DeLisi acknowledges that recent evidence points to structural lesions in the brains of schizophrenics, especially in the limbic system and parts of the neocortex. But she notes at least three areas of controversy related to the findings. First, many of the studies have methodological problems, and not everyone agrees on how the results should be interpreted. Weinberger concedes that, whereas psychiatrists who study brain abnormalities in schizophrenia report enlarged ventricles, neuroradiologists regard the same CT scans as normal. But the real controversy, he says, is whether a subtle change in ventricular size has clinical meaning.

Second, DeLisi points out that "these changes, at least in the ventricles and those in the temporal lobe of the cortex, are not specific to schizophrenia." And third, she sees a discrepancy between the static nature of a structural lesion and the very nonstatic course of the disease. The idea is that, if the brain abnormality is there all the time, then why do patients with schizophrenia experience episodes of disease?

Researchers also observe abnormalities in the prefrontal cortex of schizophrenics. Some patients, particularly those who are older and mentally deteriorated, have reduced blood flow in the frontal and prefrontal cortex as compared with other brain regions. This hypofrontality, as it is termed, may result from either a primary defect in the cortex or exist because nerve pathways that project to that area are abnormal, according to David Ingvar of University Hospital in Lund, Sweden.

Recently, Weinberger, Karen Berman, and Ronald Zec, all of NIMH, reported that young schizophrenic patients also display hypofrontality. "But only when there is a need for increased neuronal function in the prefrontal cortex is the deficit seen," says Weinberger. The NIMH group finds that the Wisconsin card-sort test—in which patients try to sort cards in a new way when the tester indicates that the present sorting method is incorrect—specifically requires the function of the dorsolateral region of the prefrontal cortex. A nonschizophrenic person performs the test easily and shows increased blood flow to the prefrontal cortex during the task, but schizophrenic patients fail to find new ways to sort cards and show no increased blood flow.

But again, experimental results are not consistent. Not all schizophrenics exhibit reduced blood flow to the prefrontal cortex, people with other neurological conditions show similar deficits, and not all neuroscientists accept the card-sort test as a specific physiological demand of prefrontal cortical function. Still, many researchers think that abnormalities of the prefrontal cortex, including metabolic function, dopamine activity, and possible structural changes, warrant further investigation.

A related area of schizophrenia research focuses on asymmetries in the brain. Recent work by Gavin Reynolds reveals that the amygdala on the left side of the brain of some schizophrenics has an increased dopamine content, whereas the right amygdala does not. But whether this and other indications of asymmetry are part of the disease process or simply reflections of the brain's natural asymmetry have yet to be determined.

Because the symptoms of schizophrenia that first require treatment often appear in early adulthood, some researchers are beginning to ask whether milder pre-schizophrenia symptoms occur even earlier and whether certain developmental processes in the brain that take place around puberty may be related to schizophrenia. More males are diagnosed with schizophrenia before age 25, and early onset often means a poorer outcome. Whether a second category of psychotic patients, whose symptoms appear at 60 years or older, differs at least in terms of the cause of psychosis is also being investigated.

For every point of view about the biology of schizophrenia there is a counterpoint. Theories about the origin and disease process of schizophrenia are often built on a multitude of empirical observations and a paucity of hard facts. Differing and sometimes contrasting interpretations are applied to the data that do exist. Sometimes experiments are poorly designed. But the looming issue is the overwhelming complexity of schizophrenia. New techniques and attempts to integrate existing data into coherent theories may soon produce some understanding of the mental disorder that afflicts 1.5 to 2 million Americans. ■

DEBORAH M. BARNES

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A Geophysics Potpourri In San Francisco

When the American Geophysical Union and the American Society of Limnology and Oceanography held a joint meeting last December, the result was 5000 registrants and 20 to 30 simultaneous sessions for 5 days. The meeting encompassed everything from the feeding habits of zooplankton to galactic cosmic rays, so it cannot be summarized. Here are a few samples of the varied fare.

Getting a Full View of The Earth's Innards

For more than 10 years geophysicists have had two complementary means of imaging the earth's crust and the upper mantle below it—refraction seismology and reflection seismology. Within the past few years researchers have gone from largely independent, uncoordinated, and often small experiments involving one or the other technique to large, multi-institutional experiments combining both approaches at the same site. To judge from talks and posters at the meeting, combined experiments are becoming de rigueur. The early results are promising.

