Geophysics on the fifth force's trail

Isaac Newton made one of the greatest discoveries in classical physics when he realized that the force that draws an apple toward the ground is the same one that keeps the moon in orbit around the earth. For hundreds of years, his formula for the gravitational attraction between two bodies has helped scientists and engineers calculate everything from the orbits of planets to the trajectories of rockets.

But gravity has given modern theorists a problem. As physicists have tried to combine all four known forces of nature — the gravitational, electromagnetic, weak and strong forces — into one unified field theory, they have been unable to incorporate gravity without postulating the existence of other, as-yet-undiscovered forces (SN: 7/26/86, p.55). In particular, the unified field theories say that the force of attraction between two bodies is given by Newton's formula plus a much smaller "fifth force" that seems to come into play at distances of about 100 to 1,000 meters.

Since this range is outside the scale of gravity measurements in the laboratory, theoretical physicists have turned to earth scientists to hunt for the fifth force. Indeed, a number of geophysical experiments have indicated such an effect, but because of experimental uncertainties they have yet to convince most scientists. A new generation of experiments is now in the works, and scientists reported on two of these in San Francisco at the recent meeting of the American Geophysical Union.

The basic purpose of the experiments is to measure the force of gravity at different elevations over several hundred meters and to compare these measurements with what Newton's formula predicts, based on the measured masses of nearby bodies. In practice, scientists measure an effective gravitational constant, which, in Newton's expression, relates the force of gravity to the masses and the distance between them.

One of the most comprehensive geophysical experiments so far has been conducted by Frank Stacey at University of Queensland in Brisbane, Australia, and his colleagues. Working in two metal mines, the researchers have measured a gravitational constant that is 0.7 percent greater than that measured in the laboratory — suggesting the presence of a fifth force. Other scientists, however, worry that Stacey's group has been unable to determine the density of surrounding rocks with sufficient precision. After making 14,000 boreholes into mine rocks, Stacey maintains that the mine density is well known, but he is worried that there may be some unknown, deeply buried bodies that are affecting his group's results.

So Stacey and others have been searching for geologic settings in which the densities and distribution of nearby masses are as uniform and well known as possible. Mark E. Ander at Los Alamos (N.M.) National Laboratory and Mark A. Zumberge, George E. Backus, Alan D. Chave, John Hildebrand and Fred N. Spiess of Scripps Institution of Oceanography in La Jolla, Calif., report that they are planning to do an experiment next summer in a 2,000-meter-deep borehole in the Greenland ice sheet. The researchers believe they will be able to measure the gravitational constant to better than 1 part in 1,000 over depths of about 100 to 1,500 meters down the borehole. To achieve this accuracy, they are taking painstaking care in their measurements. For example, they will "season" or stretch the wire line, which will hold the gravity meter, many times before the experiment and will calibrate its absolute length in an Idaho silver mine both before and after their experiment.

Ander's group would like to repeat the ice experiment in a Soviet borehole in Antarctica. This group and, independently, Stacey's group are also planning experiments in the ocean from about 100 to 3,000 meters' depth. Measuring depths is easier in the ocean than in a borehole, and the seafloor topography is more even than the rocky terrain underlying ice. However, no one has measured gravity through the water column to such depths before, so there are technical problems still to be worked out.

Another experiment was proposed at the meeting by Christopher Jekeli and Andrew R. Lazarewicz at the Air Force Geophysical Laboratory at Hanscom Air Force Base, Mass. They want to measure gravity up along one of two several-hundred-meter-tall television towers in Houston or in Raleigh, N.C. The advantage of this approach, says Jekeli, is that the effect of the air density is far less important than that of water, ice or rock. Stacey's group has tried a similar experiment, but it did not succeed because the tower was shaking too much. Jekeli and Lazarewicz, however, think their tower will be stable enough.

Jekeli and Ander say their experiments are not likely to be definitive: If they don't find evidence for a fifth force, the theorists can respond that the force must act over greater distances than the experimental ranges, and if they do measure a gravitational constant different from the Newtonian value, skeptics can always say this result was due to experimental errors.

In this respect, these are high-risk experiments, says Ander. But over time, such experiments may yield a big payoff. What's most exciting about doing this work, he says, is that "there are very few opportunities for geophysicists to make an impact on fundamental physics, and this is clearly one of them." — *S. Weisburd*

Boning up on bowhead habitats

For the bowhead whales, "life has not always been zooplankton and cream," says Donald M. Schell. During the late 1800s, whalers almost drove the animals to extinction, and now some people are concerned that the bowheads may be threatened by the offshore oil industry's expansion into Beaufort Sea, north of Alaska and the Yukon Territory, where these whales summer.

In order to determine whether a whale species is threatened, Schell says, scientists must understand its life cycles and favorite habitats. Most of the information on bowhead feeding habits is based on their migration route: It has been assumed that the bowheads do most of their feeding in the Beaufort Sea and then live on their fat reserves as they migrate west and south through the Chukchi Sea and into the Bering Sea, where they spend the winter.

But now Schell and his colleagues say they have found a more precise method for learning about bowhead feeding patterns and for age-dating the animals. And their preliminary results, presented at the recent San Francisco meeting of the American Geophysical Union and the American Society of Limnology and Oceanography, are challenging conventional thinking about the bowhead.

Schell and Norma Haubenstock, both at the University of Alaska in Fairbanks, have studied the levels of carbon and nitrogen isotopes contained in whale baleen, or the plates that grow from the roof of the animal's mouth. These plates — which, like fingernails, are made of keratin — fray on their inner edge into a fringe of coarse filaments. The filaments enable the whale to filter out food particles from the seawater.

The researchers have found that, along the length of a plate, there are cyclic changes in isotopic content that can be related to the whale's geographic movement. In particular, Schell and Ken Dunton at the University of Texas in Port Aransas reported at the San Francisco meeting on their measurements of the carbon-13 to carbon-12 ratio in zooplankton, which whales consume. This ratio increased as the researchers moved westward from the Beaufort Sea to the Bering Sea. As the whales migrate back and forth between the Beaufort and Bering seas each year, the isotopic content of their growing baleen records their diet and movement.

Schell also looked at how the carbon-14 levels in baleen had changed with time. Scientists know the rate at which global carbon-14 levels have been falling in the environment after large amounts were released by nuclear weapons testing in the 1960s. The carbon-14 decrease along the