Research in Progress

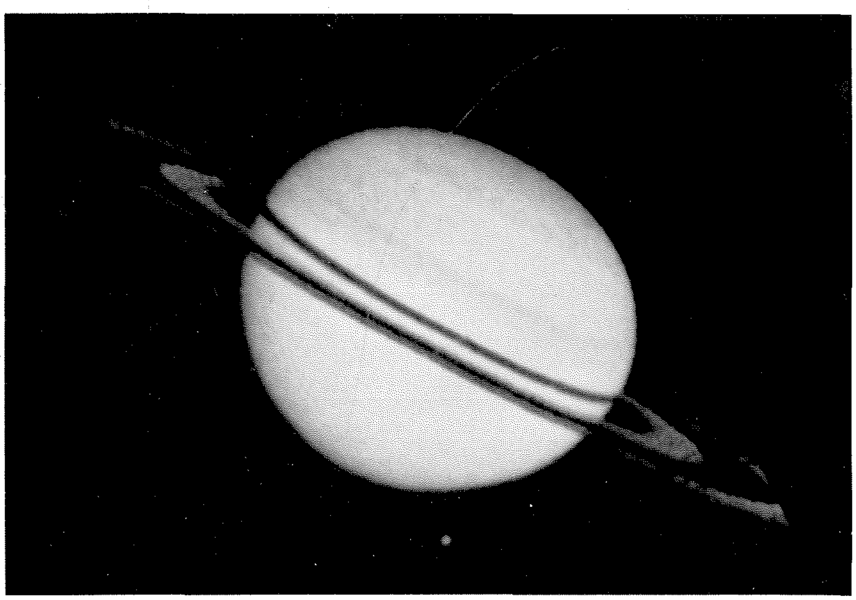
Saturn

Although the Voyager (1 and 2) pictures of Jupiter were a main feature of 1979, old Pioneer 11, launched nearly seven years ago, is still out there providing some very interesting information as well as some nice previews of coming attractions. Renamed Pioneer Saturn for its latest encounter, the spacecraft reached Saturn on September 1, 1979, passing through the ring plane outside the A-ring, and under the rings to within 21,400 kilometers of the planet's clouds. Its cameras took the closest pictures yet of Saturn, which, although they are not as close as and don't have the fine resolution of the recent Jupiter shots, still offer more detail than the best earth-based photographs. In addition to pictures, Pioneer's instruments sent back data that are revealing previously unknown facts about Saturn and helping to confirm theories about the solar system's formation.

For one thing, Saturn's helium is sinking into the planet's interior, says Professor of Planetary Science Andrew Ingersoll, principal investigator for Pioneer's infrared radiometer. Jupiter and Saturn and the sun have the same ratio, in bulk, of hydrogen to helium, the two most abundant elements in the universe. But whereas Jupiter appears to have that same percentage of helium (12 to 13 percent of the total number of molecules) in its outer layer where it can be measured, Saturn has approximately 6 percent.

This was discovered by superimposing the results of two experiments. The measurement by Ingersoll and his co-workers of the infrared radiation coming out of the atmosphere can be related to the temperature in the upper atmosphere, but this measurement is not very sensitive to composition. However, when JPL's Arvydas Kliore compared radio occultation data on the structure of the index of refraction for the same portion of Saturn's atmosphere with Ingersoll's temperature measurements, the composition shown in Kliore's results could be adjusted to match the temperature. About half the helium that should be in Saturn's outer layer isn't there.

John D. Anderson, also of JPL, was principal investigator for the celestial mechanics experiment. Using the Doppler shift signal in the microwave carrier that tracks Pioneer, he was able to measure Saturn's gravity field. Essentially, the spacecraft itself was acting as an instrument, allowing him to look at its motion and measure how the gravity field affected it. These data can be interpreted in terms of gravity sounding (a technique suggested by William Hubbard of the University of Arizona), which is the only experimental technique for "getting into" the interior of



Pioneer Saturn's imaging photopolarimeter took this picture of the planet and its rings 2,500,000 kilometers away, 58 hours before its closest approach. Here the rings are illuminated from below and look different from earth-based photographs where the illumination is from above the rings. The planet's banded structure can be seen particularly in the upper half above the distinct shadow cast by the rings. Saturn's moon Rhea is the bright spot below the planet.

large planets. Anderson's and Hubbard's data, together with Ingersoll's temperature measurements, show that Saturn's mass is concentrated at the center, which supports the conclusion that the heavier helium has sunk inward.

