EARTHQUAKES: THE SOLAR CONNECTION

BY PATRICK HUYGHE

A maverick scientist is shaking up quake predictors by suggesting that solar flares trigger seismic activity.

Editor's note: Much to the consternation of her colleagues, a California scientist believes the sun may trigger such diverse calamities as earthquakes, human illness and arson. Officials charged with earthquake prediction have encouraged her even as scientists scoff. Is this researcher a pioneer in the tradition of Galileo or is she just another overeager soul who has misinterpreted her data to fit her pet theory? Here is her story. After you have read it, decide whether you believe all, parts or none of it.

Geologists understand the action of plate tectonics perhaps better than any other aspect of the earthquake-generating process. The one great mystery that remains is knowing precisely when one tectonic plate will break free of another and set the Earth's crust to crumbling. The key to solving that mystery lies in isolating the final nudge that upsets the balance of frictional forces locking the edges of the plates together.

Biologist Marsha Adams, 38, thinks she may have found that key 93 million miles away from the Earth in the hot, turbulent atmosphere of the sun. Moreover, Adams, who is at SRI International, a nonprofit California think tank, has data she says indicate that certain people can somehow sense the forces that trigger earthquakes *before* they occur.

"I didn't start out as a sun freak," says Adams candidly. "But I've come to realize that almost all variations that occur in biological and physical processes may be the result of fluctuations in solar activity. I have to think very hard to come up with one that isn't. I suspect that geophysical processes—including volcanoes and weather fronts—are related to solar activity in some quite comprehensible way."

Biologist Marsha Adams, seen standing on the San Andreas Fault, links solar flares (top) to health problems as well as quakes.

Adams's journey to solar consciousness began a decade ago in a basement laboratory of the Stanford Medical School, where the young biologist was conducting a study of cardiac stimulants on embryo chick hearts.

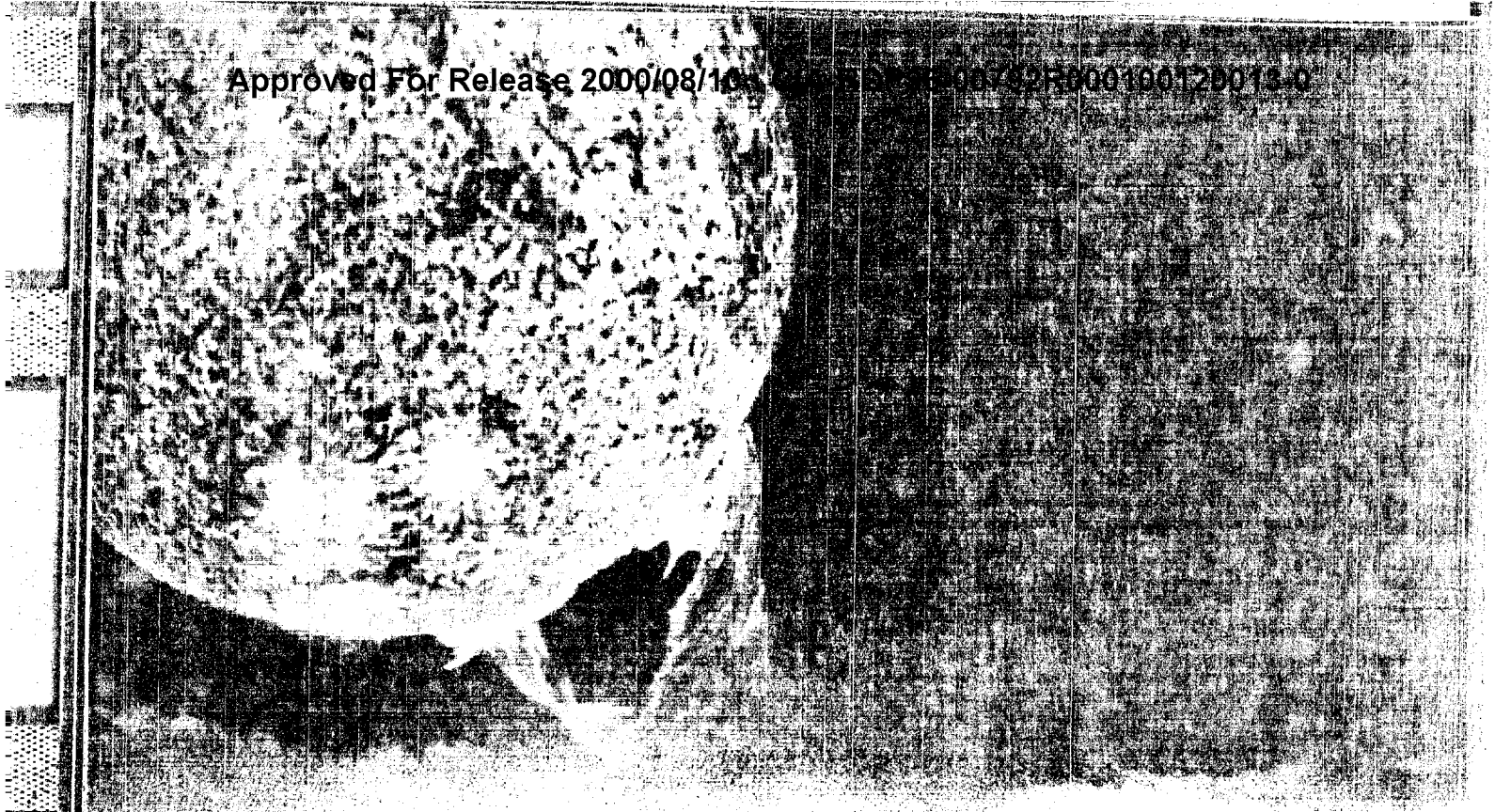
Once the study was completed, Adams prepared to present her results to the American Heart Association, but just a few weeks before she was to do so, her results reversed themselves. Instead of stimulation, the embryo chick hearts began exhibiting depression. Assuming the experimental setup was at fault, Adams dismantled the entire system and changed the platinum electrodes, the stock solutions and the air tanks. No matter what she did, she couldn't replicate her results.

