not randomly oriented but has a preferential direction. As reported by Dean *et al.*, the electric field appears to be very closely aligned with the pulsar's jet axis, suggesting that the highly energetic particles are produced close to the pulsar, where the magnetic field has a predominantly toroidal or donut-shaped configuration. Such a field geometry is also likely to be responsible for the collimation of the detected light and particle beams.

Polarimetry (the analysis and interpretation of polarized light) from radio to optical frequencies has been a powerful diagnostic tool in astronomy. However, its use at higher (x-ray and gamma-ray) energies has been hampered by the difficulty not only in reconstructing the polarization direction for the photons, but also in achieving a high enough sensitivity to apply it to astronomically distant sources. The next generation of polarimeters, which are now under development (*10*, *11*), will be able to measure polarization levels of a few percent even in extragalactic sources. The potential for astrophysical studies is fascinating, not only for understanding pulsars. The new polarimeters will help elucidate processes within active galactic nuclei, where collimated flows, moving at 99% the speed of light, are formed, and thought to be powered by black holes with masses millions to billions of times that of the Sun.

Polarimetric information, as demonstrated by Dean *et al.*, is expected to provide a diagnostic for the origin of their powerful emission in the x-ray and gamma-ray bands. Perhaps an even more intriguing prospect is the possibility of shedding light on the nature of the high-energy emission in gamma-ray bursts. These cosmological sources are the most luminous events known, and are believed to be the aftermath of the explosion of stars even more massive than those leading to Crab-like remnants, and ending their lives as black holes. But here, too, there is life after death.

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GEOPHYSICS

When Seamounts Subduct

Data from an array of seismometers on the sea floor show the complex pattern of earthquakes around subducted seamounts.

Roland von Huene

Volcanoes on the sea floor of ocean basins—called seamounts—migrate with the ocean plates as they subduct beneath continental plates. This process creates shear interfaces called subduction zones, where most of the world's earthquakes nucleate. It has been proposed that scraping a subducted seamount from the oceanic plate nucleates great subduction-zone earthquakes (magnitude 8 or above) (*1*). However, at crustal depths below 10 km, where great earthquakes nucleate, ship-based seismic techniques cannot image subducted seamounts. On page 1194 of this issue, Mochizuki *et al.* (*2*) use an array of seismometers on the sea floor to investigate these issues. They show that seamounts provide an opportunity to investigate causes for a transition from stable to the unstable slip that nucleates earthquakes and find a clear beginning limit of seismogenic behavior.

Numerous seamounts with heights of 2 to 3 km and basal widths of 20 to 50 km exist on oceanic plates that migrate toward continents. The converging plates meet at deep ocean trenches, where the ocean plate carrying the seamounts bends downward into trenches to subduct beneath the continental plate. When high seamounts collide with the wedge-shaped continental margin, they first plow open the thin apex of weak material, creating an embayment in the landward slope of the trench (see the figure). As the colliding seamount plows into an increasingly thick part of the continental wedge, the entire seamount tunnels beneath the continental framework. Insertion of the seamount produces a broad bulge in the overlying sea floor; collapse of the trailing flank layers sends debris slides toward the trench (see the figure). Removal of collapse debris produces a furrow in the sea floor for distances proportional to the seamount's height.

Initially, the seamount collides with weak rock of the continental wedge apex, and plate interface friction is relatively low. Rock in the apex of the upper plate wedge contains ~30%

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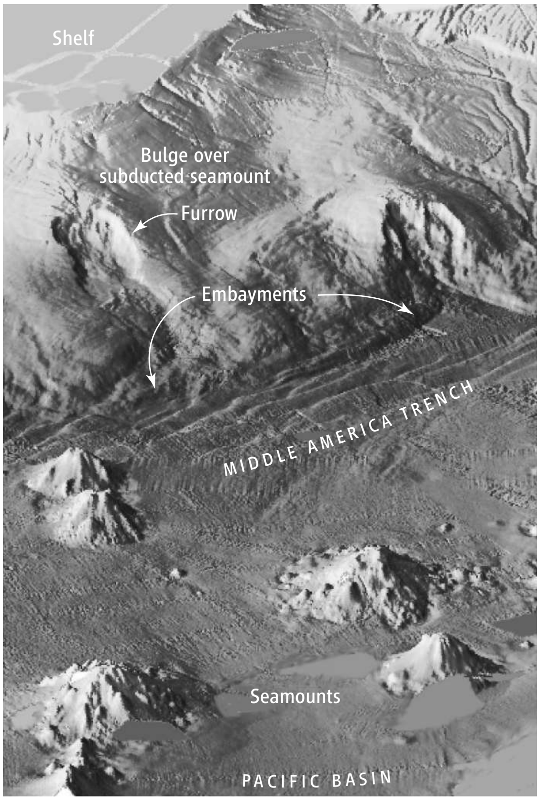

Seamounts off the central Costa Rica continental margin. Seamounts in the Pacific Basin (five of which can be seen in the lower part of the image) typically have diameters of ~20 km and heights of 2 to 2.5 km. At this location, the oceanic and continental plates converge at a rate of 90 km per million years. As the ocean crust flexes into the 4.5-km-deep Middle America Trench (middle), bend faults form the stepped topography of the trench axis. On the trench slope are two circular bulges above subducted seamounts. Across the seaward slopes of the bulges and down slope are furrows from slides as the sea floor steepens seaward.

