MEETING BRIEFS

Geophysicists Take a Tour Around the Solar System

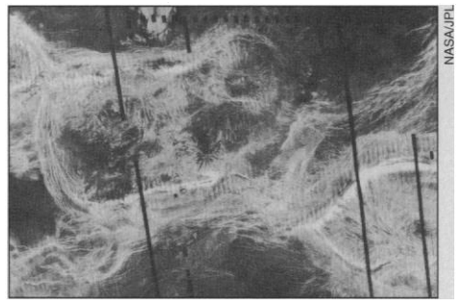
Never one to take its middle name too literally, the American Geophysical Union indulged the interests of a range of extraterrestrial researchers at its spring meeting last month in Montreal. In a session on the big icy bodies of the outer solar system, attendees saw the first view of the face of Pluto. In another session, on dating small rock samples, listeners heard evidence that the moon might have been battered in its youth. And a session ostensibly devoted to Earth's mantle yielded news that some form of plate tectonics seems to be operating on Venus.

Venus May Be Earth's Half-Sister After All

"I am convinced there are places on Venus where there is some sort of plate tectonics going on." So Dan P. McKenzie of Cambridge University began his American Geophysical Union talk, plunging right to the heart of an issue that has plagued Venusian specialists ever since spacecraft first returned radar images from Earth's neighbor planet in 1979. Based on those low-resolution images, some researchers had proposed that global plate tectonics might be at work on Venus, as it is on Earth, but the first round of images from the Magellan spacecraft ruled that out last year. Now a close look at Magellan images has convinced McKenzie that a sort of plate tectonics is at work on Venus after all. But this is plate tectonics of a more modest kind than on Earth, where new crust created along globe-encircling ridges moves thousands of kilometers in great plates before finally sinking into the planet's deep interior at trenches on the ocean floor.

McKenzie's picture of plate tectonics on Venus would limit it to patches: the so-called coronae, great circular regions filled with volcanic outpourings and often rimmed by troughs. The granddaddy of the coronae—and McKenzie's case in point—is Artemis, a 2600-kilometer blotch on the edge of the equatorial highland Aphrodite Terra. "In Artemis, I don't think there's any doubt" that new crust is forming and spreading outward, as it does at mid-ocean ridges on Earth, says McKenzie. And beyond the perimeter of Artemis are 4-kilometer-deep gouges that, to McKenzie, look for all the world like the deep-sea trenches where Earth's plates dive into the mantle.

Recognizing a bit of Earth on Venus wasn't all that hard, according to McKenzie. "The key was knowing what the earth looks like when imaged the same way [as Magellan images Venus]." The telltale comparison was with images from GLORIA, a towed, unmanned submersible that uses sonar to trace the features of the sea floor much as Magellan uses radar to trace those on Venus. GLORIA's images of Earth's mid-ocean ridges emphasize not the ridges themselves but less massive features such as the offsets between ridges—known as transform faults—and the low volcanic hills scattered around the ridges. And Magellan picked up much the same features in the interior of Artemis, says McKenzie. Indeed, when he showed Magellan images to a colleague down the hall, without letting on where they came from, "his first reaction was, 'I haven't seen these before; what part of the world's ocean are they from?'"



A sinking sensation. A crustal plate is likely descending into Diana Chasma (*bottom*).

The trenches just outside Artemis, where subduction seems to be occurring, were just as easy to recognize for what they are, says McKenzie. The Magellan observations reveal striking similarities to deep ocean trenches on Earth, according to comparisons reported at the meeting by McKenzie and his colleagues and by Gerald Schubert of the University of California, Los Angeles, and David Sandwell of the Scripps Institution of Oceanography.

Viewed from above, two of the most prominent of these features, Diana Chasma and Dali Chasma, trace out arcs that could be mistaken for the scalloped lines of trenches in the southwest Pacific. And in cross-sectional views based on Magellan's altimetry observations, the chasms have a telltale bulge on the side facing Artemis, reminiscent of the sea-floor swelling found on one side of deep ocean trenches. On Venus just as on Earth, it seems, plates bulge upward as they bend down into the mantle. But geophysicist Sean Solomon of the Massachusetts Institute of Technology, a colleague of McKenzie's on the Magellan team, has difficulty with that interpretation. He points out that, according to calculations by Sandwell, the bulges imply that the subducting plates on Venus are just as thick—40 to 50 kilometers—as plates on Earth. Yet because of its 475°C surface temperature, Venus is thought to have a much thinner rigid layer at its surface than Earth.

