Mimicking the deepest quakes

Scientists know earthquakes originate as deep as 690 kilometers within the earth. But explaining these deep quakes has proved difficult because decades of laboratory experiments have shown that at the high pressures present in the earth's mantle, rocks do not fracture, which is the usual method of generating earthquakes. This week, however, scientists report successfully fracturing rocks under mantle conditions — a result that may help explain the deepest of earthquakes.

"Basically, the observation of deep earthquakes is well established, but no one could understand where they came from," says Raymond Jeanloz of the University of California at Berkeley, who worked with colleague Charles Meade on the project. "At least for the first time now, we've been able to reproduce these earthquake-like events in the laboratory and we think we know one mechanism by which this may be happening at high pressures."

Meade presented the new findings at the spring meeting of the American Geophysical Union in Baltimore.

The deepest quakes, so-called deep-focus earthquakes, occur at subduction zones — where a collision between two of the earth's great plates sends one plate diving beneath the other and down into the mantle. Meade and Jeanloz recreated the conditions of a subduction zone by using a diamond-tipped anvil — a small device in which tiny amounts of a material are placed between two diamonds and squeezed to enormous pressures. The two squeezed rocks to more than 200 kilobars, which is 200,000 times atmospheric pressure. This pressure corresponds to 600 km in depth.

To get the rocks to fracture, the researchers heated the sample and subjected the rocks to a small sideways stress that was perpendicular to the pressure from the anvil. When the temperature of the rock reached over 600°C, the rock shifted suddenly and emitted a snapping sound — two telltale signs of a fracture.

Previous experiments that mimicked mantle conditions had failed to produce these fractures. When most rocks reach 10 kilobars, high frictional forces on the crystals prevent them from breaking. Instead, the rocks deform slowly. According to Meade, one experimenter did fracture rocks at 50 kilobars, but only by using an excessively high sideways force, a condition not applicable to the inner earth, he says.

Meade and Jeanloz induced fracturing in a sample that combined olivine, pyroxene and serpentine. Olivine and pyroxene, believed to make up much of the mantle, would not fracture on their own; they required the addition of serpentine, a hydrous version of the other two minerals that forms when water seeps into rock below the ocean's floor.

The researchers say hydrated minerals may play an integral role in enabling rocks to break under high pressure. They surmise that when the rock reaches 600°C, the crystalline structure of serpentine suddenly releases its water. This quickly decreases the frictional forces within the rock, allowing the crystals to slide microscopically.

Since the sinking plates at subduction zones are the floors of ancient oceans, Meade and Jeanloz believe this kind of behavior by hydrous minerals may explain the deep earthquakes, which apparently occur only at subduction zones. According to this theory, when subducting plates heat up, the crystals of hydrous minerals release water as they do in the lab.

If true, this mechanism not only will explain why deep-focus earthquakes occur, but also may help scientists understand why no earthquakes originate below 690 km. Some geophysicists believe quakes stop at this mark because it represents a boundary between two sections of the mantle that plates cannot penetrate.

Meade, however, says that if deep-focus earthquakes are generated by the role of hydrous minerals, then plates "may easily subduct into the lower mantle." Quakes stop at 690 km, he suggests, because by the time the slabs reach that depth, the heat of the mantle has driven all water out of the minerals.

For now, Meade says, the theory about the mechanisms of deep-focus earthquakes remains speculative. But other scientists say that cracking rocks under pressure in the lab is the first step toward finding a viable theory.

"I think it's extremely important and exciting work," says Don L. Anderson, a seismologist at the California Institute of Technology in Pasadena. "Because of the kind of apparatus they are using, they will eventually be able to do experiments to show exactly what's causing this brittle failure-type behavior. They haven't done it yet; they've just made things that go pop. But now they can start looking at it in more detail." *— R. Monastersky*

A leafy home for one insect hormone

A Malaysian plant called grasshopper's Cyperus apparently uses a built-in pesticide for insect control by producing its own supply of a common insect growth hormone, scientists reported this week. The hormone, called juvenile hormone III (JH III), is one of the so-called juvenoid hormones important in the molting process, a stepwise shedding of external skeletons as an insect grows.

When fed the plant, grasshopper juveniles — which look like adults but are not fully developed — grew at the same rate as those fed wheat seedlings lacking the hormone. By the time they reached maturity, however, nearly all of the Cyperus-fed insects had some abnormality, including underdeveloped egg formation in females and twisted wings.

The discovery is the first time scientists have isolated JH III — the most widely occurring juvenoid hormone among insects — from a plant, according to the authors of the May 12 NATURE report. Coauthor Yock C. Toong at the Universiti Sains Malaysia in Penang was seeking plant extracts with drug potential when he found what resembled an insect hormone in the grass-like plant. David A. Schooley and Fred C. Baker of Sandoz's Zoecon Research Institute in Palo Alto, Calif., purified and characterized the substance, which they then found in large amounts in greenhouse-grown Cyperus.

"It is believed that all insects need [juvenoids] to control the nature of their molt," Schooley said in an interview. Proper control requires a feast-or-famine approach, an ebb and flow of hormones. When these hormones are present, for example, a larva will molt into a larger larva. For a larva to molt into the pre-adult stage called a pupa, however, juvenoids must be absent. And for insects without a pupal stage, such as cockroaches and grasshoppers, there still must be an absence of the hormones before the adult stage can develop normally. But then the juvenoid hormones must reappear in the adult female to trigger ovarian development. Their role in male adults has not been determined, Schooley says.

For about 20 years, scientists have periodically isolated compounds found both in insects and plants. Among those compounds have been a few juvenoids, yet those have been very limited in terms of the plants involved or the number of insects affected, Schooley says.

While thoughts about an evolution-based strategy that places juvenoids in plants are enticing, Schooley says he is reluctant to claim that evolutionary pressure guided the appearance of JH III in plants. "Plants make a wide variety of chemicals, and [the presence of juvenoids] could be completely accidental," he says.

The latest finding is primarily of scientific interest, without obvious commercial applications, according to Schooley. "It's very trendy these days to speak of transferring these types of genes into plants to make them resistant to insects, but these hormones are a complicated multi-gened trait not easily transferred," he says. *— D.D. Edwards*