Soon after, though, for no apparent reason, the experiment began to work again. Although they watched several of these reversals, neither she nor her supervisor could explain what was happening. Having taken into account humidity, temperature and all the other factors that biologists usually control in their experiments, Adams was left with only one conclusion: "The chick embryo results were a clue that something in the environment was profoundly influencing biological processes, but at the time I didn't know where to look for the something."

Adams then began to accumulate other instances of biological variability. In 11,000 cases of measured surgical bleeding, for example, she noticed that the measurements of blood loss varied. She screened these cases against a variety of factors in the geophysical environment: cosmic radiation, several measures of geomagnetic and solar activity and a number of standard weather variables such as barometric pressure, temperature and relative humidity. She found that the bleeding anomalies occurred following periods of increased solar activity and preceding large-magnitude earthquakes.

The clinical staff at the Women's Community Clinic in San Jose, where Adams was then research director, wasn't surprised, she says. "They said they could have told me that because everything goes haywire around there a few days before an earthquake. People in the recovery room showed an increase in emotional disturbances and there was an increase in the number of people vomiting and reacting to anesthetics. They didn't have to look at the data to tell when an earthquake was coming. When I challenged them to predict the next earthquake, they did, and the bleeding data showed the expected anomalies."

Opening photograph by Roger Ressmeyer; solar-flare photograph courtesy of NASA



THE SOLAR

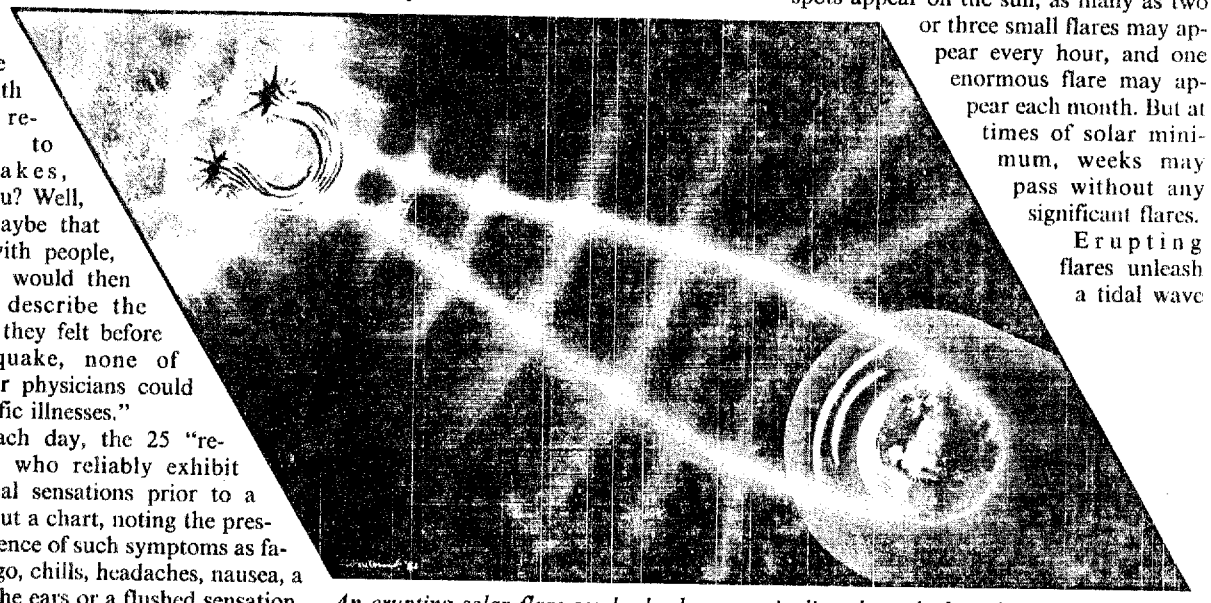
Aware of the fact that certain animals seem to act strangely just prior to earthquakes, Adams formalized a study that used human subjects to forecast them. She had moved to her present position at SRI International, and her only contact with most of the 25 people who are now participating in the study has been over the telephone. She has taken great pains, in the interest of scientific objectivity, for them not to know one another. "Most of them contacted me because they had themselves recognized that their flu-like symptoms seemed to precede earthquakes," says Adams. "Many of those who called would tell me the same story. One said: 'You are my last hope before seeing a psychiatrist.' Another said: 'I feel really weird about this, but you've heard about those Chinese studies with animals responding to earthquakes, haven't you? Well, I think maybe that happens with people, too.' They would then go on to describe the symptoms they felt before an earthquake, none of which their physicians could tie to specific illnesses."