Even so, Solomon says he's "inclined to think that [McKenzie] may be right; it's certainly the best hypothesis we've got." Researchers had already surmised that plumes of hot rock rise beneath the coronae, driving the volcanic activity at the surface. Solomon can imagine that the rock added by the volcanic activity might form new crust that would slide outward and down into a trench.

But even though such cycling of interior rock through the surface is the main way Earth loses its internal heat, the process is unlikely to play the same role on Venus, says Solomon. Though potential subduction sites are more widespread—Schubert estimates that there are at least 15,000 kilometers of trenches or troughs around coronae—McKenzie can find no other example of crustal spreading as clear as that in Artemis. Solomon suspects that only the largest coronae could manage this semblance of plate tectonics. With plate tectonics as nothing more than a sideline, Venus would have to find some other way of keeping cool.

Did the Moon Suffer a Cataclysmic Bombardment?

After a traumatic birth, conventional thinking holds, the moon settled down to relative quiescence. Late in the bumper-car pileup of planetesimals that formed Earth 4.5 billion years ago, one Mars-sized impactor smashed into the newborn planet and splashed off the rock that would coalesce into the moon. But over the next few hundred million years, so the theory goes, most of the remaining planet-forming debris was swept up, leaving only scattered rocks to pelt the earth-moon system. Two lunar researchers, however, think that wasn't the end of the story.

Armed with new analyses of moonrocks from the Apollo missions, geochronologist Brent Dalrymple of the U.S. Geological Survey in Menlo Park and planetary scientist Graham Ryder of the Lunar and Planetary Institute in Houston are reviving a 20-year-old idea that the moon suffered a late spasm of bombardment from an as yet unidentified source, some 600 million years after its formation. This delayed barrage, they say, is responsible for all of the major features visible on the moon today, including the great basins that later filled with dark lavas to make the man in the moon. And because Earth would also have been caught in the barrage, the cataclysm might have influenced the emergence of life.

The suggestion of delayed birth pangs in

the earth-moon system dates to the early 1970s, when geologists were feverishly studying the moonrocks returned by the Apollo missions. By dating bits of rock that congealed from the puddles of magma left by large meteorite impacts, researchers tried to trace the moon's history of bombardment. They expected to find a steady decline in the impact rate after the moon's birth, 4.5 billion years ago. But instead they found no impact ages greater than about 3.9 billion years, when a flurry of impacts seemed to have struck. Thus was born the concept of a "terminal lunar cataclysm."

But in the 1970s and 1980s, the tide turned against the concept. Nobody could explain why a major bombardment should have held off until so long after the formation of Earth and the moon. And some researchers argued that the daters might have been led astray because they were analyzing widely scattered samples from a single giant impact 3.9 billion years ago, or because older melt rocks in their samples were contaminated with younger rocks.

At the meeting, Dalrymple and Ryder presented new data they think is less open to such criticisms. Their evidence comes from 12 impact melt rocks returned by Apollo 15 astronauts from the highlands between the huge Imbrium and Serenitatis impact basins. Ryder picked samples with differing compositions, on the assumption that each composition represents melt rock from a different impact. And Dalrymple used the latest in radiometric dating—the laser argon-argon technique—to date samples as small as 60 micrograms. That allowed him to analyze single bits of melt rock rather than larger samples that might be a jumble of rocks of different ages. The result: All 12 melts are younger than 3.87 billion years old.Given these results and previous impact dates, says Ryder, "you can't be totally definitive, but it seems to me it almost hits you in the face" that there was something like a hundred-fold increase in the rate of impacts about 3.9 billion years ago, lasting some tens of millions of years.

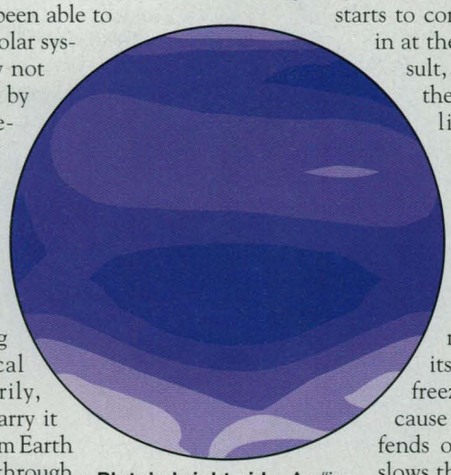
Despite Ryder's enthusiasm, most specialists in planetary cratering remain to be convinced. William Hartmann of the Planetary Science Institute in Tucson thinks Dalrymple and Ryder can't find impact melts older than about 3.9 billion years precisely because impacts were more frequent before that date—so frequent that they obliterated the earlier record. Only when the bombardment rate declined after 4 billion years ago would datable impact melt have remained. Dalrymple and Ryder disagree. "The big flaw in Hartmann's argument is that older material was preserved," says Dalrymple, referring to older maria basalts and crust dated in earlier studies. Hartmann responds that finding a bit of old crust is not the same as identifying less common melt rock.

