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1. Introduction

[1] *Beck and Housen* [2004] agree that the paleomagnetic directions observed by *Butler et al.* [2002] from the Ecstall pluton require folding of the pluton, but they disagree with the geometry that we proposed for this fold. *Beck and Housen* [2004] then proceed to show that the paleomagnetic directions, corrected for their choice of fold geometry, are "fully compatible with an origin far to the south." We first address issues concerning the fold geometry and then address the alternative tectonic and paleogeographic interpretation advanced by *Beck and Housen* [2004].

2. Fold Geometry

[2] There are several specific points of disagreement between our interpretation of the fold geometry for the Ecstall pluton and that of *Beck and Housen* [2004]:

[3] 1. In numerous passages in their comment discussing our publication on the Ecstall pluton, *Beck and Housen* [2004] discuss paleomagnetic directions from "sites near its eastern margin". In fact, we did not use paleomagnetic directions from near the eastern margin of the Ecstall pluton and specifically explained in our publication the reasons for rejecting results from that margin. Our measurements of anisotropy of magnetic susceptibility (AMS) indicated that this portion of the pluton has a strong anisotropy that could deflect directions of remanent magnetism. This anisotropy is likely related to deformation associated with the Coast shear zone that lies near the eastern margin of the Ecstall pluton. Other parts of the Ecstall pluton have minor anisotropy with scattered orientations of AMS principle axes indicating that the paleomagnetic directions are unaffected by anisotropy.

[4] 2. *Beck and Housen* [2004] claim that we concluded that "the eastern sites with steep inclination are undisturbed (presumably because their steep inclinations approximate the Cretaceous expected direction), hence lie on or near the fold axis". Again, we did not use results from near the eastern margin and we most certainly did not choose the location of the fold axis because that portion of the pluton yields steep paleomagnetic inclinations. Instead, we used regional and local structural geologic observations to constrain the location of the axial surface to the central portion of the Ecstall pluton. From patterns of metamorphic grade, orientations of fabrics, and regional map patterns, *Crawford et al.* [1987] interpret the Prince Rupert shear zone as a Late Cretaceous west directed thrust with the Ecstall pluton in the upper plate. Numerous researchers have inferred a convex upward geometry for thrust faults within the Western Metamorphic Belt, including the Prince Rupert shear zone [e.g., *Crawford et al.*, 1987; *Chardon et al.*, 1999]. It is thus quite sensible to infer that the large deflections of paleomagnetic directions from the western margin of the Ecstall pluton could be explained by local deformation (folding) of the western margin during thrusting along the Prince Rupert shear zone. We inferred that the axial surface of a fault bend fold like geometry lies in the central portion of the pluton because this area is remote from the Prince Rupert shear zone to the west and the Coast shear zone to the east. We did not choose a central location for the fold axis based on paleomagnetic directions. In their alternative interpretation of the paleomagnetic directions from the Ecstall pluton, *Beck and Housen* [2004] choose a fold axis "where observed inclinations are approximately 50–60°" without regard to any geological observations local or regional.

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[5] 3. *Beck and Housen* [2004] claim that the fold geometry we proposed is inconsistent with our own barometric observations. They argue that a symmetric anticline with limb dimensions of 11 km would require structural relief between the axis and the extremities of the limbs that exceeds that permitted by the barometric data. We understood completely that the barometric constraints would not permit the broad (~11 km limb dimension) symmetric fold geometry that *Beck and Housen* [2004] claim we advanced. In fact the fold geometry we proposed and illustrated in our Figure 11 is a strongly asymmetric fault bend fold like geometry as one might expect to be associated with thrusting along the Prince Rupert shear zone. The large (~75°) tilt that we propose affected the western edge of the Ecstall pluton is limited to sites within 3.5 km from that margin that is adjacent to the Prince Rupert shear zone. With this limited dimension, the western edge of the pluton can tilt by a large angle without requiring a pressure difference that exceeds the observed barometric variations.

3. Discussion

[6] Can paleomagnetic directions in the Ecstall pluton, or any single intrusive igneous rock lacking direct paleohorizontal control, uniquely rule out large-scale translation or require a unique tectonic interpretation? We think not and we did not claim so. (Neither the word "unique" nor "uniquely" occur anywhere in our publication.) It is not the paleomagnetic results from the Ecstall pluton alone that motivate us to examine the importance of local deformations in explaining discordant paleomagnetic directions from Cretaceous rocks of the North American Cordillera. Instead we are interested in the geologic evolution of the North American continental margin and have studied specifically the tectonics of the margin in western British Columbia and southeastern Alaska [*Gehrels*, 2001; *Gehrels and Kapp*, 1998; *Gehrels et al.*, 1991; *Davidson et al.*, 2003]. Through these studies and those of other geologists and geophysicists working in the region, we have come to appreciate that Tertiary deformations are widespread, dominantly extensional, and often result in east-side-up tilting of crustal panels.

