Probing inner Mars: Advice for tomorrow

The surface of the moon had been studied for years, decades, centuries. But it was not until July 20, 1969, when the Apollo 11 lunar module "Eagle" successfully delivered a seismometer to the moon's Sea of Tranquility, that mankind was finally in a position to undertake the active study of an extraterrestrial planet's interior. Even on earth, most information about the deep interior comes from seismic studies of the changes wrought by the planet's structure in the shock waves triggered by quakes, artificial explosions, temperature changes and other sources. And since such measurements require being in physical contact with the planet being shaken, the list of thus-studied worlds is short indeed. Beyond the earth-moon system, it reads: Mars.

The inner Mars has undergone a long, churning evolution. Researchers have estimated that as much as two-thirds of the surface has been made over by volcanic activity (SN: 11/10/79, p. 329), and the formation of a huge, possibly tectonic bulge called the Tharsis rise has been tentatively credited with redistributing up to 7 percent of the planet's mass.

Only two seismometers have ever been sent to probe the Martian depths, delivered by the two Viking landing craft that touched down on the surface in the summer of 1976. The first seismometer never worked at all — it refused to come unstuck from the "caged" position in which it had made the trip from earth — and at least half of the measurements from the second one were obliterated by vibrations due to wind that shook the lander on which it was mounted. The experience was made still more trying for the scientists involved by the resounding successes of other Viking research groups, and the seismology team's final report, just published by the National Aeronautics and Space Administration, evokes a lot of frustration, only a little insight into the inner Mars — and a list of recommendations about how to do the job differently in the future.

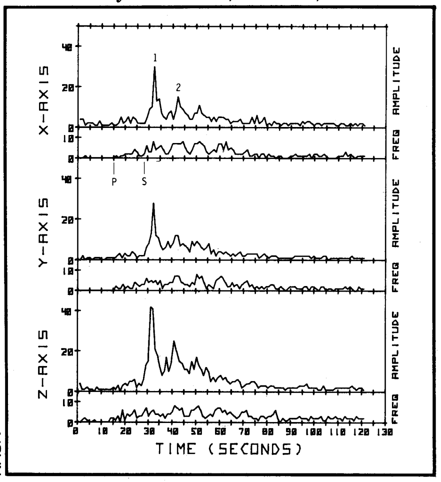
"Viking was designed primarily as a biologically oriented mission," says the report, prepared by team leader Don L. Anderson of Caltech and a dozen other scientists from the group. "The search for extraterrestrial life was the motivating force, and other scientific goals were secondary." The original tentative instrument list, in fact, did not even include seismometers, and the ones later added were severely limited as to "weight, power and cost, in that order." (The other Viking experiments faced similar constraints.)

One major consequence of such restrictions was that the seismometers had to be mounted atop the lander structure, since it would have cost too much money and weight to include a deployment device that would set them out on solid ground. The relatively shaky perch, combined with the instruments' enforcedly small size, led to "a relatively insensitive and noisy seismic system." Over most of the frequency band of seismological interest, says the team report, the instruments left on the moon by Apollo were generally 100 to 1,000 times more sensitive than the Viking ones. Furthermore, because the devices were being placed *on* the landers, the team felt it imperative to know in advance how the lander structure would alter seismic vibrations on their way up to the instruments; early tests failed to answer the question for the most important frequencies, unfortunately, and a necessary modification to the instruments (to counter a lander resonance at a higher frequency) used up the money that would have bought further testing. As a result, says the report, "Viking went to Mars without knowing the lander response function." Other problems concerned the amount of time during which data could be taken at high enough rates to show the fine details of possible seismic events.

With all of its constraints, the Viking 2 lander managed to accumulate about 2,100 hours of apparently wind-free data at rates of one sample per second or higher. In that batch, subsequent analysis revealed only one event which may have been of seismic origin. It occurred on Nov. 24, 1976, the Viking 2 lander's 80th day on Mars. "If it is seismic in origin," says the report, "the high frequency and short duration of this event suggest, but do not require, that it was generated locally (certainly within 100 kilometers of the lander)." It would also indicate that Mars is less seismically active than the earth, since earth-style plate tectonics on Mars would be expected to yield about 2 or 3 events (detectable by the Viking seismometers) in the same time span.

But that's it. The extent of Viking's new knowledge about the inner Mars. The direction of the possible tremor remains unknown, since the lander 1 seismometer was unavailable to help get a fix on it. And it is impossible to rule out the wind, since no wind measurements happened to be taken within 20 minutes of the event.

Possible Marsquake detected by Viking, recorded by Lander 2, Nov. 24, 1976.



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On the other hand, the team points out in its report, "the first seismometer on the moon (Apollo 11) was noisy and told us little about the moon. A great wealth of information was obtained, however, by later Apollo seismometers, and we are confident that the same will be true when more advanced seismic systems are installed on Mars." In fact, notes the team, "one of the major accomplishments of [the Viking] experiment was an improved ability to design similar future missions."

The team makes four basic recommendations for such designs (though the present budgetary climate may place their implementation many years away):

- Placing the seismometer on the ground instead of on the spacecraft, and giving it a small cross-sectional area to the wind, could quadruple the instrument's sensitivity while still leaving it free of wind noise. Placing it in a hole could help even more, as could deploying it from orbit in a spike-like probe called a "penetrator," which would simply stick in the surface like a javelin.
- Networks of seismometers placed in selected locations of possible seismic interest (such as the Tharsis rise) could have significant advantages over one- or two-instrument systems. One type of network, for example, could either be used as a "steerable beam" to triangulate signals from different directions, or "point" in one direction for a localized study. Early in the Viking mission, some researchers proposed that a good follow-up mission might be an orbiting vehicle equipped to send down as many as 24 penetrators to form a planet-wide array of seismic and other sensors.
- Another desirable feature, says the team, would be increased control of the seismometer from earth — primarily a matter of computer software. This would allow such options as making the seismometer amplifiers less sensitive to certain vibration frequencies whose interfering effects might be discovered only after the instruments were on the planet. The high-frequency lander resonance discovered during Viking's development, for example, says the team, would have been "devastating" to the already constrained experiment if it had not been caught.
- One recommendation that may depend upon first amassing more experience with seismometers on other planets is to develop a way of having the instruments transmit only those parts of the data that appear seismically significant, automatically weeding out the 90 percent or so of the data that represent quiet periods. This could help make more efficient use of limited spacecraft data-handling capacities.

But to make such recommendations worthwhile, of course, there first needs to be a Mars mission to use them. □