Ingersoll's infrared radiometer also discovered that Saturn, like Jupiter, has an internal heat source. Both planets have retained a significant amount of their primordial heat, generated 4½ billion years ago by the astronomical event that formed the solar system. Saturn, however, since it is less massive than Jupiter and farther from the sun, should have cooled off more than it has; the earth, although it is closer yet to the sun, has lost all but an insignificant part of its primordial heat because it is so much smaller. Discovery of this greater-than-expected internal heat source adds still more evidence to the argument that the helium is settling, since that process would generate heat.

Actually, the separation of helium had already been predicted. Theoretical calculations by David Stevenson, currently at UCLA, on the behavior of mixtures of hydrogen and helium at the high pressures characteristic of the interiors of giant planets indicated that the two elements should stay mixed on warmer planets, such as Jupiter, and separate on Saturn and other cooler planets. Pioneer's data bear this out.

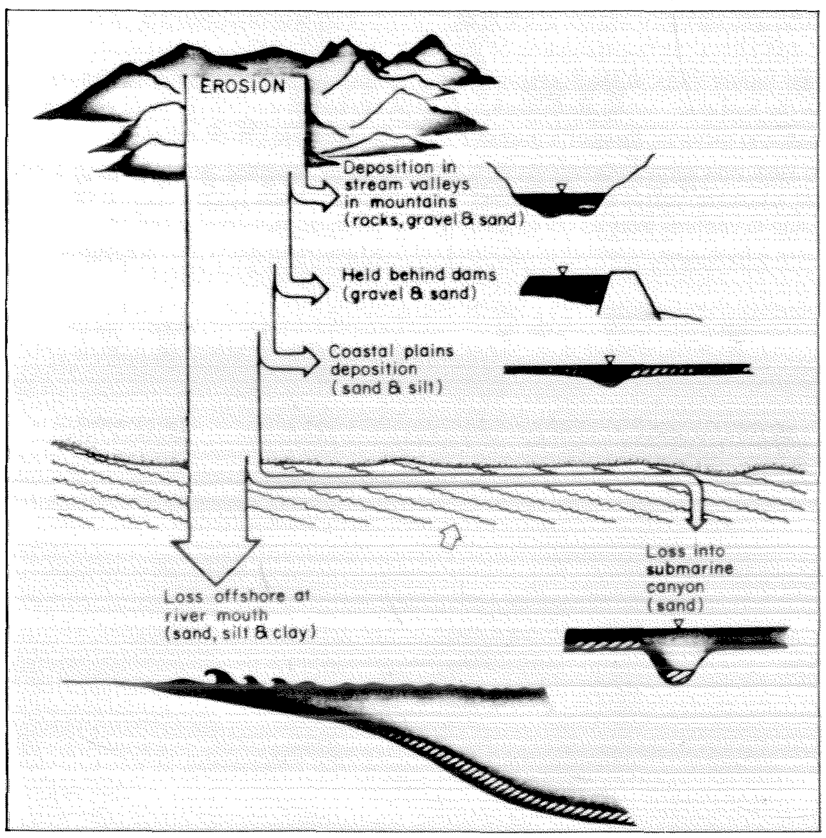
This new information on the differences in heat flux between Jupiter and Saturn is consistent with planetary scientists' observations and theories of the cooling history of the solar system, based on the idea that all the planets originated at the same time in a violent event. Pioneer's evidence gives scientists more confidence that their understanding is correct.

Pioneer 11 is now on its way out of the solar system into interstellar space. But Saturn is expecting other visitors. Voyager 1 is scheduled to arrive in November 1980 and Voyager 2 in August 1981. And a Saturn Orbiter Probe is proposed for the late 1980s or early 1990s. Although Saturn is not expected to be as "cooperative" or "photogenic" as Jupiter, all these closer pictures and experiments should reveal still more of the secrets of the solar system.

