GeoPRISMS White Paper - Theme 4.6 (Subduction Inception)
The SW North American Cordillera: an exposed, accessible and underutilized archive of Paleozoic to Cenozoic subduction-initiation processes

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A major question asked by the GeoPRISMS Science Plan concerns the conditions that control subduction zone initiation and subsequent arc maturation. One approach is to study modern examples of this process (e.g., Mussau, Puysegur), which, given their largely submarine setting, would rely largely on geophysical data, and core, submersible, and dredge samples. Some older intraoceanic examples (e.g., Izu-Bonin-Mariana) are also limited to these sorts of data sets. Alternatively, the Pacific margin of North America offers the opportunity for broader field-based studies of the *in situ* products of subduction inception along a continental margin, as well as potential intraoceanic examples in accreted terranes.

The SW North America Cordillera contains a rich history of subduction initiation events as recorded in its ophiolite belts, and patterns of arc magmatism, regional deformation and basin subsidence. At least five distinct events are readily recognized spanning early Paleozoic to mid-Cenozoic time (Fig.1), and additional less obvious events can be argued for. There is much to be learned about this fundamental plate tectonic process from integrative studies of structure-stratigraphy, petrology-geochemistry and geodynamic modeling applied to each of the five principal events. These events are diverse in nature, some having close analogues in active plate tectonic settings potentially offering an approach of comparative and iterative studies between exhumed crustal sections and active patterns of deformation, magmatism and plate kinematics. The essential features of these five events are summarized below primarily from the perspective of ophiolite petrogenesis and tectonic history. Even though there is an abundance of geological data in the literature for each event, little research has been conducted that specifically targets key features and relations focused on the process of subduction initiation. We bring the key features of each case into focus here with aims of stimulating and drawing together multi-disciplinary researchers in the fields of structure-stratigraphy, petrology-geochemistry and geodynamics in order to move our understanding of subduction initiation (SI) to a substantially deeper level.

1. Early Silurian SI is well recorded in the polygenetic Trinity ophiolite consisting of Early Ordovician MORB mantle lithosphere and nonconformably overlying supra-subduction ophiolitic crustal rocks (cf. Metcalf et al., 2000). SI in this case was within an intra-oceanic environment located off the distal flank of the Cordilleran passive margin continental rise with subsequent arc activity in later Silurian through Devonian time constructing a regional fringing arc system (McCloud-Stikine system) that runs most of the length of the central to northern Cordillera. The scale and internal complexity of this accreted arc terrane are comparable to the Philippine arc. The Trinity ophiolite segment of the McCloud-Stikine arc is perhaps the only area where this event can be studied in detail because of the subsequent accretion of a second outboard arc system (Insular arc), which has severely overprinted most of the McCloud-Stikine arc.

2. Late Permian SI is well recorded along the Sierra Nevada western Foothills ophiolite belt and its oblique truncation locus across the southwestern terminus of the Cordilleran passive margin and its fringing McCloud-Stikine arc (cf. Saleeby, 2011). The ophiolite belt records large offset transform tectonics, and related oceanic core complex development in Ordovician through Pennsylvanian MORB lithosphere. The oceanic transform circuited directly into a complex boundary transform system that truncated the passive margin and its fringing arc. The MORB ophiolite belt was accreted to the hanging wall of a Late Permian neo-subduction zone. Regional extensional tectonism and strike-slip slivering along the truncated passive margin, its marginal basin and the fringing arc are in accord with the timing and kinematics of oceanic and boundary transform displacements, and the superposing of thrust belt deformation across the same region is in accord with the kinematics and timing of SI. Regionally extensive upper plate thrusting indicates a substantial forced phase of SI, which in early Mesozoic time rapidly changed to self sustaining with the widespread eruption of typical proto-forearc volcanic associations. The early stages of the Foothills ophiolite belt SI event has a number of similarities to the Macquarie-Puysegur trench/Alpine fault system, which to our knowledge has yet to render proto-forearc volcanic associations that would signal transition to self sustaining subduction.

