Getting to the bottom of the San Andreas

Last month, scientists began drilling a 5-kilometer-deep hole in California, which they expect will get to the bottom of a long-standing paradox about the stresses and heat generated in the nearby San Andreas fault.

The hole, located within the fault zone, 3.5 kilometers from the fault itself, is in the Cajon Pass, northeast of Los Angeles. It will be the deepest hole ever drilled in the United States solely for research, according to Mark Zoback, a geophysicist at Stanford University and chief scientist on the project. By using the hole to study fundamental properties of the earth's crust as well as to monitor the San Andreas over the next few decades, scientists hope to improve their earthquake prediction abilities considerably.

Earthquakes are generated along the San Andreas as the Pacific plate to the west of the fault grinds northward past the North American plate. In the Cajon Pass area, the Pacific plate moves at a rate of a few centimeters per year. This motion is resisted by friction in the fault. Scientists, using laboratory studies of the strength of rocks, calculate that the frictional stress shearing the fault should be high, about 1,000 bars. Indeed, measurements at shallow levels reveal a strong stress gradient, suggesting that high stresses are present at lower depths.

But with such high frictional stress, scientists have also expected that the San Andreas would be generating much heat as the rocks grind past one another. And there is the rub, because essentially none of the more than 100 shallow heat-flow measurements made during the last 20 years has detected any anomalous heat coming from the San Andreas; the heat levels near the fault are no greater than those 10 kilometers away. These heat-flow measurements are consistent with shear stresses in the fault that are 5 to 10 times lower than the 1,000 bars predicted by the laboratory and theoretical studies.

Because the heat and stress studies have been made near the surface, where all kinds of factors can complicate the measurements, scientists are cautious about extrapolating their results to deeper levels of the fault. That's why Zoback and others have wanted to drill a deep hole near the San Andreas. "It's been our inability to address the [stress-heat] question with anything but direct observations that has been the primary motivation for this project," says Zoback.

The National Science Foundation agrees. It is providing most of the $8 million required for the Cajon Pass project. In addition to studies relating to the stress-heat paradox, 30 researchers from a dozen institutions plan to do a wide variety of experiments to investigate everything from regional geologic questions to geophysical properties of the crust. According to Zoback, the hole should be completed by March 1988.

While drilling has just begun, project scientists concerned about the stress-heat paradox already have given much thought to what they may find. One scenario is that at depths greater than about 2 kilometers, they may measure both high stresses and the "missing" anomalous heat. If so, then it's possible that the flow of groundwater, or some other mechanism, is carrying the heat away at shallow levels.

Alternatively, they may find that the shear stresses and heat levels are low at greater depths. This would mean that the fault is much weaker than previously supposed, says Zoback. "The implications of this would be quite dramatic," he says, since scientists have assumed that frictional stress on the fault is an important force controlling the movement of the earth's tectonic plates.

In support of a weak fault, Zoback and his wife, Mary Lou Zoback of the U.S.. Geological Survey in Menlo Park, Calif., have recently found that compressional stresses in California's crust point about 70° away from the trend of the fault. This orientation, they say, would tend to move the San Andreas, rather than other faults in the area, only if the San Andreas were weak enough to be susceptible to such a stress.

If the Cajon Pass study also suggests that the fault is weak, then scientists will probably want to drill other holes in the fault zone to find out why. One possibility is that fluids trapped in the pores of fault rocks and clays are exerting a strong pressure, jacking the rocks apart and nearly nullifying the frictional stresses.

The Cajon Pass hole probably won't answer all the questions scientists have about fault mechanics, but Zoback says it may help them to move beyond the realm of describing plate motion, and toward an understanding of the physics behind plate tectonics. *— S. Weisburd*

Copper: What a difference sex makes

Over the past decade, nutrition scientists have found they can induce all the symptoms of coronary heart disease in animals merely by feeding them a low-copper diet (SN: 6/8/85, p.357). Last year, a different research group reported that those coronary effects of copper deficiency were magnified dramatically when an animal was allowed to indulge its sweet tooth on a diet high in fructose, the sugar in fruits and honey (SN: 5/3/86, p.279). Their latest findings now indicate that sex may affect the susceptibility to this effect.

In their study with rats, researchers at the Agriculture Department's Human Nutrition Research Center in Beltsville, Md., observed that males began dying from ruptured hearts after five weeks on a low-copper, high-fructose diet. By the eighth week, 40 percent were dead, and the rest were dying of heart disease — with severely enlarged hearts, anemia and high cholesterol levels. Meanwhile, except for having high serum-cholesterol levels, the females were healthy and disease free.

"I couldn't believe it," says biochemist Meira Fields. "By the eleventh week my rats were either alive or dead — there was nothing [illness-related] in between." And the only factor differentiating them was their sex.

What this means, she says, is that "an animal was protected against death just by being female." In her search for reasons, Fields is focusing on the possible role of sex hormones in making males more vulnerable or females less so.

It also prompts speculation, Fields says, that a sex-related difference in susceptibility to heart disease may help explain why U.S. women experience less heart disease than men (SN: 11/2/85, p.279). Nutrition researchers have estimated that, at least in the United States, as much as 70 percent of the population may be copper deficient. And fructose is becoming an increasingly larger part of the average diet as processed-food and soft-drink manufacturers increase their reliance on this inexpensive natural sweetener.

Fields says it's unlikely that the dramatic sex-differentiated effects seen in her low-copper, high-fructose experiments are unique to copper. Many trace metals have similar effects on the body. So she suspects that if there is a sex-linked vulnerability to copper deficiency's effects, there may be a similar one for zinc, manganese, vanadium or nickel.

She points out, however, that probably half of all human nutritional studies involve only males. While male-only experiments avoid the complicating variable of widely fluctuating sex-hormone levels in premenopausal women, Fields says they also risk ignoring significantly different nutritional needs of women, or effects of diet on them.

"It appears that [Fields] is on to a nutritional factor that could be very important," says Edward J. Calabrese at the University of Massachusetts in Amherst, author of a textbook on sex differences in toxic susceptibility. His research indicates that "probably less than 30 percent of the time" are both sexes used in toxicological studies. However, he says, "we found well over 150 to 200 or more examples of significant sex differences in mice and rats." Moreover, he says, the few human studies looking