# EARTH SCIENCES

*Cheryl Simon reports from San Francisco at the annual winter meeting of the American Geophysical Union*

## A soft spot for earthquakes

One of the outstanding puzzles of seismicity on the San Andreas fault is why major earthquakes do not usually cause the 6- to 30-meters displacement geophysicists expect. Instead, measurements of seismicity fall off sharply 5 kilometers from the fault, and 10 kilometers away stress is quite constant. Donald Turcotte of Cornell University in Ithaca, N.Y., reported results of studies indicating that a thin crustal layer on the lower mantle portion of the fault is soft relative to the stiff upper crust and stiff upper mantle. Turcotte said this softness enables the layer to damp periodic motions on the fault and may be responsible for the narrow zone of deformation. The presence of the soft layer at moderate depth also may help explain why seismic energy propagates so much more effectively in the central and eastern United States, where seismic waves may travel hundreds of kilometers and still be powerful enough to damage buildings (SN: 10/10/81, p. 232). A contributing factor, Turcotte said, may be that heat generated as the Pacific plate is subducted beneath the continental margin causes the temperature of the crust to increase faster with depth than it does mid-plate.

## Reconstructing the Mt. St. Helens blast

Tremendous ash clouds produced by the eruption of Mt. St. Helens May 18, 1980 obscured much of what happened on the mountain, making it difficult for scientists to reconstruct the volcanic event. Now, satellite images, ground photographs and eyewitness accounts suggest that a second explosion rather than the first was responsible for much of the damage and that the main blast occurred not at the main crater but at the toe of the landslide. James G. Moore of the U.S. Geological Survey in Menlo Park, Calif., said most geologists agree that the event began when a magnitude 5.0 earthquake caused landslides and cracking, which in turn relieved the confining pressures on the cryptodome, a circular structure that caused a bulge on the mountain's north flank. The bulge and the mountainside slid off in a gigantic avalanche, the confining pressure was relieved, and the historic explosion began. With Carl J. Rice of Aerospace Corp. in Los Angeles, Moore reported that when the landslide reached Spirit Lake and the water-soaked soils of the north fork of the Toutle River, the water and hot lava combined to produce a steam explosion that caused a "dramatic" condensation of an atmospheric layer at an elevation of about 6 kilometers. A cloud of ash swept in front of the first explosion, Moore explained. When the second explosion occurred a minute and a half later 6 kilometers north of the main crater, it accelerated the surge to the east and west as well as to the north. The ensuing increase in infrared intensity recorded by satellites led the scientists to this reconstruction of events.

## Ice thickens in the Bering Sea

Waves lapping at banks of ice gnaw the edges, rendering them thinner than the interior of ice sheets. Right? Wrong, at least in the Bering Sea. Scientists from the University of Washington in Seattle, the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration find that the southern edge of ice in the Bering Sea forms bands oriented at right angles to the wind. The bands stretch from 10 to 20 kilometers and may be as much as 2 kilometers wide and up to 5 meters thick. Northward into the pack, ice may be less than half a meter thick for areas of several kilometers. Seelye Martin of the University of Washington reported that it looks as though the ice bands move faster than interior ice because the bands absorb part of the momentum from ocean-generated waves. The bands move southward until, reaching warmer water, they melt.

# SPACE SCIENCES

## What shaped the face of Enceladus?

It was in March of 1979 that the Voyager 1 spacecraft made the stunning discovery of active volcanoes on Jupiter's moon Io, attributed by many researchers to tidal heating. Periodic gravitational tugs from Europa, the next satellite out, keep Io in an elliptical orbit so that it varies in distance from Jupiter, subjecting it to a varying gravitational attraction that essentially pumps Io in and out, producing the heat. A few weeks after the find, Charles Yoder of Jet Propulsion Laboratory suggested (NATURE 279:767) that Saturn's icy moon Enceladus, in a similar "resonant" relationship with Dione, might turn out to be another satellite "whose past and present state is controlled by tidal friction." Four months ago, Voyager 2 photos of Enceladus indeed revealed an unusual surface, with cracks, "ropy" features and other markings, though no apparent eruptions.

But the answer is not that simple, as Yoder himself points out. The scarcity of craters on parts of Enceladus' surface suggests to some scientists that those portions may be relatively young, as though recent or even ongoing processes have been erasing them. Yet the amount of tidal heating likely to be taking place on Enceladus at present, Yoder says, seems too low to do the job, even with optimal assumptions about the satellite's interior. Only about half an erg of energy per second would be coming out of each square centimeter of the surface (direct heat-flow measurements have not been made, and may be impossible without landing there) — about 1 percent of the heat-flow at Io. What, then, is the source of energy that has reshaped the icy terrain, melting or resurfacing its earlier appearance?

One possibility is that Enceladus used to be in a similar orbital resonance with another Saturnian moon, Tethys, which is closer than Dione and could thus produce greater tidal heating by forcing Enceladus into a more elliptical orbit. But that resonance, Yoder calculates, would have been disrupted more than a billion years ago.

An alternative, he says, could be that tidal heating does affect Enceladus' surface as a result of the existing Saturn-Dione tug-of-war, but only at certain times, separated by periods of quiescence. As the orbital eccentricity increases, the idea goes, the accumulating tidal stress reaches a critical threshold above which the tidal heating *rate* rapidly increases as the interior temperature rises. The escape of the rapidly produced heat softens and reshapes the surface, while the heat's generation decreases the orbital eccentricity until the heating rate falls back below the critical threshold, bringing the episode to an end. Such episodes, Yoder calculates, could last about 10 million years out of each 10 billion, with an outward heat flow 10 times that of the quiet periods.

As yet unclear, however, he notes, is whether the accelerated heating may instead reduce the orbital eccentricity and shut itself off before ever reaching the point of making a visible difference on the surface. That possibility requires further study.

Enceladus' limited tidal heating could also have a greater effect if, as has been suggested by several researchers, the ice includes not only water but ammonia, whose combined melting point is about 100°C lower than that of water-ice alone. In fact, David Stevenson of Caltech cites one study's conclusion that a water-ammonia mixture can snap-freeze at extremely low temperatures into a glass-like phase that, when heated even a slight amount, releases its own latent heat by exothermic reaction. Perhaps, he suggests, water-ammonia ice in Enceladus' early days could have been melted by the satellite's then-active radiogenic heating, then migrated to the surface (where the temperature is about −200°C) and snap-froze. Tidal heating would then need to raise the near-surface temperature by only about 30°C to trigger the exothermic reaction — which could be retriggered at each new thermal "kick."