Midcontinent heat may explain great quakes

While most North Americans think of California as "The Earthquake State," three of the largest tremors in U.S. history struck the nation's heartland near New Madrid, Mo., during the winter of 1811-1812. Why such massive jolts should rock the continent's otherwise stable center has long puzzled geologists. This week, two researchers proposed that excess heat under the New Madrid region may explain its seismic unrest, which is expected to continue in the future.

At a meeting of the American Geophysical Union in Baltimore, Lanbo Liu and Mark D. Zoback of Stanford University suggested that heat in the mantle underneath the New Madrid area has weakened this portion of the North American plate, making it more susceptible to earthquakes.

"On the basis of our calculations, the strength of the New Madrid seismic zone is much, much less than in the surrounding region," Liu says.

Most earthquakes occur along the edges of the dozen large tectonic plates that cover Earth's surface like a cracked egg shell. When two plates crash together as in the Himalayas, or when they grind past each other as in California, their margins absorb the brunt of impact, leaving the stronger interior land undeformed.

In U.S. history, large jolts have rattled only two sites within the stable eastern half of the North American plate: the New Madrid area and Charleston, S.C., which although on the coast lies several thousand kilometers from the plate boundary in the mid-Atlantic. The three New Madrid quakes had estimated strengths of magnitude 8.0 or greater; an 1886 Charleston quake had an estimated strength of 7.8. For every one-point increase in magnitude, the power of an earthquake increases 30-fold.

Geologists traditionally seek to explain such intraplate earthquakes by focusing on weaknesses within the crust. By this thinking, previous tectonic injury in a particular location would fracture the upper crust there, predisposing the plate to break again in the same spot. New Madrid, for instance, sits atop a scar formed 600 million years ago after a great rent started, but failed, to rip the North American plate in two.

Liu and Zoback took a different approach by considering the upper mantle, which forms the underside of the plate. In most of eastern North America, the upper mantle is relatively cool and stiff; it provides a strong layer that keeps the plate from breaking under the tectonic force pushing North America away from Europe. But in the New Madrid area, they suggest, the mantle is too hot and malleable. Without the support of a strong mantle, the crust in this region cannot stand up to the force, so it breaks and causes earthquakes.

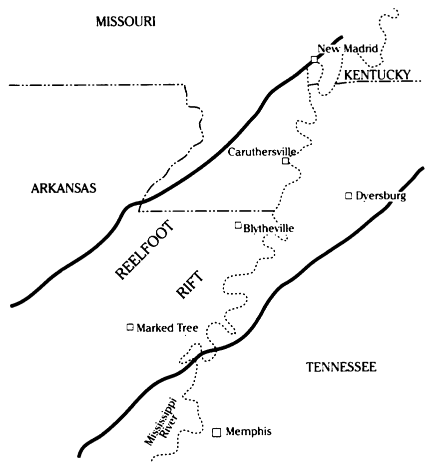
According to Liu and Zoback, several lines of evidence suggest the mantle underneath New Madrid is warmer than surrounding areas. Heat coming out of the crust averages 58 milliwatts per square meter near New Madrid; heat flow values in other areas of the eastern United States average 20 percent lower.

Seismic waves passing through the lower crust underneath New Madrid move slower than elsewhere, providing another indication that the upper mantle has excess heat, Liu says.

Lastly, he cites evidence that molten rock rose up into the crust underneath the New Madrid region 40 million years ago, relatively recent by geologic standards. Heat from that volcanic episode would have lingered in the mantle even until today, he says.

The new theory would explain measurements reported last year by Liu and others, showing that the New Madrid region is being squeezed at an extremely high rate. While the plate tectonic forces push on the entire eastern United States, New Madrid compresses more than others because the lower part of the plate can't support the force, Zoback says.

— *R. Monastersky*



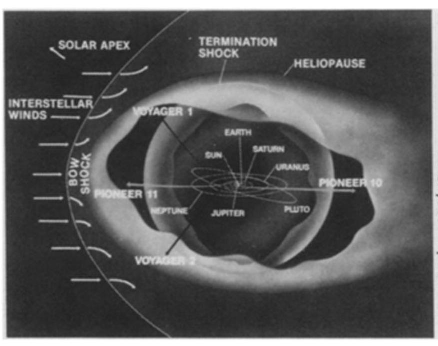
New Madrid, Mo., was hit by huge quakes in the past. Small jolts continue in a seismic zone running from Marked Tree, Ark., past New Madrid. Solid lines show borders of this ancient rift.

