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Oligocene-Neogene lithospheric-scale reactivation of Mesozoic terrane accretionary structures in the Alaska Range suture zone, southern Alaska, USA: Reply

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INTRODUCTION

Topics of discussion raised by Lowey (2021) include the correlation of ultramafic-intermediate intrusions hosted within the Clearwater metasediments/Dezadeash Formation and their displacement by the Denali fault. These topics were not main points of Waldien et al. (2021), but instead logical extrapolations of the information presented and synthesized therein. Here we re-emphasize the key findings of Waldien et al. (2021) and discuss only the relevant aspects of the ultramafic-intermediate intrusions and their displacement.

KEY POINTS OF WALDIEN ET AL. (2021)

In our original contribution, we used geologic mapping, zircon U-Pb geochronology, $^{40}Ar/^{39}Ar$ thermochronology, geochemistry of spinel group minerals, and receiver function seismology to fingerprint metamorphic rocks and establish the relative importance of various structures within the metamorphic belt. Our main conclusions are:

(1) As has been established in other regions of the Alaska Range suture zone (e.g., Hampton et al., 2010; Box et al., 2019), suture zone metasedimentary rocks in the Alaska Range can be parsed into two belts with independent geologic evolutions prior to final accretion of the Wrangellia composite terrane. The protolith of the northern belt (Maclaren schist/gneiss) was likely sourced from the North American continental margin at ca. 90 Ma. The protolith of the southern belt (Clearwater metasediments) was likely sourced from Jurassic arcs built upon the Wrangellia composite terrane at ca. 150 Ma.

(2) The contrasting protolith compositions, protolith ages, and structural features of the two metasedimentary belts illuminate the structure between them as a major tectonic boundary. In the Clearwater Mountains, the structure is a ca. 75 Ma thrust shear zone called the Valdez Creek shear zone, which is interpreted as the master collisional structure during final accretion of the Wrangellia composite terrane (Davidson et al., 1992; Ridgway et al., 2002). Given the disparate protolith and tectonic histories established for metasedimentary rocks across the Valdez Creek shear zone, we interpret that the shear zone occupies a former convergent plate boundary that existed between the Wrangellia composite terrane and North America. To the east in the Alaska Range (our study area), the boundary between the Maclaren schist and Clearwater metasediments is a discrete zone of cataclastic deformation, which we interpret as a reactivation of the Valdez Creek shear zone. We named the reactivated structure the Valdez Creek fault.

(3) To the west of the reactivated region, a moderately north-dipping seismic interface is present in P-wave receiver function seismology. The interface penetrates the crust and links the surface trace of the inherited Valdez Creek shear zone to the active Denali fault shear zone in the lithospheric mantle. We thus interpret the interface as evidence that the Valdez Creek shear zone penetrates the crust. We further argue that the tectonic history of the Valdez Creek shear zone as a major collisional structure and likely as a former convergent plate boundary primed it for reactivation when southern Alaska began experiencing flat slab subduction of the Yakutat microplate in the Oligocene. Reactivation of the Valdez Creek shear zone after ca. 32 Ma nucleated an imbricate thrust system that progressed southward into the Wrangellia terrane, which facilitated erosional exhumation of the suture zone metasedimentary belts and uplift of the eastern Alaska Range south of the Denali fault.

ALASKA-TYPE ULTRAMAFIC ROCKS

Lowey (2021) emphasizes the original literature describing ultramafic-intermediate intrusions in southwestern Yukon. However, the more detailed descriptions contained within those references do not alter our interpretation of the geology, in fact, they strengthen our arguments regarding the potential correlation of ultramafic-intermediate intrusive rocks in southwestern Yukon and the eastern Alaska Range. Dodds and Campbell (1988) synthesized data leading to the classification of the Pyroxenite Creek intrusion as a part of the Alaska-type zone ultramafic suite that is present throughout southeastern Alaska and adjacent regions of Yukon. The geochemical data from spinel group minerals presented in figure 13 of Waldien et al. (2021) clearly show that the zoned hornblende-biotite-pyroxenite body in Ann Creek and other samples of mid-Cretaceous ultramafic rock within the Clearwater metasediments classify as Alaska-type ultramafic intrusions. Stout (1965) and Stout (1976) presented detailed petrographic descriptions of the hornblende-biotite-pyroxenite body in Ann Creek, and Bittenbender et al. (2007) described and dated similar ca. 120 Ma intrusions in the region surrounding Ann Creek; we refer the deeply invested reader to those publications.

