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Arc/Forearc Lengthening at Plate Triple Junctions and the Formation of Ophiolitic Soles

John Casey and John Dewey

University of Houston, University of Houston, Department of Earth and Atmospheric Sciences, Houston, United States (jfcasey@uh.edu, 713748796)

The principal enigma of large obducted ophiolite slabs is that they clearly must have been generated by some form of organized sea-floor spreading/plate-accretion, such as may be envisioned for the oceanic ridges, yet the volcanics commonly have arc affinity (Miyashiro) with boninites (high-temperature/low-pressure, high Mg and Si andesites), which are suggestive of a forearc origin. PT conditions under which boninites and metamorphic soles form and observations of modern forearc systems lead us to the conclusion that ophiolite formation is associated with overidding plate spreading centers that intersect the trench to form ridge-trench-trench of ridge-trench-tranform triple junctions. The spreading centers extend and lengthen the forearc parallel to the trench and by definition are in supra-subduction zone (SSZ) settings. Many ophiolites likewise have complexly-deformed associated mafic-ultramafic assemblages that suggest fracture zone/transform t along their frontal edges, which in turn has led to models involving the nucleation of subduction zones on fracture zones or transpressional transforms. Hitherto, arc-related sea-floor-spreading has been considered to be either pre-arc (fore-arc boninites) or post-arc (classic Karig-style back arc basins that trench-parallell split arcs). Syn-arc boninites and forearc oceanic spreading centers that involve a stable ridge/trench/trench triple or a ridge-trench-transform triple junction, the ridge being between the two upper plates, are consistent with large slab ophiolite formation in a readied obduction settting. The direction of subduction must be oblique with a different sense in the two subduction zones and the oblique subduction cannot be partitioned into trench orthogonal and parallel strike-slip components. As the ridge spreads, new oceanic lithosphere is created within the forearc, the arc and fore-arc lengthen significantly, and a syn-arc ophiolite forearc complex is generated by this mechanism. The ophiolite ages along arc-strike; a distinctive diachronous MORB-like to boninitic to arc volcanic stratigraphy develops vertically in the forearc and eruption centers progressively migrate from the forearc back to the main arc massif with time. Dikes in the ophiolite are highly oblique to the trench (as are back-arc magnetic anomalies. Boninites and high-mg andesites are generated in the fore-arc under the aqueous, low pressure/high temperature, regime at the ridge above the instantaneously developed subducting and dehydrating slab. Subducted slab refrigeration of the hanging wall ensues and accretion of MORB metabasites to the hanging wall of the subduction channel initiates. Mafic protolith garnet/two pyroxene granulites to greenschists accrete and form the inverted P and T metamorphic sole prior to obduction. Sole accretion of lithosphere begins at about 1000°C and the full retrogressive sole may be fully formed within ten to fifteen million years of accretion, at which time low grade subduction melanges accrete. Obduction of the SSZ forearc ophiolite with its subjacent metamorphic sole occurs whenever the oceanic arc attempts subduction of a stable buoyant continental or back arc margin.