Mysterious radio bursts hint at heliopause

Hurtling through space a few billion kilometers beyond Neptune and Pluto, two aging spacecraft have recorded intense bursts of radio waves that may originate from the very edge of the solar system. If verified by further analysis, the bursts will provide a new way to gauge the size of the solar system, as well as reveal the structure of the heliopause — the proposed boundary between the solar system and interstellar space.

The radio emissions, detected by Voyagers 1 and 2, peaked in intensity in December. Their discovery marks a new era of exploration for the nearly 16-year-old probes, best known for their close-up portraits of Jupiter, Saturn, Uranus, and Neptune. Voyager 1 is now 52 astronomical units (AU) from the sun (one AU equals about 149.6 million kilometers), while Voyager 2 lags behind at 40 AU.

Since July 1992, the craft have recorded radio emissions from an unknown source whose total power exceeds 10 trillion watts. These bursts have about two to 30 times the intensity of an equally puzzling group of bursts detected by the Voyagers in 1983 and 1984, says Donald A. Gurnett of the University of Iowa in Iowa City, and may represent the most powerful radio source in the solar system. However, the bursts are too low in frequency to penetrate the solar system's sea of charged particles to reach Earth.



NASA/Jet Propulsion Lab.

Drawing shows location of spacecraft now probing the outer solar system.

Gurnett, William S. Kurth of the University of Iowa, and their colleagues reported the findings in Baltimore this week at an American Geophysical Union meeting. They trace the radio emissions to events that began in May 1991. A series of large solar flares erupted then, accompanied by an explosive release of gas into the solar wind, the stream of charged particles emanating from the sun.

Three months after this explosive release, the two Voyagers and the Pioneer 10 craft recorded a sudden drop in the intensity of cosmic rays — high-energy particles from outside the solar system. One explanation for the falloff is that the enhanced solar wind deflected the cosmic rays. The time lag between the flare activity and the cosmic-ray decline suggests that the solar wind traveled at a speed of 600 to 800 kilometers per second, compared to the 400 km/sec speed of the average solar wind, John A. Lockwood of the University of New Hampshire in Durham and William R. Webber of New Mexico State University in Las Cruces calculate in the May 1 JOURNAL OF GEOPHYSICAL RESEARCH.

Eventually, Gurnett suggests, the bulkier solar wind reached the heliopause. At this boundary, the solar wind must halt: Pressure from the interstellar wind equals the pressure from the solar wind. This collision created intense bursts of radio waves, some of which headed back into the solar system and were detected by the Voyagers, he speculates.

Gurnett says measurements from different orientations of the Voyagers indicate the bursts come from where the solar wind collides head-on with the interstellar wind. He adds that the emissions have gradually shifted to higher frequencies. This suggests a well-defined heliopause width, with lower-frequency radio bursts created earlier at the boundary's near, lower-density edge, and higher-frequency signals created later, when some of the solar wind penetrates deeper into the heliopause's denser parts.

Researchers a decade ago had proposed that the heliopause would lie closer to the sun, about 70 AU distant. Based on the new radio data, Gurnett places it some 100 to 160 AU from the sun. Ralph L. McNutt Jr., of Johns Hopkins University Applied Physics Laboratory in Laurel, Md., estimates the boundary may lie between 90 and 120 AU away. These new estimates are consistent with recent Hubble Space Telescope data that suggest a distance of 100 AU (SN: 5/22/93, p.326).

— R. Cowen

Method probes chemistry of stroke, aging

A technique used to measure fats and proteins in food products may now help scientists detect chemical changes in the brain that occur with stroke and aging, a group of researchers reports.

Robert A. Lodder and his co-workers at the University of Kentucky Medical Center in Lexington have found that, in gerbils, near-infrared light can penetrate the skull to reveal the degree of tissue oxidation — the chemical damage to fats and proteins — in the brain.

"We actually get the scans through the skull, the hair, and the brain and get chemical information back," says Lodder. But some scientists express skepticism about applying the work to humans.

The technique, called near-infrared spectrophotometry, gives researchers a non-invasive tool for probing the chemistry of living systems. While magnetic resonance imaging (MRI) and CAT scans provide excellent views of anatomical structure, they reveal little about molecular structures. Hospitals use near-IR spectrophotometric devices to monitor the oxygen-carrying state of hemoglobin in the blood of newborns suffering respiratory distress, and health clubs use the technique to estimate patrons' body fat. The Kentucky group, however, is the first to adapt the method for stroke and aging research, Lodder says.

