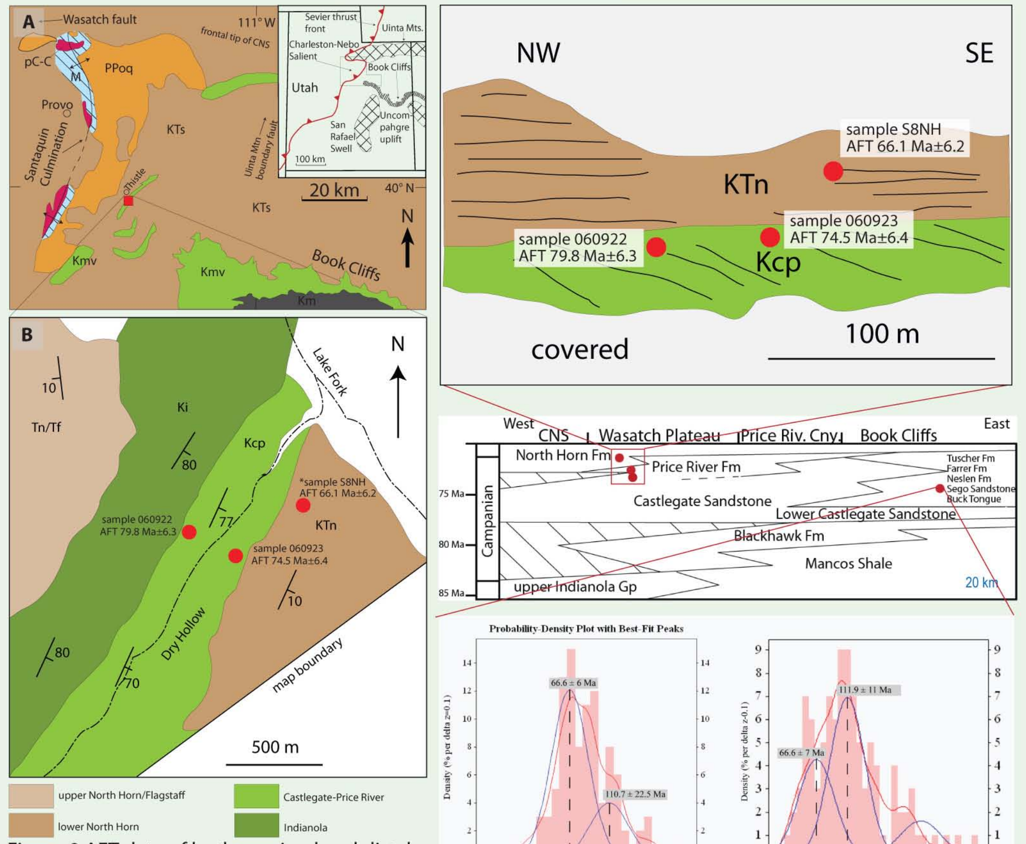
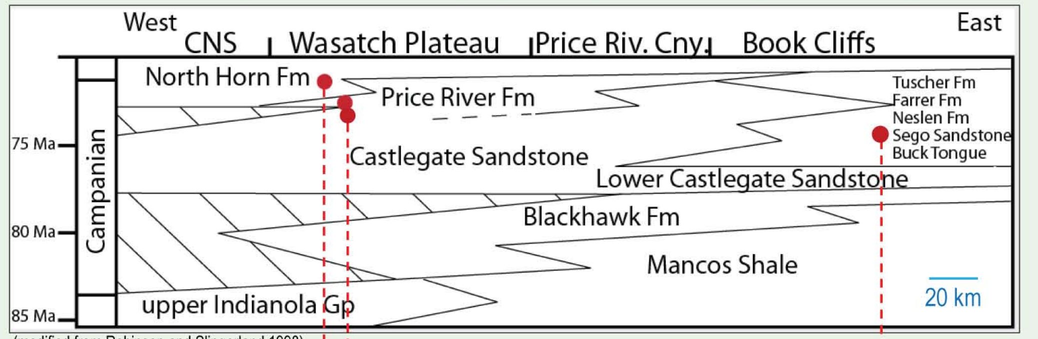


Figure 9 AFT data of both proximal and distal samples (maps and cross sections from Horton et al. 2004)

Thermochronologic Data (cooling ages) depositional ages and 0 lag times-



(modified from Robinson and Slingerland 1998)

Maastrichtian – Paleocene (70 Ma – 58 Ma)
Palynology
(Horton et al., 2004)

AFT = 66.1 Ma ± 6.2

Campanian (76-70 Ma)
(Horton et al., 2004)

AFT = 74.5 Ma ± 6.4
AFT = 79.8 Ma ± 6.3

Campanian
DZ data = 76.6 Ma ± 1.5
(maximum depositional age)
(York, 2010)

Biostrat (*Baculites scotti*) = 75.8 Ma ± .3
(Molenaar and Wilson, 1993; Cole et al., 1997; Cobban et al., 2006)

Detrital AFT (youngest population) = 66.6 Ma ± 6
Detrital AFT (youngest population) = 66.6 Ma ± 7

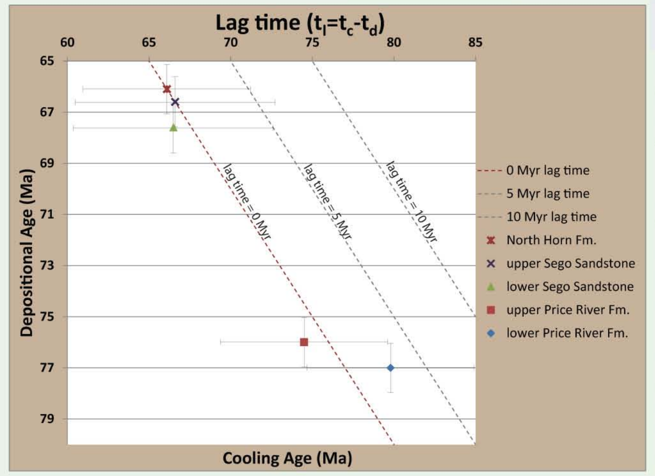


Figure 10 Above is a synthesis of all of the thermochronologic data and geochronologic data. In all cases, except for the detrital samples of the Sego Sandstone, cooling ages are within error of the depositional age, making the lag time ~0 Myr. The young cooling age of the Sego Sandstone could be problematic. Maximum burial only reached ~1.5 km, so partial resetting is unlikely. It could be that the Sego Sandstone near Rangely, CO is actually younger than the better constrained Sego Sandstone in the Book Cliffs area. Left - A lag time plot of all of the samples that are shown above. Lag time is ~0 Myr.

Conclusions:

Apatite fission track thermochronology of synorogenic conglomerates is an effective thermochronometer within the Charleston-Nebo and its foredeep counterparts to track source exhumation.

Paleozoic source strata within the Sevier fold-thrust belt reached temperatures above 80-100 °C and were exhumed from ~4-5 km depth within the Sevier fold and thrust (assuming ~20°C/km).

Lag-times of both the Price River Cgl. And the North Horn Fm. and Sego Sandstone is approximately 0 Myr, indicating rapid exhumation and transport (i.e., sediment is not stored for long periods of time in the proximal foredeep). This appears to be consistent with a syntectonic setting.

Short lag-times (i.e., rapid exhumation of source material) support growth in the hinterland through back thrusting and duplex growth – all indicating that the orogenic wedge was subcritical during the Campanian to Maastrichtian.

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