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Co-axial superposed folding and inverted regional metamorphism in the Tonga Formation: Cretaceous accretionary thrust tectonics in the Cascades crystalline core

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The Cascades crystalline core forms part of the Cretaceous magmatic belt of western North America and exposes a crustal section composed of primarily tonalitic plutons that intruded siliciclastic metasediments of an arc-derived accretional system, and local meta-basalt/chert sequences. This study is the first attempt to correlate the well understood intrusive and P-T-t history of the metasedimentary and plutonic terrane with the kinematics and tectonic boundary conditions by rigorous analysis of structures documented in the Tonga Formation exposed at the western edge of the core. The Tonga Formation comprises pelite-psammite metasediments, which increase from greenschist (∼300-350° C) to amphibolite grade (∼500-600° C) from south to north. This metamorphic gradient is inverted relative to a major westward verging and downward facing fold system that dominates the internal architecture of the formation and implies that the initial regional metamorphic signature was established prior to the early fold generation. Subsequent co-axial fold superposition is seen as a consequence of the persistent accretional west-vergent thrusting in the foreland of the magmatic arc.

The central section of the Cascades Range, exposed in western Washington, forms part of the Cretaceous accretional/magmatic arc extending over 4,000 km along western North America from Baja California to British Columbia (Fig. 1a) (e.g. Misch, 1966; Brown, 1987; Tabor et al., 1989). Two models exist for the evolution of the Cascades crystalline core with one invoking magmatic loading (e.g. Brown and Walker, 1993) as the major cause for rapid loading, consequent regional metamorphism and vertical uplift (Evans and Berti, 1986). Conversely, other workers favor a model that suggests loading as a consequence of tectonic, thrust-related thickening, followed by rapid exhumation of the exposed crustal section of 10 to 40 km paleodepth (e.g. Matzel, 2004; Patterson et al., 2004; Stowell et al., 2007). In this context, the Tonga Formation, on the westernmost boundary of the Cascades crystalline core, records Cretaceous plutonism, contact to regional metamorphism, and multiple episodes of folding, evidencing intense, arc-perpendicular contractional deformation, similar to that observed in the neighboring Chiwaukum Schist to the east (Miller and Paterson, 1992; Miller et al., 1993; Paterson and Miller, 1998; Miller et al., 2006). Building on previous extensive mapping and metamorphic and petrologic analysis in the Cascades, we use the Tonga Formation as a means to a comprehensive tectonic synthesis incorporating detailed analysis of the kinematics and timing of structural evolution, magma emplacement, and metamorphism.