A TECTONIC VIEW OF EARTH

Want to see what's happened on earth in the past million years? Take a look.

BY SUSAN WEST

Let's say you had to draw a map to illustrate the dominant forces and movements of the crust that have shaped the earth during the last million years or so. How would you go about it?

If you were Paul D. Lowman Jr., you'd know exactly what to do. Being Lowman, you'd have one big advantage. Having worked on the orbital photography systems for everything from the Mercury mission to Landsat, you would have seen the earth as do only a select few—from space. From that vantage, you would have developed a sense of global geology far different from earthbound geologists. If you applied that sense to the usual means by which one constructs such a map, you'd probably come up with something unique.

That's just what Lowman did. The result is the global tectonic and volcanic activity map on the facing page.

Now, there's really nothing on this map that can't be found somewhere else, cautions Lowman, who works in the Geophysics Branch at the National Aeronautics and Space Administration's Goddard Space Flight Center in Greenbelt, Md. But none of it has been together in one place before and no one has used orbital photography to construct a global tectonic activity map. Consequently, says Lowman, his map illustrates some things that are not usually shown on similar renditions. It shows, for example, that the boundaries between tectonic plates are not always clear and distinct but sometimes mangled and diffuse, that volcanoes frequently occur where two continents collide, not only where oceans and continents meet, and that there are little-known places of intense volcanism.

Lowman never really intended to construct such a map. But when NASA found it needed a map that would help interpret the tectonic causes of anomalies in the earth's magnetic and gravity fields, Lowman discovered that none of the existing ones were adequate. Magnetic and gravity anomalies can often be linked to a particular continental formation, such as a volcano or a fault zone. But most tectonic maps, Lowman says, show only a general picture of how the earth is divided into a mosaic of a dozen or so plates and neglect to show the relationship between continental geology and tectonics.

During 1975, Lowman began working on his first version. He began with worldwide data on earthquake epicenters collected by the National Oceanic and Atmospheric Administration. Because earthquakes occur most frequently where two continental plates or a continental and oceanic plate meet, a map of their locations traces an outline of the edges of the plates. But the seismicity-generated outline was not enough for NASA's geophysical needs. Lowman began to fill in the kinds of features — the spreading ridges, strike-slip faults, overthrust belts or volcanoes—associated with those earthquake-designated boundaries. And that's where his special view of earth came in handy.

NASA/Lowman

Apollo 7 photo, looking north, of Zagros Mtns, Iran, which are convergence of Arabian and Eurasian plates. Photos like this led to detail in map at left.

"Simply, that's the only way I could have learned enough global geology," he explains. "See that little dot up there [pointing to a volcano in central north Africa]? I'll bet you not one geologist in ten thousand ever heard of it. It's the Haruj al Aswad. Now, once you know it's there, it turns out it has been written up in the French literature and the Italian literature and I was able to learn more about it. The thing is, knowing there is something there to begin with, I can do the background work and fill it in." Between his familiarity with thousands of views of earth from space and the plentiful but scattered literature sources, Lowman says, he was able to piece together a more complete picture of a dynamic earth.

Space photographs were a particular help, says Lowman, in deciding if a feature should be included on the map. The sharpness of the physiography in the photographs told him whether volcanic and tectonic features in poorly mapped areas had been active in the past 1 million years. Short enough to still be considered an instant geologically but long enough to include the range of geologic activity, one million years is the necessary period, he says, to get a true idea of the present state of the earth.

While Lowman is quick to note "there's really nothing much new on this map that isn't on somebody else's map, though they're just in too many different places," he does point out certain findings, some obscure, that are not usually included. For example, the geology of the Shansi region in China, near what is labeled the Baikal Rift on the map, has been disputed. Some geologists claim it to be a region of strike-slip faults — faults whose movements are mostly horizontal — while others believe the dominant motion is along rifts — features that show vertical movement. This is an important distinction from NASA's viewpoint, because strike-slip systems and rift systems may produce different magnetic or gravity anomalies. Lowman, having studied Landsat photos of the region, sees distinct rifts and grabens — blocks of rock that have dropped down between two faults — and draws his map accordingly.

