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PROBE Expedition 2: Exploration of the Puerto Rico Trench
The Deepest Part of the Atlantic Ocean

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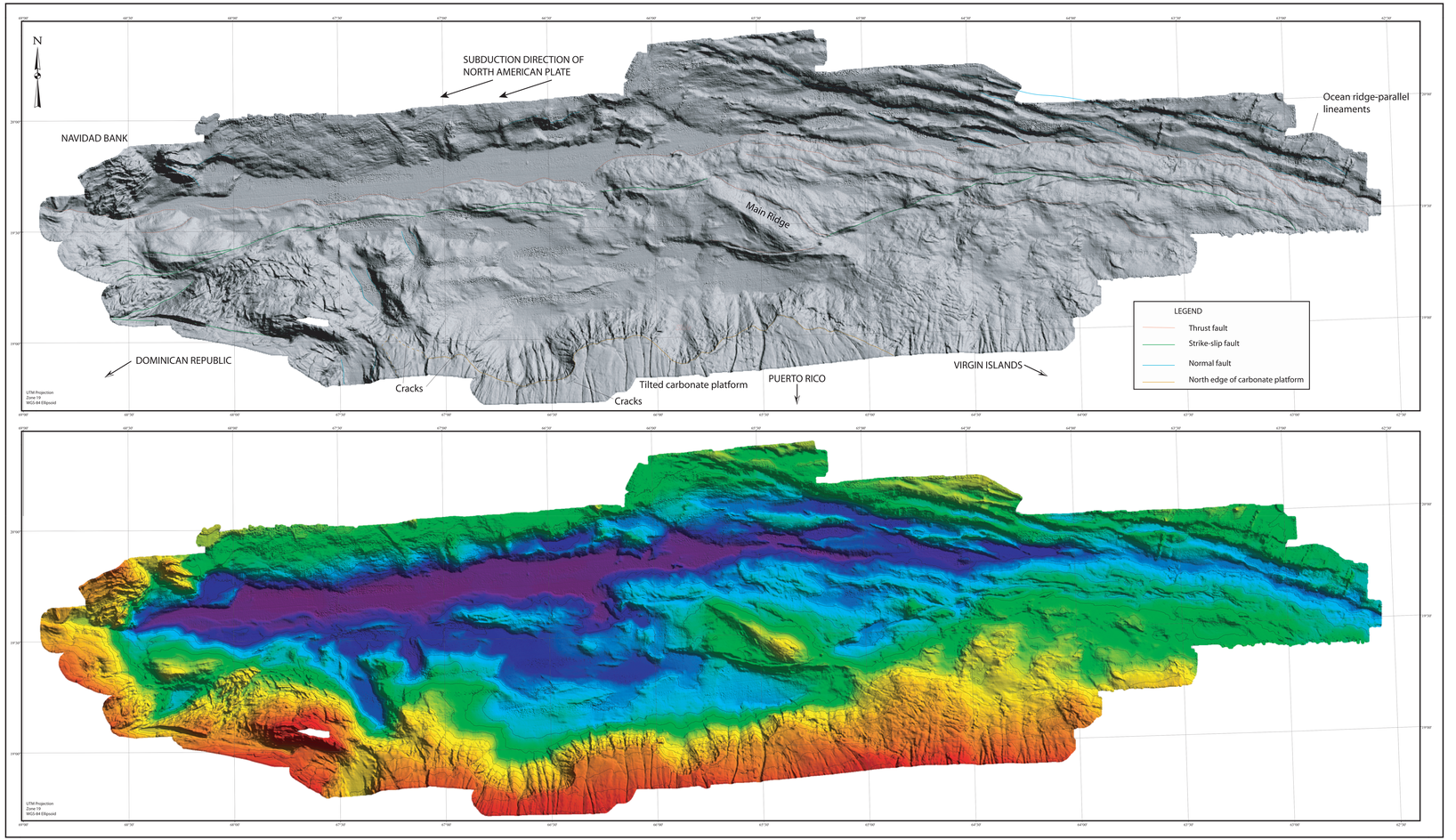
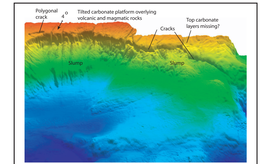


