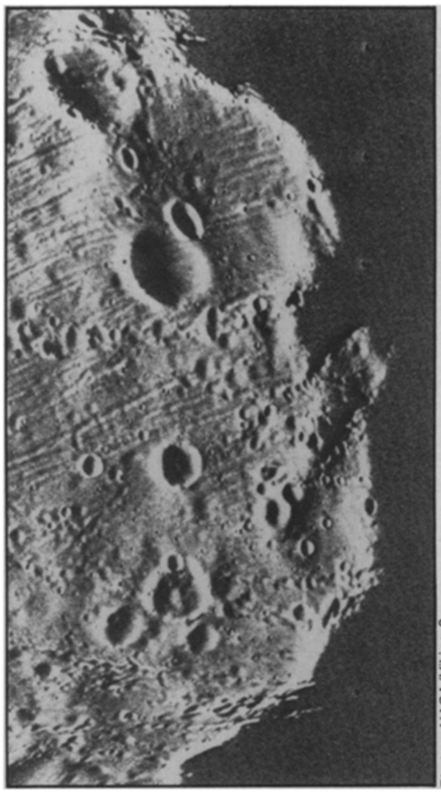
Viking: Moons, Ice Caps and Magnetospheres

The latest week in the long-running, multispacecraft Viking Mars mission has surely set some kind of record for scientific diversity, ranging from a record-close photo of the planet's larger satellite, Phobos, to possible evidence for a Martian magnetic field, to the discovery of important trace constituents in the atmosphere. And more. So heavy was the flow of data and instructions through the mission's computers, in fact, that by Sept. 24, when the Viking 1 orbiter completed its two-week photographic "walk" around the planet, geologists had seen only a single day's worth of pictures from the trek. But there were plenty of other results to go around.

Orbiter 2's remarkable close-up of Phobos, for one, taken from only 880 kilometers away, crowned the triumphal achievement of a feat that had been accomplished in previous spaceflights only with the aid of astronauts or multimillion-dollar automatic motion compensators. The problem was to get close to the target without having the resulting photos blurred from the motion of the target or the spacecraft. On Gemini 5 and Apollo 14, the task was accomplished by rolling the spacecraft in a direction that would compensate for the changing geometry. The last three Apollo missions used gyroscopic compensators much like those employed in airborne photo-reconnaissance, but these were deleted from the Viking orbiter cameras to save money. The Viking solution was to slew, or turn, the "scan platform" on which the cameras and other instruments are mounted, a complex calculation job involving the scan rate, the motion of Phobos and the speed, orientation and direction of flight of the spacecraft itself. Five photos were attempted; two of them were right on the money.

Revealing features as small as 40 meters across, the photos showed central peaks in some already known large craters, as well as chains of much smaller craters (such as are believed to be secondary craters on Mars, Mercury and earth's moon) and a mystery: numerous, pronounced striations, covering more than half of the part of Phobos that is visible in the images. "We've never seen these before," says Thomas C. Duxbury of Jet Propulsion Laboratory. "In fact, this is really puzzling." One proffered idea was that they could be grooves carved by ejecta from a large crater not visible in the photos but close enough for the tracks to seem nearly parallel. Other possibilities included the effects of Phobos's passage through a cloud of debris, or fracture lines


Photos: NASA/Viking 2

Phobos up close: Mysterious striations.

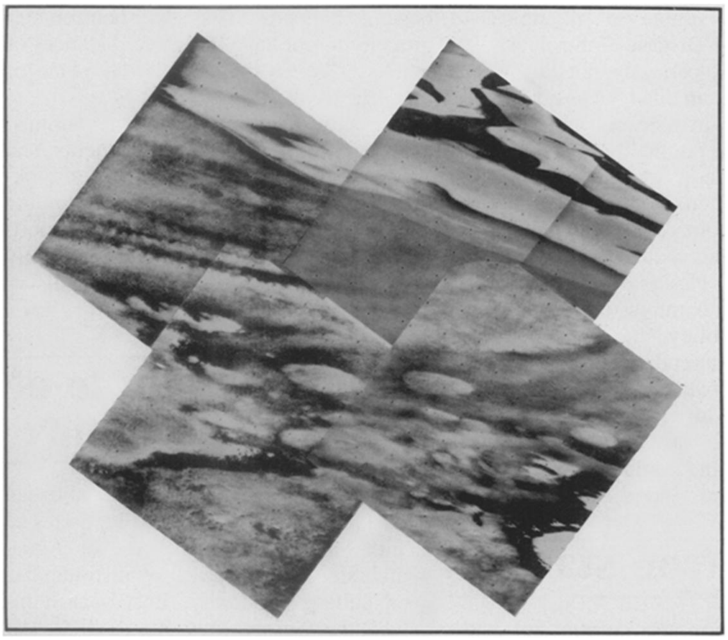
created when a large part of Phobos (Deimos perhaps?) might have broken off in some ancient cataclysm. None of these ideas yet have much weight behind them, however, Duxbury says. "We're kind of still in gee-whiz-type mode."