George McMechan of the University of Texas at Dallas and Randy Keller of the University of Texas at El Paso reported early results from an experiment in southern Oklahoma, the largest such seismic experiment ever conducted by academic institutions. Eight hundred seismometers with six sensors each were deployed in three steps along a 100-kilometer line across the sediment-filled Anadarko Basin and the Wichita Uplift. Every 2 milliseconds these seismometers recorded the waves generated by 25 separate borehole blasts of 130 to 1600 kilograms of TNT. That left the experimenters with 13 billion bytes of data.

This vast amount of data required 2 years of effort to develop and apply useful processing techniques, but now the two types of seismic wave data are in good shape, says Keller. The refracted waves, which traveled nearly horizontally as they passed through the crust and upper mantle at different depths, provide precise velocities of seismic waves, which depend on rock composition and temperature. But refracted waves provide only a fuzzy picture of structure within the crust. Seismic waves that reflect from boundaries between bodies having different velocities paint a detailed picture of crustal structure, but refraction seismology's precise velocities are necessary to calibrate the boundary depths and resolve ambiguities of interpretation. Thus a combined experiment is greater than the sum of its parts.

Even to the untrained observer, a dramatic feature of the reflection profile in southern Oklahoma is a reflection diving through the upper mantle to a depth of 75 kilometers, which is perhaps three-quarters of the way through the continental plate. That makes it the deepest identifiable reflection ever seen beneath the North American continent. Keller is confident that it is a true reflection from a boundary and not diffracted waves because those can be distinguished when the waves reflect at wide angles, as in this experiment, rather than vertically, as in the simplest stand-alone reflection experiment. He is not saying what created the reflection, but it could be from a continuation of the Mountain View fault.

In a similar combined experiment this past spring in Arkansas and Louisiana, Keller, McMechan, Lawrence Braile of Purdue University, and their colleagues in the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL) probed the Ouachita Mountains, an extension of sorts of the Appalachians. Everyone had agreed that the continental plate tore apart here, an ocean formed in the resulting rift, a continent then collided with North America to destroy the ocean, and new rifting opened the present Gulf. But the question of what hit where at what time remained controversial. The PASSCAL group failed to find any typical continental crust south of the Ouachitas, suggesting that the 350-million-year-old margin survived later collisions and now forms the Gulf coast, along with far-traveled continental blocks gently lodged against the continent during the collision.

John Behrendt of the U.S. Geological Survey (USGS) in Denver, Alan Green of the Geological Survey of Canada, and William Cannon of the USGS in Reston, Virginia, reported on an increasingly popular variation of the typical seismic survey. Because ship-borne seismic reflection surveys return higher quality data at less cost than land surveys, researchers of the Great Lakes International Multidisciplinary Program on Crustal Evolution (GLIMPCE) collected reflection profiles across Lakes Superior, Michigan, and Huron, in the midst of North America's stable cratonic crust and across the ancient Keweenawan Rift. They also conducted refraction surveys. Beneath Lake Superior, they found an unusually thick layer, spanning depths of 15 to 20 kilometers, of lava flows interbedded with rift lake sediments, and a Moho, the bottom of the crust, that deepens from the 35-kilometer depth typical of the continent to 55 kilometers.

In an attempt to summarize what can be said about the crust on the basis of reflection and refraction seismology, Walter Mooney and Thomas Brocher of the USGS in Menlo Park surveyed the results from 50 regions where both techniques had been employed. In 80% of the cases, the upper crust in reflection profiles is largely featureless while the lower crust produces many reflections. The seismic velocities provided by the refraction studies were no help in making sense of this layering. Mooney and Brocher suggested that the most reasonable explanation is that the upper, more brittle, crust reflects seismic waves from smaller, more steeply dipping structures that reflect less efficiently. The lower crust would then have reflectors that are larger, more laminated, and more horizontal.

Possible lower crust reflectors, they suggested, might include layers of rock injected as magma, layers that formed in larger bodies of injected magma, sediment layers, layers of wet or water-altered rock, and rock stretched into an efficient reflecting layer. Further application of combined seismic surveys will delve into the nature of some of those reflectors.

U.S.–Soviet Seismic Monitoring Advances

Although nontechnical considerations continue to impede progress toward a complete ban on underground testing of nuclear weapons, the first results of an unprecedented U.S.–Soviet cooperative venture confirm predictions of test ban proponents that detection of any cheating at the principal Soviet test site would be relatively easy. If other claims hold up, a network of only 25 seismic stations within the Soviet Union would appear to allow the detection and identification of blasts of 1 kiloton despite any attempts to hide or camouflage them. The weapon dropped on Hiroshima was about 20 kilotons and the currently recognized threshold for underground testing is 150 kilotons.

