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 baleen gave Schell and Haubenstock an independent way of determining the length of the carbon-13/carbon-12 cycles. With this method they confirmed that the cyclic isotopic changes were annual.

The isotopic shifts in the baleen, along with isotopic studies of whale muscle tissue, enabled Schell and Haubenstock to estimate where the bowheads were doing most of their feeding. Contrary to previous thinking, says Schell, the whales are getting about 60 percent of their food in the Bering Sea, and not from the Beaufort. Schell hopes that with further work comparing carbon and nitrogen isotope ratios, his group will be able to pinpoint where the whales spend their time.

"One of the most important aspects of this whole study is to find out where the animals' energy comes from at different times of the year," he says.

The annual isotopic shifts also enable Schell and Haubenstock to determine the age of the animals. Until now, scientists have estimated bowhead ages by looking at the size distribution of bowheads harvested by Eskimos and assuming that the largest numbers were 1 and 2 years old. With the baleen, however, the researchers have found that the whales are considerably older than they were reported to be in the literature. This technique, says Schell, provides marine biologists with a powerful tool for describing life histories of the bowheads, including their age of sexual maturation and their growth rates. It could also play a role in decisions about their management.

Schell plans to focus next on the isotopic variations of the zooplankton and to determine how oceanographic conditions, including El Niños, affect these variations. "This study has led us in so many directions so fast that it's been a full-time effort to keep up with it," he says.

Beyond its importance to the bowhead, Schell adds, the study demonstrates the use of stable isotope chemistry in ecological studies in general. "This use," he says, " . . . is the field of the future," as evidenced by the "rapid growth in the audience size of these stable isotope lectures" at meetings like the one in San Francisco. *—S. Weisburd*

The 2-million-year-old meat and marrow diet resurfaces

Two scientists have taken the first detailed look at a collection of stone tools and fossilized animal bones found in East Africa 25 years ago and, as a result, have put early human ancestors back on a red-meat and marrow diet.

Henry T. Bunn and Ellen M. Kroll of the University of Wisconsin in Madison say that early members of the human lineage appear to have hunted at least small animals and possibly driven predators away from still-meaty carcasses of large animals. Whatever the ratio of hunting to scavenging, choice pieces of prey were carried to the site containing the bones and stones.

"Given the large quantities of meat and marrow available during hominid [human-like species] feeding events, it is likely that cooperative food sharing on a scale unknown among modern non-human primates occurred nearly two million years ago," they report in the December CURRENT ANTHROPOLOGY.

In a sense, this conclusion brings paleoanthropologists full circle. About a decade ago, it was widely assumed that hominids were meat-eating hunters who took animal remains back to "home bases," where bones and stone tools were discarded. In the last several years this view has succumbed to a number of other explanations (SN: 3/9/85, p.155). Researchers have suggested that hominids mainly scavenged fat and bone marrow, with a few bits of remaining flesh on the side, at lion kill sites. Some investigators say that human ancestors were primarily interested in obtaining usable material such as tendons and skin from animal carcasses. Another proposal is that hominids were marginal scavengers of bone marrow from carnivore kills.

But Bunn and Kroll contend that the remains they studied, which were first uncovered in 1959, show that early hominids were avid meat-eaters. The collection of thousands of stone tools and fragmented animal bones was found at Olduvai Gorge, Tanzania, in sediment dating to 1.75 million years ago.

After reconstructing long-bone shaft fragments, the researchers found that skeletal parts at the site that could be clearly identified — which numbered about 3,500 — included a high proportion of prime meat-bearing bones from large, adult mammals and whole haunches of smaller mammals. This indicates, in their view, that selected, highly nutritious carcass portions were transported to the site.

The scientists then microscopically studied 172 bone specimens containing cut marks. These marks were concentrated toward the meatier, midshaft areas of limb bones from both small and large animals. According to Bunn and Kroll, the cut marks most likely resulted from the slicing motion of a simple, sharp stone tool edge. In bones from large animals, a higher proportion of cut marks occurs on nonlimb parts, add the investigators, since meat is more abundant on these animals' ribs, vertebrae and pelves.

This pattern, they say, suggests that "early hominids at Olduvai were butchering carcasses by an efficient and systematic technique that involved skinning, dismemberment and defleshing operations."

Since smaller animals are eaten rapidly by predators, the researchers hold that hominid hunting of these creatures was likely. They are less certain of how large animal parts were obtained. Hominids may have scavenged carcasses at times of the year when predators eat less of their prey, a practice documented among modern savanna predators. Hunting cannot be discounted, but Bunn and Kroll say it is most likely that hominids drove predators away from carcasses soon after the kill.

Some paleoanthropologists writing in the same issue agree with Bunn and Kroll's interpretation. Stanley Ambrose of the University of Illinois in Urbana-Champaign adds that the brain expansion of early *Homo* species around 2 million years ago would have required the consumption of nutrient- and energy-rich foods such as meat. Henry M. McHenry and Christopher J. O'Brien of the University of California at Davis note that a reduction in hominid cheek-tooth size at around the same time probably heralded a greater reliance on meat and on tools for food preparation.

Anna K. Behrensmeyer of the Smithsonian Institution in Washington, D.C., finds the evidence for carnivorous activity among hominids convincing, but adds a caveat. A previous study of bone weathering (SN: 4/26/86, p.261) indicates, she says, that carcasses slowly accumulated over five to 10 years at several Olduvai sites; thus, seasonal scavenging most likely took place. Bunn and Kroll contend, however, that bone weathering at the Olduvai site suggests carcasses were taken there over two to three years.

A more pointed criticism of the Olduvai study is lodged by Lewis Binford of the University of New Mexico in Albuquerque. Binford, who conducted a preliminary analysis of the same bone collection several years ago, says the data actually show that hominids probably scavenged bits of leftover meat and marrow from previously ravaged carcasses. Skeletal-part frequencies are similar to carcasses left behind by predator and scavenger animals, he asserts. Cut mark occurrence is overestimated in the study, according to Binford, and marks on bone shafts suggest hominids had difficulty processing limb remains. Extensive gnaw marks, he adds, indicate that predators and scavenging carnivores such as hyenas had first crack at the meatiest portions.

The proportion of gnawed bones, respond Bunn and Kroll, is markedly smaller than that now observed in spotted hyena dens. Furthermore, they note that similar cut mark frequencies were found on limb shafts at a more recent site of carcass defleshing by stone-tool-using modern humans. *—B. Bower*