The photos' most exciting implication may be for Mars itself. The camera-slewing technique, now proven, has prompted excited Viking researchers to plan to send the orbiters as close as *300 kilometers* to the Martian surface in 1977, less than one-fifth of their present lowest altitude, with the hope of photographing objects as small as 10 meters across. Although this would still not show the two landing craft, it might enable geologists to relate the terrain photographed by the landers to that in the orbiters' lofty view.

At least two other technological triumphs led to scientific bonuses last week. Paramount, perhaps, was the discovery of two important trace elements—krypton and xenon—in the Martian atmosphere, using the mass-spectrometer half of lander 2's organic chemistry instrument. The original version of the instrument would have been incapable of such measurements, since it was designed only to measure organic molecules in the soil after they had been vaporized and selectively passed along by a gas chromatograph. "After it was conceived," says Dale Rushneck, a member of the instrument team, "we thought since we had a mass spectrometer on Mars, we may as well use it to analyze the atmosphere." So an atmospheric inlet was added, after which, to aid biologists seeking even minute traces of nitrogen, a filtration assembly was built in to "subtract" the atmosphere's main constituent, carbon dioxide, so that the much smaller amounts of other components could be "enriched" in the spectrometer for easier detection. The last major hurdle was crossed when the atmosphere was found to be low enough in argon not to "clog" the instrument's ion pump, so that many successive enrichments could be run. The tiny traces of krypton (82 through 84) and xenon (128 through 134) were not revealed until lander 2's atmospheric sample had been enriched 15 times. Chief experimenter Klaus Biemann of the Massachusetts Institute of Technology predicted that it might take another two weeks or more before the actual quantities could be pinned down.

Like other noble gases, krypton and xenon are valuable keys in unlocking a planet's atmospheric history. They are inert, so they don't get tied up with other elements, and they are heavy enough to not escape into space. On Mars, although the precise numbers are still unclear, it's clear that there is more krypton than xenon. "That's an interesting result in itself," says Tobias Owen of the State University of New York, "because that's also true in the case of the earth's atmosphere. But in the (carbonaceous chondrite) meteorites, which we think are representative of the kind of gases that would be available to form planetary atmospheres, the reverse is true." Mars, in other words, is in the middle. The relative shortage of xenon in earth's atmosphere, Owen says, is thought to be due to its adsorption in sedimentary rocks. "So it would be quite interesting to try to pin down these numbers and see whether the same mechanism may have been responsible for the apparent depletion on Mars."

When refined, the noble-gas measurements and their isotope ratios should give researchers a much better handle than they've ever had before on the characteristics of the presumably thicker atmosphere of the early Mars, as well as on the amount of it that may still be frozen into the planet's crust. "We're in much better shape than we were before Viking, when we had numbers for the total volatile inventory that ranged from 6 millibars to 10 *bars*," says Owen. Already the ceiling



Ice-filled craters (white ovals in lower part of mosaic) below edge of Martian north polar ice cap (at top) raise estimate for thickness of the cap to hundreds of meters of frozen water.

on some models is down to about 800 millibars, with the minimum up to about 60.

But where is the rest of that primitive atmosphere hiding—the part that didn't escape into space? A leading explanation among pre-Viking theorizers had been that it was frozen into the residual polar caps, a vast blanket of dry ice perhaps equal to several times the carbon dioxide content of the entire atmosphere.

Last week, however, Viking experimenter Crofton B. Farmer of JPL provided additional data confirming his conclusion of a month ago that the residual north polar cap (and presumably the residual southern cap as well) consists entirely of water ice (SN: 8/28/76, p. 133). The conclusion is based on measured temperatures that would have long since caused the CO_2 to sublimate away.

The lack of a permanent CO_2 supply at the poles, says Hugh H. Kieffer of the University of California at Los Angeles, puts a large dent in the theory that the Martian atmosphere thickens cyclicly every few million years or so, since the poles were the prime storage candidate for the additional gas to do the job. "The only suggestion which we're still discussing," says Kieffer, "is that there's CO_2 somewhere—solid CO_2—but not only is it buried in the polar regions, it's completely out of communciation with the current atmosphere. That means it's sealed off somehow." That, he says, is a tall order. "It would have to have been made cold a long time ago and sit in the poles and get water covering it which seals it off somehow, and stay cold—colder than the average temperature of the environment—for a period of thousands or millions of years." It could perhaps be absorbed into the planetary regolith, he says, except that the regolith—the surface rocks—has such a vast surface area compared with the poles that there could be no positive feedback to sustain the process. Over the poles, such feedback would take the form of a little CO_2 coming off, which increases the heat-carrying capacity of the atmosphere over what is essentially a localized area, which sublimates more CO_2, and so on. But the poles, Farmer reminds, are water.

