Logging-while-drilling determines where and why the plate boundary localizes and the origin of its distinctive seismic reflections

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ODP scientists have integrated Logging-While-Drilling (LWD) technology and three-dimensional seismic surveys to better understand how fluids and physical properties affect tectonics and seismic imaging in the active environment of the Barbados accretionary prism. The LWD results indicate that the décollement or plate-boundary detachment formed in mudstone of low density, a low density inherited from a unique radiolarian depositional event. The LWD results also confirm that a distinctive "negative polarity" seismic reflection from this fault represents residual fluid accumulations not zones of active dilation or expansion. Neither result would have been forthcoming without the resolution or *in situ* sensitivity of LWD technology.

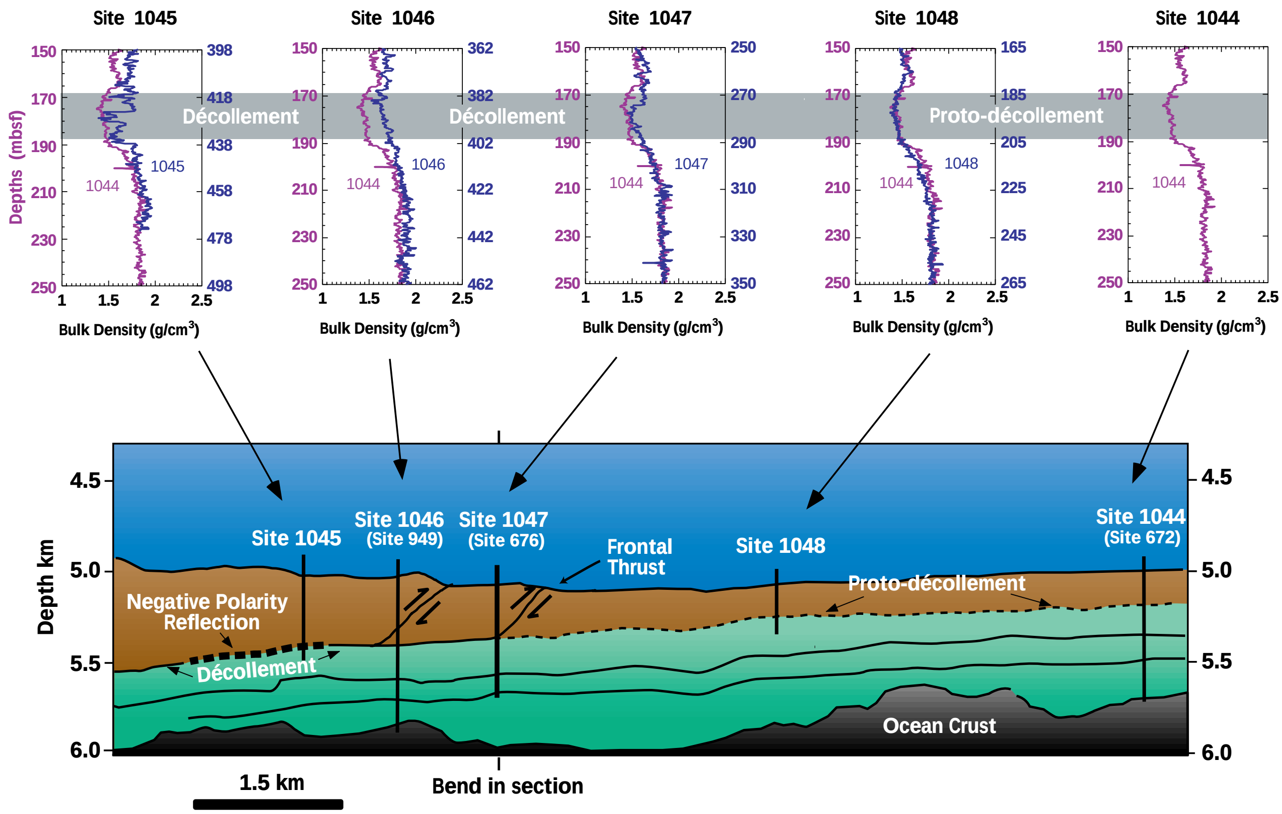
In December 1996 offshore of Barbados, LWD technology measured physical properties *in situ* in a difficult environment where traditional wireline logging has been virtually impossible. Numerous LWD penetrations of the plate-boundary detachment or décollement of the Northern Barbados subduction zone (or its incipient equivalent) define how the detachment localizes and explain its locally distinctive seismic reflection signature. An earlier three-dimensional seismic survey of this region provided the seismic reflection information correlated to the LWD results.

