Mud Volcanoes in the Eastern Mediterranean

Achim J. Kopf, Scripps Institution of Oceanography, USA
Alastair H.F. Robertson, University of Edinburgh, UK

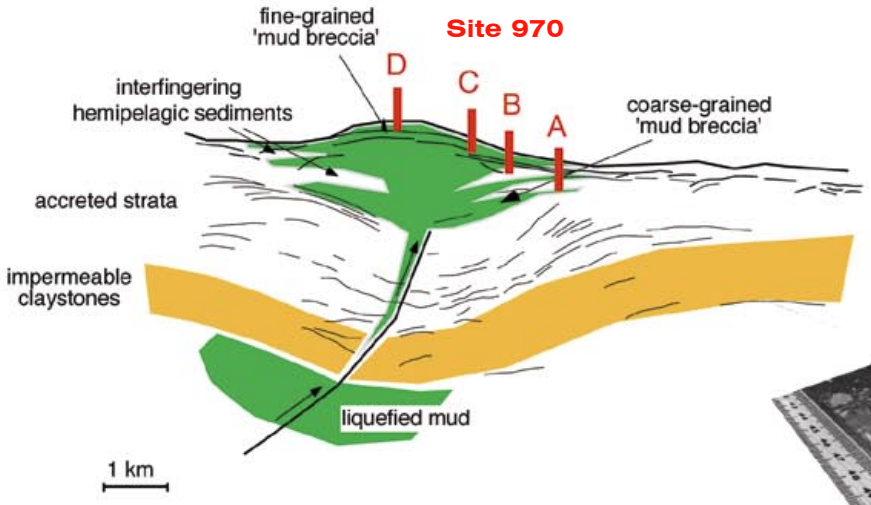
In 1995, ODP conducted the first scientific ocean drilling of active mud volcanoes, which are dome-shaped seafloor highs composed of clay-rich mud (Robertson *et al.,* 1996). Mud volcanoes occur almost everywhere on Earth, but are commonly associated with compressional tectonics at convergent margins (Higgins and Saunders, 1974). ODP Leg 160 drilled two mud volcanoes, the Milano and Napoli domes, at the backstop of the mud-dominated Mediterranean Ridge accretionary complex. This complex was created by subduction of the African plate beneath the Eurasian plate to the north. Only by drilling could the age, subsurface structure, and processes of mud volcanism be determined.

The main results were, surprisingly, that both mud volcanoes were periodically active for more than one million years and that they are dominated by multiple debris flows composed of fragments of claystone, sandstone and limestone in a muddy matrix. The most probable origin of the mud is that it was derived from overpressured fluid-rich sediment located beneath the Mediterranean Ridge accretionary complex within the subduction zone. The recognition of a debris flow origin of the "mud breccias" changed earlier views involving an origin as viscous mud intrusions.

The inward dip of the seismic reflectors towards the volcanic center suggests that progressive collapse of the volcano cone has taken place through time. Early eruption constructed a cone of unstable sediment fragments, including muddy debris flows. Voluminous outpourings of mud flows then followed, interspersed with pelagic accumulation, eventually constructing the present cones (Figure 1).

Post-cruise research focused on the depth of origin of the solid and fluid phases as well as on the quantification of mud and fluid discharge. The mud domes drilled occur along deep-seated backthrust faults some 150 km behind the toe of the accretionary prism (Kopf *et al.,* 1998). A considerable volume of previously accreted sedimentary rocks was remobilized as pieces within a mud matrix (Kopf, 1999). Research also shows that the fluid discharge through mud volcanoes in this part of the Mediterranean Ridge exceeds that of the frontal prism elsewhere (e.g., Alaska, Nankai; see Kopf *et al.,* 2001). Mud volcanism thus has an important role in the flux of water, solids and gases into the ocean in accretionary settings (Deyhle and Kopf, 2001), especially where involved in continental collision such as the Mediterranean Ridge.

Milano mud volcano
Mediterranean Ridge accretionary prism



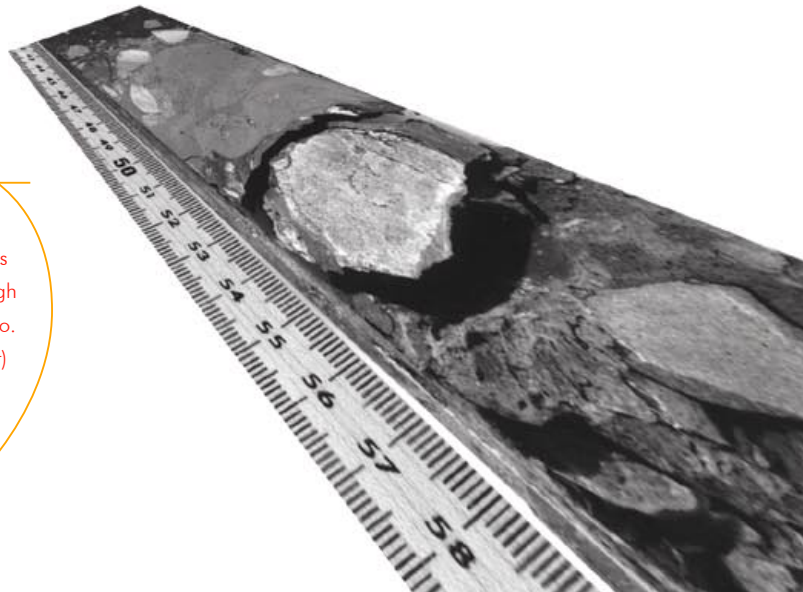


Figure 1. (above) Schematic cross section through Milano mud volcano.
Figure 2. (right) Mud breccia core from Hole 970A.