CREDIT: BACKGROUND IMAGE, W. WEINREBE/IFM-GEOMAR pore fluid pressured by the overburden weight that reduces subduction zone friction. Therefore, subduction produces few recordable earthquakes until fluid drains to 10 to 15% and the continental wedge is thick enough to accumulate the elastic strain released in earthquakes (*3*). Earthquakes of magnitude ~3 or above can be recorded at stations on land. But with only distant land station records, the precise location of these offshore earthquakes cannot be determined.

Sea-floor seismic records indicate deep anomalous features along subduction zones that are associated with aftershock clusters beneath the shelf (*4*–*6*). However, it will be difficult to prove that seamounts nucleate these earthquakes without understanding the mechanism through which they do so. Mochizuki *et al.* now show that with two-dimensional data from an array of sea-floor seismometers, a subducted seamount at 10 km depth along the subduction zone can be outlined as a diffuse bump on the subducting plate. Leaving the array above the seamount for extended periods to record local earthquakes provides sufficient precision to resolve the relation between seismicity and the seamount. Surprisingly, seismicity around the studied seamount is concentrated in front of its leading flank, rather than over its crest. These data imply that friction over the seamount is less than in adjacent deeper areas. They also indicate a steady or stable sliding over the seamount, whereas the subduction zone in front of the seamount slides intermittently during earthquakes (referred to as unstable sliding).

Recent observations are consistent with the inferred low friction. In a study of a subducted Costa Rican seamount (see the figure), Sahling *et al.* found large volumes of fluid vent from sediment layers exposed by trailing flank collapse (*7*). The strata ramped upward over the subducting seamount will create a hydraulic gradient up its flanks, which will concentrate fluid above its crest and thus reduce friction. This can help explain the distribution of friction off Japan found by Mochizuki *et al.*

Whether scraping seamounts from the subducting plate produces great earthquakes is still speculative (*1*). Mochizuki *et al.* examined a seamount subducted to a depth where earthquakes first nucleate, so their experiment does not answer this question. Subducted seamounts at depths of 20 km are proposed to uplift the coast of Costa Rica (*8*), so they remain attached at least to these depths. Some detached fossil seamounts are exposed in outcrops on land, although a graveyard of many detached fossil seamounts is not commonly recognized in outcrops on land. The low friction indicated by Mochizuki *et al.* is consistent with seamounts remaining attached in shallow regions of the seismogenic zone. Perhaps lower friction at the beginning of seismogenesis increases deeper in the subduction zone to detach subducting relief. Although detachment must sometimes occur, its relation to great earthquakes remains unresolved.

Recording a grid of signals from a surface ship (commonly two or more intersecting lines of shots are recorded) could provide the required three-dimensional seismic coverage. Three-dimensional data can also be acquired from an array of seismometers in a drill hole, yielding vertical seismic profiles. From such data, physical properties in subduction zones can be derived (*9*). Such data will help to elucidate whether frictional behavior changes are a result of physical relief or changes in the physical properties of fault materials.

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BIOCHEMISTRY

Opening the Molecular Floodgates

Structural studies reveal how mechanosensitive channels respond to membrane tension.

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The uncontrolled flow of water can be devastating. Engineers have tamed water by creating structures ranging from dams, levees, and aqueducts to faucets, drains, and microfluidic devices. Biological systems face comparable challenges. One of the most fundamental involves the permeability of cell membranes to water. For example, osmotic downshock, which occurs when a bacterium is suddenly exposed to fresh water, leads to an influx of water across the membrane. Without safety valves to release their cellular contents, such cells cannot withstand the high internal pressures resulting from this influx. Two reports in this issue, by Wang *et al.* on page 1179 (*1*) and Vásquez *et al.* on page 1210 (*2*), shed light on how bacteria address this challenge.

About 20 years ago, Kung and co-workers identified stretch-activated (mechanosensitive) proteins in bacterial membranes that sense the increase in membrane tension during osmotic downshock (*3*). Two major families of prokaryotic mechanosensitive channels were subsequently cloned: the mechanosensitive channel of large conductance (MscL) (*4*), and the mechanosensitive channel of small conductance (MscS) (*5*), the focus of the current studies. These proteins form channels in the inner membrane that open and close in direct response to tension applied to the bilayer, allowing the efflux of cytoplasmic contents to restore the osmotic balance to sustainable levels.

How can such channels sense and couple membrane tension to reversible opening (*6*)? Some of the first clues came from crystal structures of putatively closed states of *Escherichia coli* MscS and *Mycobacterium tuberculosis* MscL (*7*–*9*), which established that packing of symmetry-related transmembrane (TM) helices—TM3 in MscS, and TM1 in MscL—creates the permeation pathway in these channels. The helix-helix interfaces in both structures contain conserved Gly and Ala residues, and are expected to rearrange to form a large pore in the open state. The structural studies of the open state of the *E. coli* MscS by Wang *et al.* and Vásquez *et al.* substantially advance our understanding of this process.

The challenge in structurally characterizing the open state of MscS is that the closed state is

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