At the meeting, seismologists James Brune, Jonathan Berger, and their colleagues at the University of California at San Diego, Keith Priestley and David Chavez of the University of Nevada, and Charles Archambeau of the University of Colorado reported on the first detailed analyses of data from three seismic monitoring sites that the group installed last summer around the Kazakh test site east of the Caspian Sea. Those installations were the first part of a cooperative program between the Natural Resources Defense Council, a private American environmental group, and the Soviet Academy of Sciences. The creation of the surface-mounted network around the Soviet test site will be followed this spring by installation of borehole-mounted instruments at three sites around the Nevada test site. Already the second phase of the program is well under way at the three Soviet sites. Hundred-meter boreholes have been drilled that will eventually house seismometers, two trailers are on each site as accommodations, high-voltage power lines have been run to each site, backup diesel generators are installed, and security fences are erected.

The whole point of the effort from the American point of view is to determine how seismic waves behave near the Soviet test site, something that has been difficult to do from afar. Earlier this year Jack Evernden of the U.S. Geological Survey (USGS) in Menlo Park, Archambeau, and Edward Cranswick of the USGS in Denver argued in a 72-page paper in the *Reviews of Geophysics* that the earth's crust in the Soviet Union is seismically quiet enough and propagates seismic waves efficiently enough that underground tests can be monitored by as few as 25 stations within the country and 15 outside it. Such a network would allow identification of blasts of 1 kiloton even if they were timed to coincide with earthquakes or set off in large caverns to muffle their seismic waves. A key to such detection and discrimination is high-frequency waves of about 30 hertz. They are far more abundant in the seismic signature of impulsive explosions than in the drawn-out rupture of a fault.

Brune, Berger, and their colleagues "confirmed that the wave propagation characteristics [of the Kazakh site] are like those of a continental shield," that is, the crust is rigid and cold enough to transmit the waves with relatively little attenuation. They recorded high-frequency waves from earthquakes and quarry explosions at distances of up to 600 kilometers. And on the basis of results from surface instruments, they expect that seismic noise levels in the boreholes will be low. So far, according to Brune and Berger, these results support the contention of Evernden and his colleagues that at least the Kazakh site would be easier to monitor than the Nevada test site, where the crust is a poorer transmitter of seismic waves. Brune and

Berger say that more analysis of the character of the waves themselves is needed before anyone can say with certainty how well blasts can be discriminated from earthquakes, but the data necessary for the analysis have been recorded.

Estimating the yields of tests at the Soviet site, which some believe have exceeded the 150-kiloton ceiling of the limited-test ban treaty still unratified by the U.S. Senate, will require two more developments. Within a few months the precise attentuating properties of the site will be calculated from the new data. The other ingredient, determining the efficiency with which explosive energy generates seismic wave energy, must await release by the previously reticent Soviets of the sizes of at least some tests. An opportunity to continue their show of good faith begun by opening the Kazakh site to American scientists may be at hand. The Soviets have warned that in the face of continued U.S. testing they will soon resume testing after a 16-month hiatus.

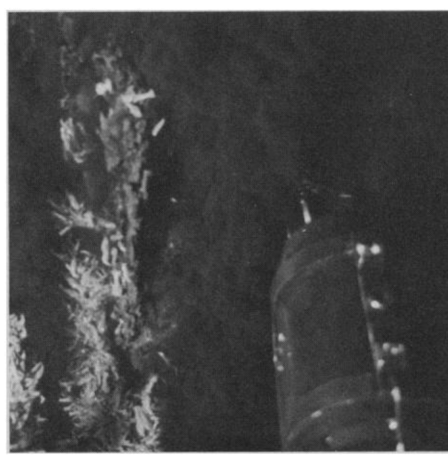
Ocean Hot Springs Similar Around Globe

Although located in different oceans, the magma chambers midocean ridges that supply three-quarters of the earth's crust are far more similar than most geophysicists expected. Because newly formed ocean crust spreads away in both directions from the Atlantic midocean ridge at only 1 or 2 centimeters per year while new crust formed at the East Pacific Rise races away at almost 10 centimeters per year, many researchers had assumed that the magma chambers beneath those ridges as well as the hot springs to which they give rise would be quite different.