Twice each day, the 25 "responsives" who reliably exhibit physiological sensations prior to a quake fill out a chart, noting the presence or absence of such symptoms as fatigue, vertigo, chills, headaches, nausea, a ringing in the ears or a flushed sensation. The form also provides spaces for depression and fights with a spouse or workmates.

Once the symptoms reach a peak of intensity, the responsives call in on Adams's hot line and give name, date, time of day, the symptom and its strength. This has allowed her to establish a track record for each person that tells her how accurate he or she is with regard to large- or small-magnitude quakes, to local versus distant quakes and to the timing of the event. One person, she reports, has only called in four times, but he has been 100 percent on the mark for earthquakes over magnitude 7 on the Richter scale (8.5 is "devastating"). As a team, the responsives have been accurate between 70 and 80 percent of the time, though Adams has made no attempt to forecast all of the more than 36 earthquakes of a magnitude 6.5 or greater that occur around the world each year. The forecasts she has made are recorded on a Burroughs computer at SRI that timestamps each entry.

"I sit up and pay attention when they call," says Adams. "It's awesome to watch the system work, especially when twelve of the twenty-five people who haven't contacted you for weeks call within a twenty-four-hour period."

She believes that whatever force is triggering these human somatic sensations is probably also responsible for triggering earthquakes and for the well-documented strange behavior of animals preceding those upheavals. Her data suggest that the agent responsible for this and other assorted mischief is an increase in solar activity.



An erupting solar flare sends shock waves rippling through the solar wind and pumps streams of high-energy particles (two horizontal lines) outward. These collide with the Earth's magnetosphere (shaded area), causing magnetic storms that may affect health.

The list of factors Adams claims may be influenced by increases in solar activity is a long one and, unbelievable as it may sound, includes not only earthquakes and periodic human illness but also freak weather conditions, arson, riots, political instability and crime waves. In fact, Adams points out, the Falkland Islands were invaded soon after an increase in solar activity. Railroad derailments and accidents involving airplanes, buses and ships appear on the list as well. All these events tend to occur in specific time slots within about a week of increases in solar activity. Humans normally begin to react within the first few days after a flare, and the earthquakes in about four days.

Adams has already provided several fire forecasts for Andrew Casper, chief of the San Francisco fire department, who has been on the track of an arsonist responsible for more than 30 fires since February of this year. "She's been right on target," says Casper. "When Adams forecasts, the arsonist hits within 72 hours. She's got it down."