Beyond that debate, there is still the question of how a sizable collection of planetary building blocks could have avoided being swept up for half a billion years and then fallen all at once. Perhaps Earth originally had several moons, speculates Ryder, which broke up 3.9 billion years ago, subjecting Earth and the remaining moon to the terminal bombardment. Wherever the source of the putative bombardment, Ryder thinks it's no coincidence that the first signs of life on Earth date from 100 million years or so after the bombardment ended. He speculates that the bombardment may have somehow created the necessary conditions for life's origin.

In search of more evidence for such speculations, Dalrymple and Ryder plan to date melt rocks from the three other Apollo missions to the lunar highlands. With no immediate prospects of a return to the moon for more rocks, earthbound geologists have to hope that the Apollo astronauts-cum-geologists picked up all the right rocks.

The Tiniest Planet Shines in Its Best Portrait Ever

A minuscule ball of ice and rock only two-thirds the size of Earth's moon, Pluto wandered the fringes of the solar system after its 1930 discovery as no more than a blurry point of light in the best telescopes. No spacecraft has ever swooped by to get a closeup view. But by watching Pluto's point of light flicker as its moon Charon sweeps across the face of the planet, researchers have been able to build up an image of the solar system's last recluse, a view not likely to be equaled even by the Hubble Space Telescope. And the newly revealed visage adds a new mystery to Pluto, showing the sunniest part of the planet to be cloaked with wintry ice.



R. BINZEL AND E. YOUNG

Pluto's bright side. An "ice cap" cloaks the south pole.

Astronomers owe this glimpse of Pluto's puzzling features to astronomical happenstance. Ordinarily, Charon's orbit doesn't carry it across the line of sight from Earth to Pluto, but from 1985 through 1990, Charon repeatedly passed in front of the planet (*Science*, 2 January 1987, p. 30). During each transit, as the moon passed across features of varying brightness, the Pluto-Charon system waxed and waned in earthbound telescopes. Those brightness fluctuations provided the data for two maps of the distribution of brightness across Pluto. One was presented at the meeting by astronomers Richard Binzel and Eliot Young of the Massachusetts Institute of Technology, and the other was prepared by Marc Buie of Lowell Observatory and David Tholen of the University of Hawaii.

In both maps, the planet's south polar region is dazzlingly bright, presumably because it is cloaked with frozen methane and other ices, while the north pole bears a smaller, less brilliant "ice cap." That's a puzzle, because the south pole is just reaching the end of a century-long summer, in which the tilt of Pluto's axis kept it in perpetual sunlight; all that time, the north pole was in shadow. That southern summer was all the stronger because Pluto has just passed its closest approach to the sun. All told, the south pole seems an unlikely place to find so much ice.

Having seen the puzzling polar cap through an accident of celestial mechanics, Young and Binzel are now appealing to celestial mechanics to explain it. Pluto's 248-year orbit, the most eccentric in the solar system, carries the planet as close to the sun as 4.4 billion kilometers—closer than Neptune—and as far away as 7.4 billion kilometers. On Pluto's excursions inwards, researchers believe, the relative warmth of the sun forms a wispy atmosphere by vaporizing frozen gases, among them methane and nitrogen (the latter first detected late last month by Tobias Owen of the University of Hawaii and his colleagues). But when Pluto plunges back into the most distant reaches of the solar system, most or all of its atmosphere should freeze again onto the coldest parts of its surface.

As it happens, the orientation of Pluto's axis ensures that just as the planet begins moving away from the sun and its atmosphere starts to condense, darkness sets in at the south pole. As a result, say Binzel and Young, the south pole is the most likely place for ice deposition when the atmosphere condenses. And even though the south pole has been in full sunshine for a century, it still bears a residual ice cap from its decades in the deep-freeze, perhaps in part because its high reflectivity fends off sunlight and thus slows the evaporation of the frost, note Binzel and Young.

Astronomers will be modeling the effects of Pluto's seasonal extremes to see if this scheme holds up. But what might confirm this picture is a closeup view of Pluto and Charon from a spacecraft. Would-be Pluto explorers will have to hurry. The planet is already moving away from the sun, so that the 12-year trip now required by any probe will only get longer; as a result, planetary scientists are pushing for a launch early in the next decade. There's another reason for haste: With each passing year, there will be less to study at Pluto—the atmosphere will soon be dwindling away.

–Richard A. Kerr