Background

The Puerto Rico trench, with water depths exceeding 8400 m, is the deepest place in the Atlantic Ocean. Its depth is comparable to the deep trenches in the Pacific Ocean. Trenches in the Pacific are located in places where one tectonic plate subducts under another one. The Puerto Rico trench, in contrast, is located at a boundary between two plates that slide past each other with only a small component of subduction. The trench is less deep farther east, where the component of subduction is larger. The deep seafloor is not limited to the trench, but it also extends farther south toward Puerto Rico. The Puerto Rico trench is also associated with the most negative gravity anomaly on earth, -380 mGal, which indicates the presence of an active downward force. Finally, a carbonate platform, which was originally deposited in flat layers near sea level is now tilted northward at a uniform angle. Its northward edge is at a depth of 4500 meters, and its southern edge can be found on land in Puerto Rico at an elevation of a few hundred meters. Many tectonic models have been proposed to explain these unusual observations, and marine exploration efforts of the type reported here are necessary to discriminate between them.

Many earthquakes and tsunamis resulting from these plate tectonic movements have occurred in historical time in the northeastern Caribbean. As the population in this region continues to grow, future seismic events could present a serious hazard to the 4 million U.S. citizens of Puerto Rico and the Virgin Islands. The hazards to these islands are mainly in the form of submarine faulting, and our expedition has discovered major new faults and submarine slides, often in areas where we did not expect to find them based on present tectonic models.

New Discoveries

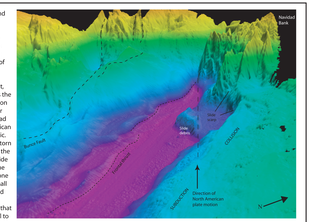


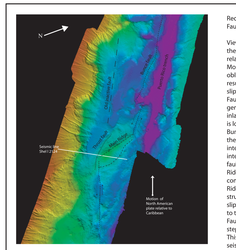
Submarine slides north of Puerto Rico: Implications for tsunami hazard

View to the south of the northern edge of the carbonate platform that caps the insular slope of Puerto Rico. Vertical exaggeration is 5:1. The carbonate cap appears as a relatively smooth seafloor, which is cut in places by narrow and deep (150-200 meters) drainage valleys. The carbonate platform is tilted approximately 4 degrees to the north reaching a depth of 3500 meters near the edge of the scarp. The slope maintains its angle as it continues upward across the northern shore of Puerto Rico and into the interior hills. The edge of the scarp, which is 35-50 km from the Puerto Rican shore, has been modified by slope failures. A large amphitheater-shaped scarp, 55 km across, first discovered by the USGS Gloria side-scan survey more than a decade ago, is imaged here at a superior resolution. The image here indicates that the top portion of the carbonate platform and underlying strata had collapsed down slope causing the foot of the slope to steepen. This interpretation is supported by the lack of large quantities of slide debris farther north. Thus, slumping is an ongoing process: A crack can be seen to continue eastward from the amphitheater-shaped scarp below the edge of the carbonate platform, and smaller slumps are observed below this crack. A polygonal crack isolates a 7x3 km area of slightly sunken seafloor, which may be an incipient slump. Submarine slides are known sources for tsunamis, and therefore, identifying incipient slumps helps us evaluate the tsunami hazard for the northern shore of Puerto Rico.

Transition between subduction and collision

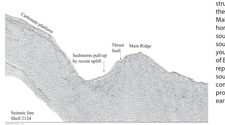
The surface effects of major plate tectonic forces can be seen in this image. This view to the southwest shows the westward termination of the Puerto Rico trench. Vertical exaggeration is 6:1. The trench narrows and ends in a narrow fault, which continued westward. This is the transition zone between subduction of the North American plate under Puerto Rico and collision of Navidad Bank (also part of the North American plate) with the Dominican Republic. Thus, the North American plate is torn at this place with the front part of the image going down and the backside staying at the surface. Note also the large landslide at this transition zone with the slide debris forming a small isolated ridge. The edge of Navidad Bank facing the transition zone is broken into jagged terraces. Note that Bunce strike-slip fault runs parallel to the trench in the front part of the image and turns southward and away from the trench as the transition zone is approached.

