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Sailing the seven seas: from seafloor images into the seismogenic zone

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The recurrence of catastrophic earthquakes and tsunamis at convergent plate boundaries provides the lasting motivation to investigate the influence of subduction zone habitats on the hazardous behavior of continental margins. Subduction zones form by the underthrusting of a lithospheric plate underneath the overriding plate along the subduction thrust fault, where interplate earthquakes are generated. The enormous diversity of processes occurring along convergent margins implicates the notion that individual subduction zones or segments thereof differ in their structure and geometry to induce the observed diverse behavior.
Major portions of subduction zones are commonly submerged in deep water and difficult to access at the majority of margins. Marine geophysical techniques, which are able to image the complex structures in these settings with sufficient coherency and depth penetration, have proven crucial to improve our knowledge on the geological framework of the different types of subduction zones and on the control of the geometry of the subduction zone on seismic rupture and tsunami hazard. The examples presented here aim to unravel the structural diversity of convergent margins and between individual subduction zone segments. Field data from different margins around the globe have provided an important stepping-stone in resolving these issues, by delivering images of the seafloor and subsurface in unprecedented resolution, which show segmentation to be far more complex than previously inferred. The observed segmentation of structure across-strike correlates to mechanics that vary during an earthquake cycle. Furthermore, the recognition of splay faults and their potential role in tsunami excitation represents an important advance for hazard mitigation efforts. Along-strike segment boundaries commonly correlate with underthrusting lower plate relief, which controls the deep deformation of a subduction zone and the spatial and temporal variation in slip behavior. While the surface effects of subducting seamounts are documented in high-resolution bathymetry data, their influence on fault zone structure at depth remains elusive. Lower plate heterogeneities occur at subduction zones worldwide and thus pose a common phenomenon, whose role as asperities or barriers to seismic rupture constitute a central control on subduction zone seismicity and segmentation.