[7] A complete review of the tectonics of the continental margin in western British Columbia and southeastern Alaska is beyond the scope of this reply. However, the importance of Tertiary tectonics along this segment of the margin can be appreciated by noting a few recent findings from a number of disciplines:

[8] 1. Within the Queen Charlotte basin, several kilometers of marine strata are preserved within Miocene and Pliocene extensional troughs. Seismic reflection data indicate that strata in the eastern portion of the Queen Charlotte basin generally dip 15°–20° southwestward [*Rohr and Dietrich*, 1992].

[9] 2. A late Oligocene-Miocene igneous complex south and west of Wrangell, Alaska contains mafic dikes that yield a discordant paleomagnetic direction (I = 70.4°; D = 39.3°; α_{95} = 4.8°; N = 72 sites). Combined with local and regional geobarometric, metamorphic, and structural observations, the discordant paleomagnetic direction indicates east-side-up tilt by 16° about a tilt axis with azimuth = 8° [*Butzer et al.*, 2004].

[10] 3. Northeast from the Ecstall pluton in the Portland Canal area, paleomagnetic data indicate that rocks within the core of the Coast Mountains were tilted as much as ~40° northeast-side-up during Eocene time [*Butler et al.*, 2001a]. This tilting occurred during regional extension, with east-side-down motion along the Coast shear zone and faults along the eastern margin of the Coast Mountains [*Andronicos et al.*, 2003; *Crawford et al.*, 1999; *Klepeis et al.*, 1998].

[11] These observations indicate that paleomagnetic observations from the Insular and Intermontane terranes may be explained with much less northward transport than suggested by the Baja British Columbia hypothesis. We contend that the vast majority of paleomagnetic observations can be understood by Tertiary extensional or transtensional deformation of Mesozoic rocks along the continental margin with post-mid-Cretaceous northward motion limited to ~1000 km [*Butler et al.*, 2001b]. We note that this amount of northward transport avoids the most confounding paleogeographic implication of the Baja British Columbia hypothesis, the operation of two parallel accretionary wedge-forearc-magmatic arc systems along the same segment of the continental margin during late Mesozoic time [*Dickinson*, 2004].

[12] We now examine the alternative interpretation of the paleomagnetic data from the Ecstall pluton offered by *Beck and Housen* [2004]. They appeal to "a general orogen-wide pattern as evidence that portions of the western edge of the North American Cordillera had been transported relatively northward with respect to the interior of the continent, through distances exceeding several thousand kilometers during latest Cretaceous and early Tertiary time." Is there consistency of paleolatitudes and latitudinal motion histories for Cretaceous rocks along the western edge of the North American Cordillera? Let us recount one of the latest versions of the Baja British Columbia hypothesis as advanced by *Enkin et al.* [2003] to account for paleomagnetic results from the southern Canadian Cordillera. Key interpretations include the following: (1) The Insular and Intermontane superterranes are linked by ~95 Ma. (2) Late Early Cretaceous volcanic rocks of the Spences Bridge Group in the Intermontane Superterrane yield paleomagnetic data indicating a paleoposition ~1000 km to the south at 100 Ma. (3) Overlying strata of the Methow-Tyaughton basin yield paleomagnetic data interpreted to indicate that the combined Insular and Intermontane superterranes were ~3000 km south by ~95 Ma. The interpreted motion history thus requires: (1) a paleolocation ~1000 km south of present location at ~100 Ma; (2) ~2000 km southward motion between 100 and 95 Ma at a rate in the range of 20 to 40 cm/yr; and (3) ~3000 km northward translation between 85 and 50 Ma at rate of ~10 cm/yr.

[13] The scenario that *Beck and Housen* [2004] propose to account for the paleomagnetism of the Ecstall pluton adds two more steps to the above motion history: (1) an admittedly totally arbitrary 33.5° clockwise vertical axis rotation to "arrive at a starting in situ direction of D = 55°, I = 53.8°" and (2) symmetrical anticlinal folding of each limb of the Ecstall pluton by ~45° about a fold axis with trend of 353.1° and plunge of 20.5°. We documented above the geological observations that we used to arrive at our proposed fold geometry. *Beck and Housen* [2004] chose

the location of their proposed fold axis based on paleomagnetic directions without regard to geological observations.

[14] In our view, the claimed internal consistency of paleomagnetic directions and paleolatitudes that formed the original basis for the Baja British Columbia hypothesis has given way to internal conflict. The implied traffic pattern of terranes along the North American continental margin grows ever more complex as more data are acquired. The inferred rates of latitudinal motions sometimes exceed those of plausible lithospheric plate motions. Adding to these difficulties is the recent determination of southward latitudinal drift of the Hawaiian hot spot [*Tarduno et al.*, 2003]. The implication of the latter finding is that the rapid northward motion of the Kula plate, often used as the agent of northward transport for Baja British Columbia, probably never happened.

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