Fault dating in the Canadian Rocky Mountains: Evidence for late Cretaceous and early Eocene orogenic pulses: REPLY

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In van der Pluijm et al. (2006), we derived $^{40}Ar/^{39}Ar$ dates from fault gouge in the Canadian Rockies based on the Illite Age Analysis (IAA) method of Pevear (1999). Price's Comment (2007) discusses both our methods and conclusions. We address his comments in order; each numbered paragraph begins with a brief restatement of Price's comment. Additional details examining the Wyoming fold-thrust belt are presented in Solum and van der Pluijm (2008), to be published in a GSA Memoir honoring Professor Price's distinguished career.

1. Price seeks evidence that dated illite in the gouge formed during, rather than subsequent to, faulting. Vrolijk and van der Pluijm (1999), van der Pluijm et al. (2001), and Yan et al. (2001) discuss gouge fabric petrography and sampling strategy. Only clay (phyllosilicate) gouge was collected; samples lacking pervasive scaly clay fabric were rejected. For all localities, undeformed mudstone country rock was also dated, using our methods; some localities were multi-sampled progressively away from the gouge zone. Subsequent burial diagenesis of the Lewis thrust gouge seems unlikely, because: (1) reactions during faulting exhaust most or all of the reactants (Yan et al., 2001), forming stable illite with an Ar diffusion blocking temperature of 250–300 °C; (2) there is a pronounced difference in mineralogy and age between gouge (more illite, younger) and nearby country rock (protolith); and, (3) uplift and erosion immediately followed final thrusting (see below).

2. For two samples, the age of the detrital component of gouge is younger than the age of deposition of the protolith, which may invalidate the IAA method. Unlike undeformed shales, mica in the detrital component of gouge sometimes has been partially or even fully reset (lost Ar, or gained K) by mechanisms that can include accelerated dissolution-precipitation (Vrolijk and van der Pluijm, 1999; Pevear, 1999), heating, and mechanical deformation. The detrital component in adjacent undeformed country rock gives ages older than deposition.

3. A northern segment of the Lewis thrust gives an older (72 Ma) age than the Gould Dome locality (52 Ma), but cannot be structurally out of sequence, as we say it is. Price makes a case based on his experiences, but we stand by our date.

4. Stratigraphy in the S. Alberta foreland basin is linked to deformational episodes, and does not record a lull in thrusting between our two age groups at around 72 and 52 Ma. But, Catuneanu and Sweet (1999) describe reciprocal sequence stratigraphy with two tectonically driven cycle pairs (pulse and quiescence deposits) between early Maastrichtian (72 Ma) and middle Paleocene (61 Ma). The timing of their first pulse agrees with our older gouge age group; their second pulse at ~68 Ma also agrees with one of our dates. Our other gouge age group (52 Ma, early Eocene) apparently has no surviving syntectonic deposits in the foreland basin due to post-tectonic uplift and erosion (Sears, 2001).

5. Isotope ages (59 Ma) from dikes that cut the Lewis thrust show that movement had ceased by this time, and that our 51.5 ± 2.2 Ma gouge age cannot be correct. The original reference (Menhert and Schmidt, 1971, p. A37) describes a single biotite K/Ar age of 58.3 Ma (no uncertainty given) from a "quartz monzonite porphyry sill" that "intruded into the [Eldorado] thrust zone." Without seeing it, a sill is not a clear cross-cutting relationship, and if the K/Ar uncertainty were several Ma, then the sill age may overlap with our gouge Ar-age. It is hard to accept this one age as an unassailable constraint on termination of thrusting.

6. An abrupt transition to an extensional regime following thrusting has been dated in several ways, with results seen by Price as inconsistent with our ~52 Ma thrust gouge age. Mulch et al. (2007) summarize the "regime change" data, which are not necessarily at odds with our thrust age. For example, U-Pb zircon dates, presumed from decompression melting in hinterland core complexes, and possibly the earliest indicator of an extensional regime, range from 57 to 52 Ma. Muscovite $^{40}Ar/^{39}Ar$ cooling ages from initial uplift of the core complexes are 50–45 Ma. Our data show either thrusting in the foreland that was contemporaneous with extension in the hinterland (DeCelles, 2004), or that our "young" date for Lewis thrusting is yet another measurement demonstrating the short duration of the transition from compression to extension.

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