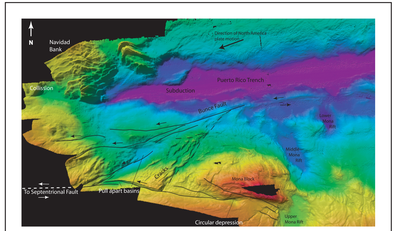




Recent migration of strike-slip motion to Bunce Fault and the origin of Main Ridge

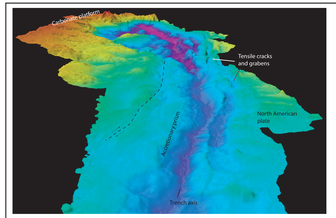
View of the Puerto Rico trench aligned along the direction of North American plate motion relative to the Caribbean plate (250 degrees). Motion along the plate boundary is highly oblique to the orientation of the trench, resulting in a predominantly left-lateral strike slip with a small component of subduction. Faults in regions of oblique subduction are generally located many tens of kilometers inland from the trench. In contrast, Bunce Fault is located only 10-15 km south of the trench. Bunce Fault is thought to be active because of the fresh-looking scarps, in contrast to a faint intermittent lineament farther south, which is interpreted as an older inactive fault. Bunce fault appears to jog to the south along Main Ridge and connects with a fault trace that continues eastward toward the trench. Main Ridge is interpreted as a linear push-up structure, generated when a left-lateral strike slip fault steps over to the right. It is analogous to the San Gabriel Mts. Along the San Andreas Fault in southern California. The material at the step over is compressed and pushed upward. This interpretation is corroborated by the seismic cross-section below. This push-up structure must be young because sediments on the seismic line appear to be dragged up onto Main ridge. Sediments usually deposit either horizontally or in a slope away from their source, which here would only be from the south. The interpretation of Main Ridge as a young push-up structure fits the interpretation of Bunce Fault as a young active strike slip replacing an older strike slip fault farther to the south (See earlier poster). The present compression and uplift of Main Ridge are probably one of the sources of frequent earthquakes in the area.

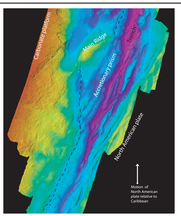




Western termination of Bunce Fault

View from above of the western end of the Puerto Rico trench provides insight into the termination of large strike-slip fault system. The map shown here is reminiscent to the termination of the Alpine Fault at the northern end of the Southern Island of New Zealand. Displacement along Bunce Fault, estimated at 15 mm/year, has to be absorbed in the surrounding area at the end of the fault. This is done by fault splays, cracks, and shattered rocks, which act to diffuse the deformation over a large area, such that the deformation at each unit is very small. The presence of numerous splays attest to the fact that Bunce fault does not simply connect to the Septentrional Fault in the Dominican Republic. If this were the case, a giant pull-apart basin should have opened where a smaller local one now exists. The eastern continuation of Septentrional Fault into our survey area is enigmatic. The fault appears to terminate eastward in a deep circular depression 25 km west of Upper Mona Rift. Other lineaments in the area do not connect to this depression. It has previously been hypothesized that the Septentrional Fault connects across the northern end of the Upper Mona Rift to faults cutting the slope north of Puerto Rico. However, there is no indication in the image shown here for such a connection, perhaps because a more recent deformation had erased this evidence





The eastern end of the Puerto Rico trench

The image on the left shows a westward view of the Puerto Rico trench, and the image on the right shows a top view of the same area aligned along the direction of North American plate motion relative to the Caribbean plate. These images show large linear tensile cracks with grabens forming between them. The deformation is due to sharp folding of the North American plate as it descends beneath the Caribbean Plate. The depth of the trench and its width diminish considerably eastward. Deformed belts of sediments form an accretionary prism on the Caribbean plate. The "rolling" morphology of these sediments may be partly governed by the graben and horst structure of the underlying subducted North American plate.

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