Solar flares, which Adams thinks are the crucial factor in this catalog of disasters, are the most spectacular and powerful of all forms of solar activity. These mammoth tongue-shaped protuberances display temperatures in excess of 20 million degrees Kelvin and release the energy equivalent of 10 to 100 billion 1-megaton H-bombs, enough power to supply the United States for thousands of years. Flares usually appear in step with the sun-spot cycle, which reaches a maximum every 11 years. At times of solar maximum, when the greatest number of spots appear on the sun, as many as two or three small flares may appear every hour, and one enormous flare may appear each month. But at times of solar minimum, weeks may pass without any significant flares. Erupting flares unleash a tidal wave of radiation, electrical and magnetic fields and high-energy particles into space, part of which enhance what is known as the solar wind. When this solar debris smacks into the Earth's magnetic field, or magnetosphere, a wide variety of terrestrial effects occur: aurora borealis, geomagnetic storms, electrical surges in power lines and even in the ground itself. During one such outburst in 1859, telegraph operators found that they could transmit and receive messages without batteries.

"What has not been appreciated," notes Adams, "is just how much biological responsiveness there is to solar activity. Unfortunately, studies on solar-terrestrial interactions do not show a one-to-one correspondence. So one wonders if there is not some other factor that might actually be the mechanism that triggers this biological responsiveness. And there is another factor that coincides

Patrick Huyghe, who writes for the New York Times *and science magazines worldwide, met with biologist Marsha Adams in San Francisco.*

with solar activity and that is ELF."

ELF is extremely low frequency electromagnetic radiation (3 to 30 hertz), in other words, very long radio waves. ELF is produced naturally in two ways. The first is through solar activity. When the main bulk of particles shot from the sun during a solar flare finally hits the Earth's magnetic field, it rattles the magnetosphere the way a hungry chimp might shake a bread box. This flapping of the magnetosphere generates ELF. ELF is also produced indirectly through a second channel of propagation—weather fronts.

THE ELF FACTOR

Adams is currently testing the hypothesis that ELF might be the geophysical variable responsible for triggering all kinds of biological and seismic processes. Unfortunately, relatively little work has been done on wavelengths below 100 hertz. But biological processes are known to respond to several frequencies within this range. A somewhat casual German study of 53,000 subjects, for example, seemed to show that people take longer to respond to normal stimuli when they are in the vicinity of ELF waves. Biologists studying ELF have come up with a list of symptoms remarkably similar to those Adams's responsives report.

It is also known that the frequency of alpha brain waves (8 hertz) has a geological parallel in what is called the Schumann Resonance, the frequency at which the length of a radio wave equals the circumference of the Earth. This piece of information set Adams wondering whether ELF might not also help directly trigger earthquakes. Although she doesn't claim to know just how ELF provides the final nudge that brings on the catastrophe, she does speculate on two possible mechanisms: piezoelectricity and magnetostriction.

Piezoelectricity is a process by which electromagnetic energy is converted to mechanical energy or vice versa. It occurs most notably in crystals, and it is the basis for the quartz watch. The quartz picks up the electromagnetic signal and converts it to a mechanical vibration that is then amplified. Perhaps the Earth's crust begins to vibrate through such an effect, says Adams, or through magnetostriction, a process by which certain magnetic materials change shape when they are subjected to a magnetic field. When subjected to an oscillating field, such as ELF, a mechanical motion, or vibration, is produced. Might such a mechanical vibration, set off by ELF at a frequency that resonates with a fault location that has accumulated the most strain, be sufficient to trigger an earthquake? Only further research will tell.

Adams thinks that responsives act as biological transducers and are quicker at absorbing and integrating information than any current scientific instrument. Eventually, however, she expects to be able to separate the human variable from the forecasts. Within a year or two, depending on the availability of funds for proper equipment that will help her create an accurate model, she hopes to make daily forecasts of earthquake probabilities, like a daily weather forecast, using direct measurements of ELF and/or solar activity to supplement the human data.

Certainly the most eye-opening aspect of Adams's current forecasting system is the finding that responsives need not be in the vicinity of an earthquake in order to forecast it. Low-frequency radio waves travel around the world many times with minimum attenuation because the cavity between the Earth and the ionosphere acts as a vast natural resonator for electromagnetic energies of these wavelengths. This effect allows responsives in one locale to predict quakes anywhere in the world.

