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Geologic constraints on the setting and dynamics of subduction initiation

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Understanding where and how subduction zones have and can initiate is important because, besides being a critical step in the plate tectonic system, it can provide insight into the complex interactions of crust and mantle rheology, forces acting on the plates, strain, metamorphic reactions, and erosional and depositional processes at the surface. Insight into the possibilities of where and how subduction zones start has been provided by numerical and analog modeling. All sites for subduction initiation are potential weak zones in the lithosphere and include the continent-ocean boundary, oceanic arc-oceanic crust boundary, oceanic transform faults and fracture zones, oceanic detachment faults, and active or recently extinct oceanic ridges/spreading centers. Within the constraints of modeling, it has also been shown that the forces involved in the initiation of subduction can be largely horizontal (induced by a collision, say, or through 'ridge push') or vertical (driven by density contrasts). The latter scenario is often referred to as "spontaneous" subduction initiation, whereas the former situation may be called "forced"or "induced" subduction initiation. It is prudent, however, not to assume that "what can happen, did happen." So, the challenge for geologists is to infer from the rock record, through structural mapping, thermochronology, thermobarometry, geochemistry, paleomagnetics, and sedimentological studies, how any given subduction zone began. Even with a complete data set, it is not always possible to fully constrain the specific geologic setting or dynamics involved in the initiation of a given subduction zone. One can, however, often rule out certain scenarios, increasing the probability of others. Part of the geologic record of subduction initiation preserved at some subduction zones are so-called "metamorphic soles," which include high-temperature (T) and high-pressure (P) metamorphosed oceanic crust that was underthrust to asthenospheric mantle depths, metamorphosed, and then preserved in the hanging wall of the eventual subduction zone. These metamorphic soles may preserve important information bearing on the timing of subduction initiation, the evolving P and T conditions during subduction initiation, and, importantly, the protolith age of the initially subducted crust. The latter parameter—the age of the initially subducted oceanic crust at the time of subduction initiation—is an important constraint that has been lacking in many previous geologic studies of subduction initiation. Recent work on metamorphic soles has provided new information on subduction initiation, including the possibility of rapidly converting oceanic divergent boundaries into subduction zones.