Taken together, the above summary shows that both the Pyroxenite Creek ultramafic body (Yukon) and hornblende-biotite-pyroxenite in Ann Creek (Alaska) are classified as Alaska-type ultramafic bodies. The correlation between the two might be strengthened, or refuted, by new data such as a U-Pb zircon age for the Pyroxenite Creek body and/or associated intermediate

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intrusions. The possibility of correlation should not be dismissed solely on the basis of previous displacement estimates for the Denali fault.

DENALI FAULT DISPLACEMENT

We have two companion publications in revision that present a Cenozoic restoration of displacement on the eastern Denali fault system, thus that topic was not a focus of Waldien et al. (2021). We encourage the invested reader to access those publications when they come online later in summer of 2021. A key aspect of recent research on the Denali fault system (Waldien et al., 2018; Berkelhammer et al., 2019; Brueseke et al., 2019) and our forthcoming publications, which Lowey (1998) also acknowledges as important, is the amount of Cenozoic strike-slip displacement on the Totschunda fault as part of the Denali fault system. Confusion perhaps has arisen, by the misassignment of this repeatedly reactivated Cretaceous structure (Trop et al., 2020) as only a Quaternary structure (e.g., Richter and Matson, 1971).

In the context of the present discussion, we would like to highlight that the western margin of the Pyroxenite Creek Alaska-type ultramafic body is mapped as cut by the Denali fault in southwestern Yukon (Eisbacher, 1976; Colpron et al., 2016). Thus, simple logic implies that an Alaska-type ultramafic body hosted within Dezadeash-equivalent rocks ought to be present near, or cut by, the Denali fault in Alaska. Waldien et al. (2021) presented new data showing that the Clearwater metasediments likely correlate with the Dezadeash Formation and that ultramafic rocks within the metasediments display geochemical characteristics consistent with those of Alaska-type ultramafic suites. These data and lines of logic led us to *propose* that: "The proximity of the hornblende-biotite-pyroxenite in the Ann Creek map area to the Denali fault suggests that it **may** be an offset portion of the Pyroxenite Creek ultramafic body, which intrudes the Dezadeash formation and is cut by the Denali fault in southwestern Yukon Territory" (direct quote from Waldien et al., 2021, p. 706; boldface added). An alternative interpretation, inferred from Lowey (2021), could be that the hypothetical offset portion of the Pyroxenite Creek body may be concealed beneath the Chisana Formation between the Denali and Totschunda faults in eastern Alaska.

CONCLUSION

Establishing a new piercing point across the Denali fault was not a main goal of Waldien et al. (2021), nor was a detailed study of the Ann Creek ultramafic body relevant for the focus of that publication. However, because the mafic and ultramafic rocks clearly intrude the Clearwater metasediments, which results in an unusual combination of rock units, we thought it important to highlight the potential for the Ann Creek and Pyroxenite Creek locales to be correlative, if not an exact match. Progress in science is based on integrating new data with existing data to develop new ideas. We think that a regionally integrative view is especially necessary in regions such as the North American Cordillera where strike-slip faulting has displaced correlative rock packages great distances across international borders. Such was our goal in suggesting that the ultramafic bodies discussed by Lowey (2021) and herein may correlate across the Denali fault. The fact that our suggested (not proven) correlation provoked a formal comment highlights the need for future study of Alaska-type ultramafic suites using modern geochronologic, geochemical, and petrologic techniques in the context of regional tectonics.

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