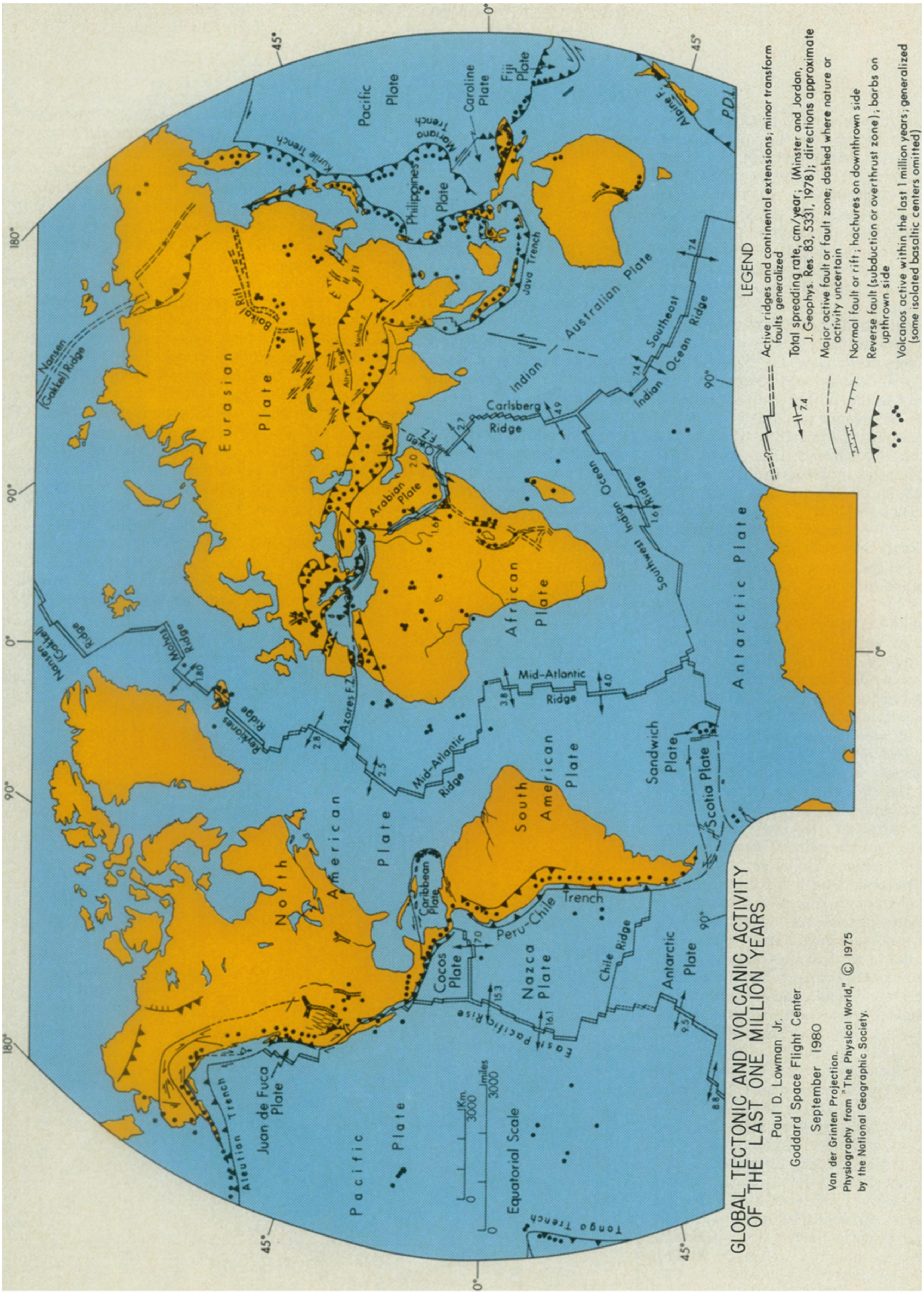
With all this data on one map, says Lowman, certain things stand out. The map, for example, supports the growing belief that plates are not always rigid as dictated by classic plate tectonic theory and therefore that the boundaries between plates are not always distinct. Lowman points in particular to the swath from the Mediterranean to Asia, where there is a hodge-podge of subduction zones.

This has implications for siting stations to be used in very precise measurements of crustal movement. Certain observatories, such as those in Bonn, Germany, Bologna, Italy, and Fairbanks, Alaska, and may be unsuitable because they are located in one of these "mushy" tectonic regions where local movements could obscure true plate movements.

Lowman also points out the apparent continuity of the Alpine belt through the Caspian Sea, across the Black Sea and to the Jura Mountains, the foothills of the Alps. "Now if you take this map at face value, you would say, 'Well, look, the whole front of the Alps is being overthrust as a unit,'" he says. He adds, however, that the map may be over-generalized to produce an illusion of unity or that the belt may be "a temporary coalescence of randomly moving tectonic elements."

In addition, he notes that nearly everywhere two continental plates meet, such as along the Himalayas, volcanoes occur. While the formation of volcanoes where an oceanic plate dives under a continent —as along the coast of South America—is fairly well understood, "there is considerable uncertainty as to how magma is generated at continental-continental convergence zones."

Lowman claims no answers to these problems. To him, this is the value of the map, that "you'll be able to see more than just schematic plates. It's going to start raising all kinds of questions." □


GLOBAL TECTONIC AND VOLCANIC ACTIVITY OF THE LAST ONE MILLION YEARS
Paul D. Lowman Jr.
Goddard Space Flight Center
September 1980
Van der Grinten Projection.
Physiography from "The Physical World," © 1975 by the National Geographic Society.
LEGEND
Active ridges and continental extensions; minor transform faults generalized
Total spreading rate, cm/year; (Minster and Jordan, J. Geophys. Res. 83, 5331, 1978); directions approximate
Major active fault or fault zone; dashed where nature or activity uncertain
Normal fault or rift; hachures on downthrown side
Reverse fault (subduction or overthrust zone); barbs on upthrown side
Volcanos active within the last 1 million years; generalized (some isolated basaltic centers omitted)
Equatorial Scale
Km
miles
Pacific Plate
Aleutian Trench
Juan de Fuca Plate
North American Plate
Caribbean Plate
Cocos Plate
Nazca Plate
Peru-Chile Trench
Chile Ridge
East Pacific Rise
Antarctic Plate
South American Plate
Scotia Plate
Sandwich Plate
Mid-Atlantic Ridge
Azores F.Z.
Reykjanes Ridge
Mohns Ridge
Nansen (Gakkel) Ridge
African Plate
Arabian Plate
Eurasian Plate
Baikal Rift
Owen F.Z.
Carlsberg Ridge
Southwest Indian Ocean Ridge
Indian Ocean
Indian – Australian Plate
Southeast Indian Ocean Ridge
Java Trench
Philippines Plate
Mariana Trench
Kurile Trench
Caroline Plate
Fiji Plate
Tonga Trench
Alpine F.
PDL
Antarctic Plate