Deformation Structures in ODP Cores: Clues to What Happens in Converging Plates

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Structural geology examines how Earth's stresses operate, induce deformation, and form structures. Traditionally, deformation structures seen in sedimentary rocks were inferred to have formed well after lithification (the conversion of sediments to rock), at substantial depths in the Earth's crust. However, ODP coring of ocean sediments has revealed a wide variety of structures that are forming early in the burial history of sediments, especially as a result of the stresses associated with plate convergence (Maltman, 1994). These include deformation bands, small-scale faults, scaly fabric, and hydraulic breccia.

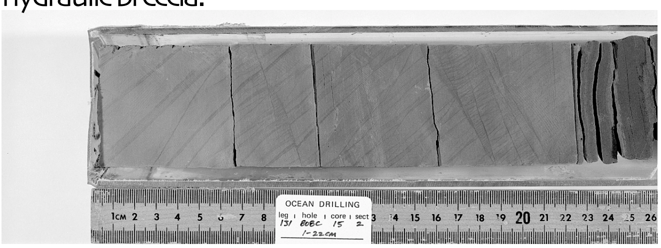
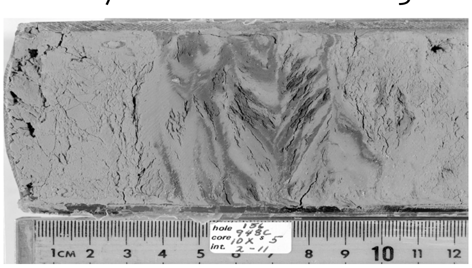
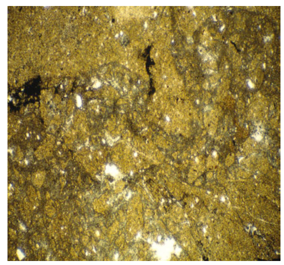


Figure 1 shows an example of deformation bands. The nature and orientation of these structures provide information on the magnitudes and directions of the deforming stresses, both during downslope mass movements and within accretionary prisms (tectonically deformed sediments at subduction zones), where they are demonstrably related to the tectonic stresses arising from plate convergence. Examples of these features are particularly well developed in the Nankai prism, offshore Japan, as demonstrated in cores recovered by Leg 190 from soft sediments as shallow as 200 meters below the sea-floor(Shipboard Scientific Party, 2001).

Small-scale faults are common in deep ocean sediments, arising from differential compaction and stresses associated with plate motion. As fluids can migrate preferentially along them, faults are important not only in understanding sediment dewatering but in any attempts to construct waste repositories in the deep ocean floor. In accretionary prisms they can evolve into zones of intense fracturing and brecciation, such as those that characterise the prism-scale faults at Nankai, and the plate-junction fault itself.

An illustration of scaly fabric – visible in drill-cores as an intricate array of net-like shiny surfaces – is shown in Figure 2. Scaly fabric is most common in sheared clays. Leg 156 cores from the clay-rich Barbados prism provided the opportunity for detailed analyses of this type of structure (Labaume et al., 1998), and these results are now helping earth scientists to understand scaly clays in such diverse settings as continental mountain belts, submarine mud volcanoes and the soles of glaciers (Vannucchi et al., in press). The scaly surfaces are commonly polished and lineated, giving an aspect often called a "slickenside". Not only can such features arise at shallow burial levels in incompletely lithified materials, but they also can be used for stress tensor analysis (Lallemant et al., 1993).





Hydraulic breccia (Figure 3) is thought to be an indicator of *in situ* fluid over pressuring, a crucial influence on prism architecture. Cores from Leg 146 revealed that it is well developed in the Cascadia prism offshore western North America Particularly curious structures are the bands of "sediment-filled veins", known from prisms found in environments as diverse as offshore Peru (Leg 112), the Izu-Bonin forearc in the sea-floor to the east of Japan (Leg 126), and in continental rocks. These structures may be indicators of past earthquake activity (Brothers et al., 1996).

These kinds of deformation structures seen in ODP drill-cores (see Maltman, 1998, for further detail), some of them previously unknown, throw light on plate convergence processes, including how sediments in accretionary prisms deform and lose their water, and they raise questions about past interpretations of deformed ancient rocks on the land.

References

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