How much water? Estimating the thickness of the polar caps has been a goal of Mars-watchers for decades, and although there's still no ready answer, says Farmer, the Viking orbiters have now provided at least three ways of making smarter guesses. First, the caps have to be at least thicker than the scale of the roughness of the surface, so they're at least meters thick. Secondly, they are presumably at least as thick as the depth of craters that orbiter photos reveal to be completely filled with ice. As the roughest of generalizations, Farmer says, many craters are about one-sixth as deep as they are wide, so the white spots representing ice-filled craters seen by Viking raise the estimate for the caps to the hundreds-of-meters range. (One such crater, Korolev, is 90 kilometers across—and filled to the brim.) Finally, in the 100-millennium cycle of Mars's orbital precession, about one-fourth of that time represents the atmosphere freezing out onto the north polar cap each northern winter, leading to a ballpark calculation of a cap about 100 to 1,000 meters thick.

Yet another of Viking's studies may have yielded the first evidence from a U.S. spacecraft that Mars has a magnetic field. This would be an important conclusion because, among other reasons, it would bear on whether the solar wind has been able to get in at the top of the Martian atmosphere and sweep away some of the components that are so important in understanding the atmosphere's evolution. As the two Viking landers descended

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Live polio vaccine: Debate over safety

During the early 1950s, some 38,000 Americans were victimized by polio each year. Then in 1954, the first polio vaccine, one made from killed polio viruses, was introduced. It drastically slashed the incidence of polio until 1961. That year, a polio vaccine made from attenuated live polio viruses started replacing the killed vaccine and has been the vaccine of choice since then. It too has kept polio to a minimum. There were only seven cases of polio in 1974.

Now there is a possibility that polio might once again sweep the United States because of a shortage of polio vaccine material. In mid-September, 14 states were critically short of vaccine. A major reason for this shortage, a Senate hearing revealed last week, is that the drug company making the live vaccine refuses to sign a new contract with the government unless all recipients be informed in advance of the vaccine's potential risk—that it may cause rather than prevent polio.

The live vaccine has indeed caused some cases of polio, several scientists testified before the Subcommittee on Health hearing, chaired by Sen. Edward M. Kennedy (D-Mass.). According to Robert Aldrich of the University of Colorado and former director of the National Institute of Child Health and Development, "Evidence for small numbers of cases of polio each year caused by attenuated live virus vaccine is conclusive." Jonas Salk, developer of the killed polio vaccine, said there have been 140 cases of polio in the United States so far because of the live vaccine, and that "in the last several years, the live vaccine has been the principal if not the sole cause of domestically arising cases of polio. In other words, it may be said that, at the present time, the risk of acquiring polio from the live virus vaccine is greater than from naturally occurring viruses."

So why did the live vaccine replace the killed one in 1961? According to Salk, the decision was largely made by the American Medical Association on the belief that more children would take the oral live vaccine than the injected killed one and on the belief that the live vaccine was somewhat more effective. But scientific evidence that has accrued since then shows that the live vaccine is *not* more effective, Salk insists. New data, for instance, reveal that booster doses of killed vaccine are not required any more than are booster doses of the live vaccine. The controversy now as then, essentially, is over benefits versus risks. Neither the live nor the killed polio vaccine is altogether ideal, a situation that exists for other kinds of vaccines as well (SN: 12/14/74, p. 380).

Meanwhile, the polio vaccine shortage

tain unavoidable environmental detriments, and the handling and chemical processing involved in the lithium-fuel economy will present certain hazards of spillage. A detailed environmental-impact study needs to be made, but proponents believe the lithium-fueled electrics will be less of an ecological insult than gasoline burners.

The battery that holds this promise began as a lithium-water cell designed by the Lockheed Missiles and Space Co. for marine use. The electricity is generated by chemical reaction between the lithium anode and the water, which is effectively the cathode. (For energy-collecting purposes an iron-wire-mesh cathode is introduced.) The chemical reactions go like this: At the anode lithium is ionized. In the cathode reaction the water picks up the released electron and separates into a hydroxyl radical and hydrogen. The hydroxyl then combines with the lithium to give lithium hydroxide so that the net reaction is lithium plus water yields lithium hydroxide (mixed in the remaining water) plus hydrogen. The total energy generated is a positive 2.22 volts. This kind of cell has the added advantage that the iron cathode and lithium anode can be pressed tightly together because the chemistry involved forms a protective coating on the lithium that prevents its corrosion by the iron. The arrangement avoids the energy loss involved in transporting the charged electrons and ions through the electrolyte in cells where the electrodes must be separated.