"I strongly suspect," says Adams, "that the information that would allow us to determine location can be found in the symptoms themselves. What seems to be happening is that even a person who has the same symptoms over and over may have additional symptoms that appear to be location dependent. For instance, I've noticed that the flushed sensation and chills seem to be prevalent for earthquakes that are to occur within a two-hundred-mile radius of San Francisco Bay. The timing of the calls may also provide location clues. Looking at track records, I've noticed that for some individuals, if the quake doesn't occur within a day of their call, the probability of the disturbance being local decreases."

The theory's potential applications probably played a large part in capturing the public's attention when news of her work leaked to the press last September. California's Governor Jerry Brown was intrigued enough to call her, and subsequently Adams was invited to describe her work before a hearing on earthquake prediction and preparedness held by the state's Assembly Committee on Governmental Operations. The committee gave her a courteous reception and wished to

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AMAZING RAYS

A painful sunburn or skin cancer are only the most obvious effects of sunlight on human health. The sun may also have the power to alter your moods, your immune system and perhaps even your fertility.

Evidence suggests that secretions of melatonin—a hormone linked to reproductive function in some animals—are regulated, in part, by daily cycles of light and dark. MIT endocrinologist Richard Wurtman and his coworkers have found that humans secrete more melatonin between 11 P.M. and 7 A.M. Further, Alfred Lewy, a research psychiatrist at the Oregon Health Sciences University, and his colleagues have recently shown that bright artificial light and sunlight turn off this melatonin secretion. These responses are thought to be mediated by visible light (part of the sun's spectrum), which acts on photoreceptors in the eye. Lewy has found that some blind people have different melatonin-secretion rhythms than people with normal sight.

Although in some animals melatonin inhibits ovulation and causes adult gonads to regress under certain conditions, evidence for a link between light and fertility in humans has so far been indirect. One four-year study reported that most women in north Finland conceived during the summers, when there are about 20 hours of sunlight a day. And an Italian study showed that in spring teenage girls had a 10 times greater secretion of a hormone that affects the ovaries than they did in autumn—presumably in response to the influence of increasing versus decreasing daylight.

Some people who suffer from manic depression, a mood disorder, are abnormally sensitive to light; Lewy and his co-workers discovered that some sufferers stop secreting melatonin at a lower-than-average light intensity. But whether the hormone directly affects mood or is just a marker for other biochemical changes going on inside the body is not known.

Other evidence indicates that the sun's ultraviolet light impairs the human immune system by causing abnormalities, at least temporarily, in white blood cells. Work with animal cells at Harvard Medical School has demonstrated that exposure to ultraviolet rays prevents the proper functioning of cells involved in fighting infection and, at the same time, stimulates suppressor cells, which normally turn off the immune system.

–Madeline Chinnici

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be apprised of further progress in her research.

The U.S. Geological Survey's (USGS) Office of Earthquake Studies in Menlo Park, California, also gave her an opportunity to present her work, but the majority of its scientists apparently felt that the evidence she presented was not persuasive enough to warrant funding by the USGS. C. Barry Raleigh, a geophysicist with the USGS at the time, however, indicates that they encouraged her to pursue her work.

Dealing with a subject of such scope involves risks, and Adams's theory has invited its share of criticism, much of it from geologists. "I never saw pulled together the kind of critical evidence required to make a hypothesis like that be even marginally acceptable," says Raleigh, currently director of the Lamont-Doherty Geological Observatory, who has been outspoken in his criticism of her work. "The idea is interesting, but it was not backed up to my satisfaction by an adequate body of objective data that could allow you to decide if there was anything to it or not. Probably the weakest link in her work is that there is no reasonable physical model that might explain the phenomenon. But there is obviously something in the idea that has her convinced."

PREMATURE EXPOSURE

Adams regrets the premature publicity she has received. It has forced her to present her work through the media, without first having the results presented in a scientific journal and, even more important, without first having completed a rigorous analysis of all her data.

Even in its formative stage, however, Adams is clearly excited by the theory. "Here is a variable that we are not aware of and yet is present and influencing all our lives," she says. "I think everyone may be sensitive to it to some degree. It's just that people are not aware of what to look for. It's a matter of exposure, recognition and awareness. Unfortunately, I think that right now we are culturally biased against this particular variable."