Magma chambers in the Atlantic were thought to lie more than 5 to 6 kilometers beneath the central ridge axis and at any one site would appear and disappear with the changing supply of magma from the mantle. On the East Pacific Rise, magma chambers appear to lie only 1 to 2 kilometers beneath the surface, where they heat seawater in the overlying porous crust to about 350°C. That water then shoots out of the bottom as spectacular jets of mineral-laden "smoke."

John Edmond and his colleagues at the Massachusetts Institute of Technology reported that hot springs at two sites on the Atlantic midocean ridge (26°N and 23°N) spew water that is just as hot as what reaches the top of the East Pacific Rise and contains as much dissolved silica. The amount of silica that can dissolve in seawater circulating near the top of the magma chamber depends on the ambient pressure. The greater the depth of the chamber, the more silica will dissolve. The silica compositions of water from the Atlantic and Pacific hot springs are very similar, said Edmond, requiring that the top of the magma chambers on both ridges be not more than 1 or 2 kilometers beneath the ridge crest. And these shallow Atlantic chambers are not ephemeral bodies compared to the faster spreading ridges, he notes; the mound of sulfide deposited by the hot springs at 26°N in the Atlantic is 10 to 100 times as massive as any on the East Pacific Rise.

The latest in seismic reflection and refraction techniques have constructed one view of magma chambers on the East Pacific Rise. According to studies by a group of researchers from Scripps Institution of Oceanography, Lamont-Doherty Geological Observatory, and the University of Rhode Island (URI) coordinated by Robert Detrick of URI, the chamber beneath the rise between 9°N and 13°N is mushroom-shaped in cross section and surprisingly narrow—as narrow as 1 to 2 kilometers, typically 3 to 4 kilometers wide, but never more than 6 kilometers wide. Some geologists expected a chamber at least 8 kilometers wide.



NOAA-WHOI-MIT Vents Research Team

New animals, familiar hot springs. *The submersible ALVIN samples a hot spring on the mid-Atlantic ridge as a newly discovered genus of shrimp swarm about.*

The top of the mushroom, or at least the shallowest occurrence of even a trace of magma, is 1 to 2 kilometers beneath the top of the ridge and the narrow stalk, through which the magma to form thousands of kilometers of present-day crust must have passed, extends to the bottom edge of the crust, called the Moho. The Moho appears within 2 to 3 kilometers of the ridge axis, suggesting that the Moho forms within 25,000 years. A single, continuous chamber as imaged by seismic waves extends at least 30 kilometers along the ridge and perhaps as far as 90 kilometers.

James McClain, Eldridge Moores, and Chen Chin of the University of California at Davis raised the question of how a magma chamber this narrow could exist. They suggested that seawater must penetrate not only the highly permeable upper 1 or 2 kilometers of the ocean crust, where hot springs are thought to originate, but also the lower crust, presumably through fractures undetectable by seismic techniques. A narrow chamber would then be the relict of a more voluminous body shrunk by the chilling of deep-circulating seawater.

How Much Drying from a Greenhouse Warming?

The coming climate warming that will be induced by carbon dioxide often conjures up images of another dust bowl in the American Midwest, but at the meeting Thomas Karl of the National Climatic Data Center in Asheville, North Carolina, cautioned against jumping to any such conclusion. The drying effects of the expected warming might easily be compensated by minor, but difficult to predict, increases in precipitation.

Karl noted that certain types of forecasts calling for extensive drying of some regions under a greenhouse climate are based on traditional methods of relating temperature, precipitation, and streamflow of different drainage basins that have quite different climatic conditions. Karl believes that a better approach is to decipher any such correlations from smaller, natural changes in the climate of the same basin that have occurred over recent decades. Based on this type of analysis of the flow of 82 streams from across the United States, Karl finds that a change of 2°C in temperature, about what is expected from a doubling of carbon dioxide, has no significant effect on streamflow relative to the 15 to 20% changes in streamflow induced by a modest 10% change in precipitation.

The problem is that although those researchers modeling greenhouse climate effects have some confidence in their predictions of a 1° to 4°C global warming and a global enhancement of precipitation, they have less faith in model predictions of temperature changes region by region. Current model predictions of regional precipitation changes appear to be nearly useless. So no matter how accurately predicted a regional warming may be, says Karl, no one can yet say how wet or dry a particular area will be on the basis of hydrologic records. Small, as yet unpredictable changes in precipitation are simply too important in determining streamflow. ■ RICHARD A. KERR