Sedimental Journey

Sediment moves. It washes down off the mountains of southern California in streams and rivers, forming large alluvial fans at the base of the mountains where the coarser material is deposited, and beaches, where many of the sand-sized particles end up at the shoreline. Still finer silt is carried offshore where it sinks in deeper waters. These are all natural processes of the environmental system.

But the presence of millions of people between the mountains and the coast in southern California has made it necessary to modify some of these natural processes by building dams for flood control and water conservation, plus harbors, piers, and breakwaters. Each year in this area hundreds of millions of dollars are spent by federal, state, and local agencies on sediment management to protect against property damage and human injury, while allowing for full use of natural resources and protecting the natural environment — all at the same time. In the past all these agencies have operated somewhat independently in their different jurisdictional responsibilities and without benefit of a clear, comprehensive description of the



A schematic drawing of the overall sediment flow from the mountains to the sea shows approximately how much of it goes where. Beach sand (lowest arrow extending right) is not a large percentage of the total. The small arrow pointing in toward the shoreline indicates the direction of the wave action.

This series of groins (or jetties) that reach out into the ocean were placed along the beach at Pacific Palisades to stop the movement of sand, and they now provide a good illustration of how the natural transport of beach sand works. Wave action piles up sand on the north side of the groins, depleting the beach to the south. The effects of this interference would be much more severe at Santa Monica beach immediately to the south, if it were not for substantial artificial nourishment of that beach.

natural system and the specific effects of human interference on the system as a whole.

That's why Caltech's Environmental Quality Laboratory, in collaboration with the Shore Processes Laboratory at Scripps Institution of Oceanography, embarked four years ago on a long-term, region-wide study of the problem, with EQL's director, Norman Brooks, and D. L. Inman of Scripps as principal investigators. Brent Taylor, also of EQL, is project manager for the study, which is officially entitled Sediment Management for Southern California Mountains, Coastal Plains and Shoreline.

The shoreline itself, however, is not the end of the line for the sand-sized particles deposited there by streams and rivers. Waves and currents continually transport the sand southward, forming and nourishing other beach areas until eventually the sand is lost from the beaches to offshore areas via submarine canyons. So the beaches must be constantly replenished. This natural system is dynamic and fluctuates widely and often unharmoniously; for example, in 1969 the Santa Clara River delivered 10 million cubic meters of shoreline sand, but in the following year only one-one-hundredth of that amount. Only over several years can any equilibrium be maintained, and when man jumps into this naturally "balanced" equation and fiddles with the sediment supply and wave actions, the beaches must ultimately suffer. Because of upstream dams and a harbor built during World War II, the beach at Oceanside has already been reduced to cobblestones.

The initial phase of the Caltech-Scripps study, currently nearing completion, intends to provide a geographically detailed quantitative definition of annual sediment movements under natural conditions throughout the coastal region and of the consequences of man's intervention in these movements.

The sediment management team has found that each year an average of more than 12 million cubic meters of sediment are eroded from upland areas between Point Conception, north of Santa Barbara, and the Mexican border. Of the 12 million cubic meters, 6 million are finer than .06 millimeters (silt and clay size), 5 million are sand-sized material, and 1 million are coarser than 2 millimeters. Under natural conditions, half of the 5 million cubic meters of sand is deposited on inland flood plains. The study indicates that human interference may have reduced the remaining half by as much as 40 percent; that is, from 2.5 million cubic meters of shoreline sediment delivery per average year to 1.5 million.

This reduction has been partially offset by artificial nourishment of beaches brought about by coastal dredging and redisposal of sand, for example, in Marina Del Rey in Los Angeles and Mission Bay in San Diego. In fact, the average artificial nourishment during the past 40 years has been roughly equal to the estimated natural supply — 2.5 million cubic meters per year — but distributed differently, as to time and place, from what would have occurred naturally. However, with increasing environmental concerns, it is doubtful that shoreline construction (harbors), which makes sand available for beach nourishment, will be permitted to keep up that pace in the future.

Study results suggest that we are probably entering a period when the full effects of human intervention will be increasingly felt — that is, there will be more and more beach erosion. So it is especially urgent that the agencies involved understand this natural system and cooperate to manage it carefully, to engineer an acceptable balance so that future generations will be able to enjoy the end product of the "sedimental journey" — sand beaches — without at the same time having to suffer the effects of its muddy onset.