While many of Adams's colleagues remain skeptical about her work, her notion that the sun has a profound effect on our lives would certainly have come as no surprise to Uncle Joe Cannon, the venerable Speaker of the U.S. House of Representatives between 1903 and 1911. During a debate on appropriations for solar research, it was Uncle Joe who argued: "Everything hangs upon the sun, sir, and it ought to be investigated." ■

Do you want to know more about how the sun affects us? See next month's Science Digest *story about the exciting research on the solar wind's role in the aurora borealis.*

KINFOLK

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effect—the character of the original gene pool. If the first ancestors did not have a particular genetic disease, then it is unlikely to appear in their descendants.

"These communities are microcosms, living laboratories of what can happen from generations of inbreeding," says Dr. Martin Greenberg, head of pediatrics at a hospital near the Ridge. Although no one has done any clinical studies on the Ridge, such as those that have been done on the Amish (see page 87), the families there reveal and talk about problems that Greenberg says may be hereditary. "From what I have seen and what I am aware of, there are some abnormalities that seem to be related to disorders of the bone, connective tissues and joints. Also apparent in some of the families is an increased incidence of neurological problems, ranging from strokes and seizures to cases of mental retardation."

FEAR OF INBREEDING

The severity of the punishments often given to those who have violated taboos against incest would seem to reflect a very profound fear of inbreeding. It is hardly surprising that the sporadic and often sudden appearance of physical or mental illness among children of consanguineous marriages is seized on as the ultimate justification for such taboos.

The problematic history of incest and the simultaneous fragility and strength of human evolution are only a few of the dilemmas one faces in trying to understand the meaning of communities like the Ridge. How can you separate the social and medical effects of inbreeding? In judging the medical effects of inbreeding, how certain can we be about the nature of the original gene pool?

How can we decide which society is more advanced: the community that tolerates and cares for the sick and the old in the normal run of family life or the one that puts them away in institutions?

Greenberg had listened for years to tales of violence and mental disturbance on the Ridge. Finally, he went up to see for himself. "What is striking about these people," he says, "is not so much their genetic problems. Rather, it's the whole area of social interaction, their tolerance and caring, the interdependence, the acceptance, the charity, the openness of their loves and their hates."

In spite of its anarchies and contradictions, occasional ugliness and the labyrinth of legends, there are lessons to be learned on the Ridge. "Nature," wrote William Harvey in 1657, justifying his interest in rare diseases, "is nowhere accustomed more openly to display her secret mysteries than in cases where she shows traces of her workings apart from the beaten path." ■

NATURE'S HIDDEN POWER LINE

Everyone knows about the kind of electric current provided by utility companies. Less familiar are the currents manufactured by nature's own powerhouse. Charged particles from the sun set off oscillations in the Earth's magnetic field at the edges of the atmosphere. These pulses in turn induce electric currents on the Earth.

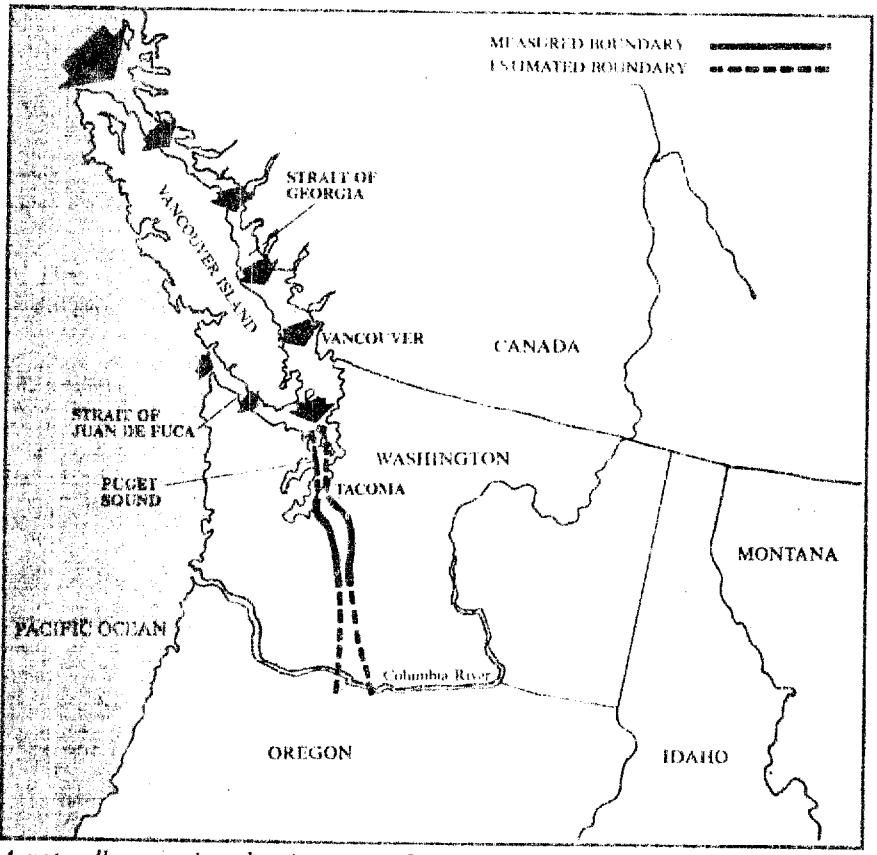
John R. Booker, a geophysicist at the University of Washington, was studying the structure of the western seacoast when he came across an immense current, one far too strong to be caused solely by local phenomena. In early 1980, he and co-worker Gerard Hensel traced the current along a line that runs roughly southeast from Tacoma, Washington, to the Columbia River.