To run this kind of battery efficiently requires controlling the concentration of lithium hydroxide mixed in the water. The Lockheed version does this by continually introducing new water. Such a procedure is not difficult in a marine environment, but on the highway it would require automobiles to carry heavy water tanks that had to be continually refilled.

A better way to control the lithium hydroxide, the Livermore group believes, is to introduce carbon dioxide and precipitate lithium carbonate. One then gets the overall reaction: Two lithiums plus carbon dioxide plus water give lithium carbonate plus a hydrogen molecule. One could stop here and just let the hydrogen go, but O'Connell and collaborators think that's an unwarrented discarding of energy. Introducing oxygen in the form of an air cathode can suppress the electrolysis of water that makes the free hydrogen so that the overall reaction is lithium plus oxygen plus carbon dioxide yields lithium carbonate, and water is no longer consumed.

A lithium-water-air cell of this type has been tested and gives a voltage of 3.4 volts. Its energy density is calculated to be 330 watt-hours per kilogram at a power density of 200 watts per kilogram. Much research on the functioning of the battery, looking to improving its performance, and the best means of integrating it into an engineering design are necessary before use is feasible. At the moment the researchers envision an optimum system that is a battery/battery (that is, primary/secondary) hybrid. If the battery is made to carry 36.3 kilograms of lithium, the vehicle could travel 1,600 kilometers between lithium changes. "Assuming an average of 16,000 kilometers travel per year," the researchers calculate, "the lithium need only be refueled every 1.2 months. Lithium replacement would not take place at the 'gas' island, but as part of a more lengthy servicing of the vehicle, similar to the 1,600-kilometer oil change. Routine refueling would then consist of adding carbon dioxide and removing lithium carbonate."

Of course after feasibility is demonstrated, there remains an important task of industrial convincing. The American automobile industry is so monolithically organized that a routine style change involves the risk of a fortune. Asking skittish industry executives to adopt an entirely new mode of propulsion might cause dangerous rises in blood pressure. Proponents of electric propulsion might have to finance new companies.

From the individual point of view, lithium electrics would be attractive only if enough service stations stocked the lithium anodes and other parts and maintenance equipment necessary. And that would be attractive to service-station owners only if there were enough electrics on the road to pay them for the investment. It makes a kind of chicken-and-egg problem that might require some economic pump priming. Nevertheless as petroleum gets scarcer, more expensive and more and more involved in volatile international politics, an automobile economy based on a fuel that is abundant and has few competing uses could look extremely attractive. □

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toward the surface, each carried an instrument that measured ion and electron concentrations in the upper atmosphere. An analysis of the electron flux reported by lander 1, according to William B. Hanson of the University of Texas, shows a transition boundary about 2,000 kilometers from the planet that just may be the bow shock formed where the solar wind and a planetary magnetic field interact. It will take several weeks to be sure, he says, but unless the plasma pressure in the upper atmosphere turns out to be sufficient to balance the pressure of the solar wind by itself, it looks as though a magnetic field—and an intrinsic rather than induced one at that—is the answer. (Such a conclusion had already been reached by Soviet researchers using data from direct-measuring magnetometers aboard their own Mars orbiters, but, says one U.S. scientist, that conclusion "sorely wanted confirmation.")

Meanwhile, Viking's biologists continued their tantalizing quest. Lander 2's pyrolytic-release experiment reported only the most limited reaction from a soil sample incubated in darkness (a 21.5-count-per-minute "second peak" compared to a 7,133-count first peak), which is a boost for photosynthesis—but also for inanimate photochemistry. It also looks bad for microorganisms that might have been living in darkness below the surface to hide from the almost unfiltered solar ultraviolet radiation. For the metabolism-seeking labeled-release experiment, which produced appropriately positive and negative results from normal and heat-sterilized soils in lander 1, Gilbert V. Levin of Biospherics, Inc., was preparing this week to run a "cold-sterilized" control cycle aboard lander 2. His plan called for subjecting a soil sample to about 50°C instead of 160° in hopes of separating easily cooked biology from inanimate chemistry that might produce the same reaction.

The biologists were also anxiously awaiting results, due to start coming in this week from lander 2's organic chemistry instrument. On Sept. 25, after exhaustive planning, the craft's scoop-equipped arm presented the instrument with a soil sample from an area topped with what was apparently an evaporite-cemented crust (SN: 9/25/76, p. 196), offering the highest hopes yet of revealing the organic molecules that could swing the balance of opinion substantially closer to the finding of life on Mars. □