3. Middle Jurassic SI is well recorded in the Coast Range ophiolite (CRO) of California and related terranes in Oregon and Washington. The CRO preserves a complete SSZ ophiolite assemblage, with early fore-arc basalts and related gabbros, boninites, arc tholeiites, and calc-alkaline arc assemblages, overlain or intruded in places by younger MORB-like volcanics and hypabyssal dikes (e.g., Shervais et al 2004). It is intimately associated with both an overlying forearc basin assemblage (the Great Valley Group) and an underlying subduction accretion complex (the Franciscan complex) (Hopson et al 2008). Choi et al (2008b) document evidence for formation of the CRO by subduction initiation along an oceanic fracture zone, a model that is supported by detailed studies of mantle tectonite petrology (Choi et al 2008a; Jean et al 2010). Nonetheless, remnants of the CRO vary greatly in stratigraphy and lithology depending on location, which implies a complex origin and evolution that likely varies along strike.

4. Late Jurassic SI is recorded for the Josephine ophiolite, which formed by Middle Jurassic inter-arc basin rifting over a period of ~5 m.y. at the end of the Middle Jurassic (cf. Harper et al., 1994). The Josephine ophiolite consists of an intact supra-subduction mafic crustal section that was rendered from the underlying Josephine peridotite. The ophiolite formed at a spreading center that split apart an Early to Middle Jurassic island arc complex, much like the Mariana Trough has rifted the West Mariana Ridge. In parallel to the Mariana system the inner ribbon of the rifted Jurassic arc became volcanically inactive as rifting progressed, and subsided to become a remnant arc while the outer ribbon became the basement for a neo-volcanic arc that fringed the Josephine inter-arc basin. Basement correlations and sediment provenance data clearly relate the remnant arc to the neo-arc basement ribbon. After ~5 m.y. of inter-arc basin spreading, subduction initiated beneath the remnant arc with a minimum of ~100 km of rapid underthrusting of the Josephine interarc basin floor. Such structural overlap is clearly seen in seismic reflection data and in superposed structural windows through the upper plate remnant arc. Following ~5 m.y. of rapid subduction the inter-arc basin ophiolite was obducted over the rear edge of the neo-arc as the neo-arc impinged on the remnant arc bounding subduction zone. The reason for the collapse of this system and the forcing of this SI event is poorly understood, but is thought in some way to be related to both the oblique impingement of the Insular arc terrane, and rapid changes in plate motions at the end of Jurassic time that are well recorded in the North America APW path. The style of subduction initiation and interarc basin closure that is so clearly recorded in this system is commonly depicted in conceptual plate tectonic cartoons, even though an active modern analogue is apparently missing on Earth at this point in geologic time.

5. Late Eocene SI is recorded for an ~600 km long segment of the Cordilleran active margin along what was to become the Washington-Oregon Coast Ranges known as Siletzia (cf. Wells et al., 1984). This event is marked by the impingement of an oceanic large igneous province into the pre-existing subduction zone that had extended along coastal California through coastal British Columbia from at least as far back in time as the mid-Cretaceous. A large fragment of the LIP was accreted to the subduction zone, and then subduction stepped westwards leaving a lithosphere-scale nappe wedged between the paleo- and neo-subduction zones. The postulated origins for the accreted LIP include a plume head centered on the, then, newly established Kula-Farallon ridge, a leaky fracture zone in the Farallon plate, or the proto-Yellowstone hotspot. There are no active environments exhibiting this form of SI on Earth today.

In sum, we suggest that the SW North American Cordillera should be considered as an auxiliary site because, as per the GeoPRISMS implementation structure, 1) it represents end members of critical parameters (continental and intraoceanic SI); 2) it supplies critical components for global comparison; 3) it exhibits phenomena likely to be obscured at primary sites (provides broader access to products through large outcrop areas that also exhume different stratigraphic/crustal levels); and 4) it documents different stages of margin evolution as well as periodicity of processes.

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FIGURE 1. Tectonic map of North America with trends of subduction events discussed in the text. Modified from Muehlberger (1992).