At subduction zones, the plate-boundary detachment or décollement zone localizes the majority of slip between the down-going oceanic crust and the overlying sediments. Classical décollements of great mountain ranges typically occur in shales or salt layers sandwiched between otherwise strong carbonate or clastic lithologies. In contrast, beneath the Northern Barbados accretionary prism, the décollement localizes in an anomalously weak layer in a uniformly muddy sequence.

Seaward of the Northern Barbados accretionary prism, LWD at reference Sites 1044 and 1048 shows that the incipient-décollement occurs in a lower Miocene radiolarian mudstone unit of unusually low density. Beneath the accretionary prism, this radiolarian mudstone unit is synonymous with the décollement zone at every site cored on earlier ODP/DSDP cruises. Therefore, the special properties of the mudstone foster detachment along this surface. The initial low density of the radiolarian mudstone suggests that these special properties are high fluid pressure and low strength.

LWD at Sites 1045, 1046, and 1047 penetrating the accretionary prism shows various stages of consolidation or densification in the décollement zone. As underthrusting proceeds, burial and shear strain lead to consolidation of the décollement zone, erasing the original low density signature. However, a local area of arrested consolidation of the décollement zone at Site 1045 correlates to an area of unique character in the seismic reflections. These seismic reflections are of "negative polarity," similar to "bright spots" in oil fields, that are classically interpreted as intervals enriched in fluid with reduced density and velocity. LWD here indicates that the negative polarity reflection is a sharply defined low density interval in the consolidating radiolarian mudstone (see Figure, Site 1045). The reduced thickness of the low density interval, relative to Site 1044, causes constructive interference or "tuning" of the incident seismic waveform producing the strong negative polarity reflection. Such reflections have never been drilled in the Barbados prism. However, seismic modeling suggested that they were zones of dilation or expansion, instead of consolidation or collapse. The degree of consolidation along the décollement zone does not vary systematically with distance of underthrusting; perhaps local features such as faults in the overlying prism may be important in controlling fluid escape from and therefore consolidation of the décollement zone.

The high quality LWD data recently acquired from the Barbados accretionary prism provides fundamental insights to difficult problems and raises additional provocative questions. Where drilled, both décollement initiation and its unique negative polarity seismic signature are explicable by simple consolidation. We still need to understand what paleoceanographic event triggered the accumulation of the low density mudstone of the décollement. We still need to understand what controls the patchy consolidation of the décollement zone, and whether the arrested consolidation or true physical dilation explains extensive areas of negative polarity reflections along the décollement zone at greater depths than we drilled.



Progressive consolidation of the plate-boundary detachment or décollement zone of the Northern Barbados Accretionary Prism. Density curve for reference site 1044 is compared to all other sites. For Sites 1045 to 1048 depth scales are on the right margin of each plot whereas the depth scale for the correlated reference curve from Site 1044 is on the left margin of the plot. Note the consistency of the anomalously low density of the incipient-décollement at both Sites 1044 and 1048. Presumably this low density distribution is a sedimentary feature and triggers detachment. With underthrusting the low density anomaly begins to disappear due to loading by the overlying prism. Seismic modeling confirms that the sharply defined low density interval from 424 to 438 mbsf at Site 1045 causes the negative polarity reflection observed in the décollement zone.