An electric current will usually flow more easily through water than through land, but rock that holds water in its pores tends to be highly conductive. Booker discovered that his current flows along a thin wedge of porous sedimentary rock squeezed between older, denser continental crust to the east and ocean crust being pushed in from the west.

Booker believes the current is induced in the Pacific and travels down between Vancouver Island and the Canadian mainland. Then, prevented by a milder incoming current from following the path of least resistance back to the ocean, it continues south down Puget Sound, where it leaks into the continental mass. The current's path coincides with a seismic fault, and scientists hope that mapping it will provide information about the region's geological structure that can help them evaluate earthquake hazards.

Although the current flows along at a powerful rate, local residents won't be able to plug their toasters into their backyards. The rock vein's high conductivity, says Booker, makes it impossible for the energy to be concentrated and tapped. □

A CAMEL CAN SURVIVE in the desert not because its hump stores water, but because it stores fat. As the fat is broken down, hydrogen is given off. This mingles with oxygen inhaled by the animal and creates--you guessed it—water.



A naturally occurring electric current flows through a wedge of porous rock in the Pacific Northwest, coincident with a seismic fault. By mapping the current's path, researchers may uncover clues to the region's geology and earthquake potential.

WORLD SPACE CAPITAL RISES IN BALTIMORE

Beginning in early 1985, the world's capital of astronomy will not be a windswept mountain in California, a volcano in Hawaii or even a huge telescope in the Soviet Union. It will be a five-story building in downtown Baltimore.

The Space Telescope Science Institute (STSI), now being built at Johns Hopkins University, will be the final destination for data transmitted from the Space Telescope, an orbiting observatory that project scientists say will see objects 50 times fainter and 7 times farther away than can be detected by the largest Earth-based telescopes.

Once the Space Telescope is placed into orbit by the space shuttle and begins its observations, a crew about 80 strong will operate the STSI around the clock. As one scientist's experiment ends, another's will begin, and by the end of one year it is estimated that the facility will have hosted more than 150 visiting astronomers from around the world.

Data and pictures from the Space Telescope will first be transmitted to NASA's Goddard Space Flight Center in Greenbelt, Maryland, where the craft's ground systems are located, and then relayed to the STSI's on-line observation area. As the data become public, after about a year, they will also be sent to a European Space Agency facility now under construction in Munich.

"Calculations suggest that the Space Telescope will be able to see any Jupiter-size planets orbiting Sun-like stars as far away as ten light-years—possibly twenty to thirty," says project scientist C. R. O'Dell. There are 11 stars within ten light-years of the Sun, 76 more within a radius of twenty light-years.

If all goes according to blueprints, astronomers at the STSI will carry out the renaissance of optical astronomy in pleasant surroundings. "The Institute is being built into the side of a hill in a very wooded section. It's a nice rural setting within a city," says chief facility manager H. James Lyall. The building will include a library, data archives, a 200-seat lecture hall, a skylit lobby, a terrace cafeteria and office space for support staff and visiting scientists.

The STSI is being built under the aegis of AURA (Association of Universities for Research in Astronomy), a NASA-funded consortium that proposed the institute. It already operates three ground-based □

Illustration by C. Y. Williams