The team shines a beam of near-IR light onto the head of an anesthetized gerbil. A spectrophotometer measures the amount of light, in wavelengths from 1,100 to 2,500 nanometers, transmitted through the brain. A supercomputer then analyzes the data and cranks out a graph showing the amounts and types of fats and proteins. After a stroke or with increasing age, the lipid signals shift to longer wavelengths, the group reports in the May 15 issue of ANALYTICAL CHEMISTRY. This observation suggests that unsaturated fatty acids convert — by oxidation — to saturated ones, or else switch the configuration of the molecule from the cis to the trans form.

Using the near-IR analytical method, Lodder's team found that these damaging changes, when spurred by a stroke, take place well after the initial clot prevents oxygen from reaching the tissue. They studied the near-IR scans of three gerbils given deliberate 10-minute strokes and found that oxidative damage began at least four hours after circulation was restored. By then, reactive chemicals called free radicals, which build up in the oxygen-starved area, would have begun attacking nearby tissues, the researchers believe.

Normal mammalian metabolism generates smaller quantities of free radicals, resulting in similar brain tissue damage that accumulates with age, Lodder says. His group could discern no difference in the near-IR scans of a young adult gerbil subjected to 10 minutes of stroke and an aged one that had a 5-minute stroke. "It looks like stroke is just an accelerated aging process, at least according to this near-IR test," he says.

Lodder's group is using near-IR to gauge the effectiveness of free-radical-quenching drugs that could potentially treat stroke and diseases of aging. The new technique reduces the number of animals needed for such studies, he notes. Because the method also detects water, the team hopes to adapt it to evaluate edema in humans, including by concussion.

Biophysicist Britton Chance of the University of Pennsylvania in Philadelphia says, "This paper calls attention to the great potential of red-light spectroscopy of tissues. But evaluation of edema is more important than the changes of brain fats, and penetration deeper than 4 millimeters will be necessary for application to the human brain."

Karl Norris of Beltsville, Md., who developed the fat meter, voices deeper skepticism. "My opinion is that they're only seeing signals from the surface of the brain," he comments. "I'm concerned that we are extrapolating too far with this technology."

— K.F. Schmidt

Chlorination products linked to cancer

A report published last summer offered the first strong link between chlorinated drinking water and an increased risk of human bladder and rectal cancers. But this epidemiologic study could not tease out the agent responsible — chlorine, by-products of the disinfectant's reaction with water contaminants, or both (SN: 7/11/92, p.23). A new animal study now fingers the by-products as the most likely culprits.

For two years, scientists at the National Institute of Environmental Health Sciences in Research Triangle Park, N.C., fed hundreds of mice and rats water containing a drinking-water disinfectant — either chlorine (Cl_2) or chloramine (NH_2Cl). In a concurrent study, they laced the diets of rodents with chloroform, bromodichloromethane, chlorodibromomethane, or bromoform — trihalomethanes (THMs) that typically form in chlorinated water. Each experiment included 50 mice and 50 rats of each sex.

In animals administered chlorine or chloramine, "the only evidence of carcinogenicity... was an equivocal response for leukemia in female rats," June K. Dunnick and Ronald L. Melnick report in the May 19 JOURNAL OF THE NATIONAL CANCER INSTITUTE. However, compared to rodents eating an ordinary diet, those dining on food containing a THM showed not only liver and kidney toxicity, but also unusually high rates of cancer.

For instance, tumors of the kidney and colorectum normally occur in fewer than 1 percent of rats, the investigators note. The new research shows that one-quarter to one-third of rats treated with chloroform, bromoform, or bromodichloromethane developed kidney cancers. Between 25 and 90 percent of the rats fed one of those three THMs also developed both precancerous and malignant colorectal tumors.

"This study provides some of the clearest evidence yet of [chlorination's] carcinogenicity, particularly its colorectal carcinogencity," says Robert D. Morris of the Medical College of Wisconsin in Milwaukee. However, THMs may not be the only carcinogens formed, he says, noting that only about half of chlorination's by-products have so far been identified.

The study also provides some of the first information on the relative potency of individual THMs, notes Stephen W. Clark of EPA's Office of Drinking Water Standards in Washington, D.C. Indeed, he says, these data will probably influence the new rules for THMs in drinking water now being negotiated by EPA and industry and environmental leaders.

— J. Raloff