A Magnet Named Earth

Tiny variations in earth's magnetic field have been charted by satellite to produce a subtle yet valuable portrait

BY JONATHAN EBERHART

In 1968, someone suggested to Michigan State graduate student Robert D. Regan that an interesting topic for a dissertation would be the use of satellite data to compile a detailed map of the irregularities in the earth's magnetic field. "I did a hand calculation," Regan recalls, "and I said, 'That's absurd!' "

The strength of the earth's magnetic field at the surface, after all, is only about 50,000 gammas, roughly equivalent to that of a toy horseshoe magnet. The irregularities, or anomalies, to be charted represented no more than 10 or 12 gammas—variations, in other words, of less than one-fortieth of one percent—to be reliably plotted from data collected at satellite altitudes.

Yet Regan, now with the U.S. Geological Survey at Reston, Va., together with Joseph C. Cain of NASA (now with USGS) and W. Minor Davis, also of USGS, have done it. Studies of their map, already under way, will shed light on a variety of geophysical questions such as tectonic movements and mineral concentrations.

The map, recently published in the JOURNAL OF GEOPHYSICAL RESEARCH (80:794), was compiled from data gathered by three U.S. satellites in the Orbiting Geophysical Observatory series: OGO-2, 4 and 6, launched in 1965, 1967 and 1969 respectively. All three were in polar orbits, so that the whole planet passed beneath them; hence their official name, POGO.

Such mapping has been done before, Regan notes, but with considerably less resolution. Data from Cosmos 49, for example, a Soviet probe of a decade ago, were organized into map form, but there were only 11 days' worth of usable observations, which yielded simply too few measurements for detailed results. In each square of the earth's surface measuring 5 degrees of latitude by 5 degrees of longitude there were only from 1 to 23 Cosmos 49 observations, or "data points." The POGO's, by comparison, yielded from 300 to 450 measurements per 5-degree square. There have been previous attempts using POGO data, but with longer wavelengths, which limits the possible resolution.

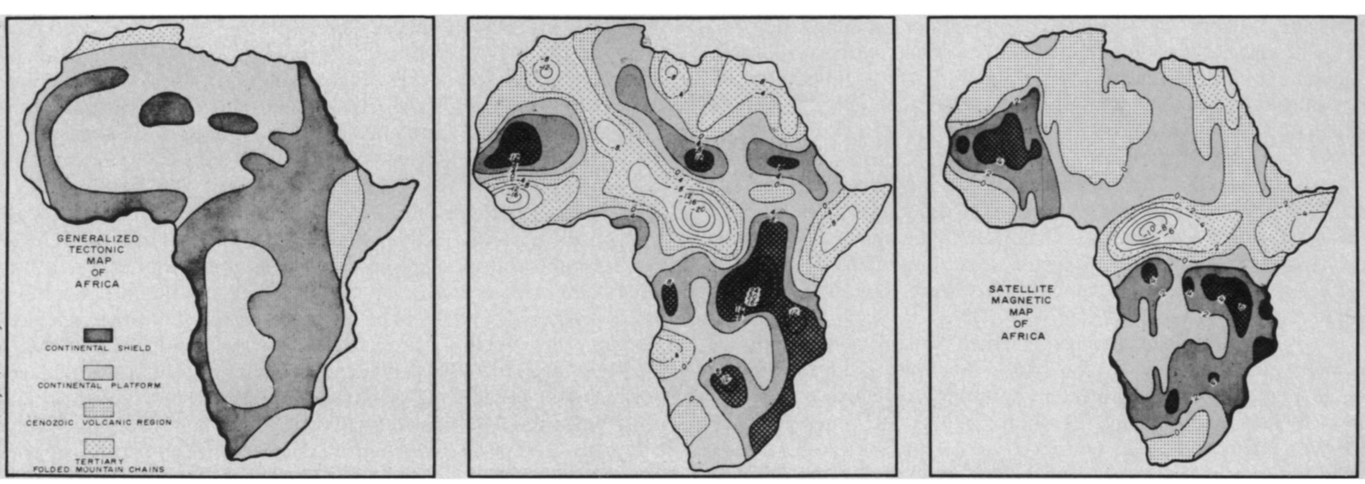
To keep distortions to a minimum, Regan and his colleagues started by throwing out most of the POGO data. They ruled out everything gathered when solar activity was having too great an influence, as extrapolated from an indicator of planetary magnetic activity called the *Kp* index. To avoid distortions in polar and auroral zones, they limited their initial effort to data from less than 50 degrees north and south of the equator. Because the extremely weak magnetic anomalies are even weaker at extreme altitudes, data gathered from more than 700 kilometers up were ruled out. Finally, measurements made between 9 a.m. and 3 p.m. local time were eliminated to avoid the effects of diurnal changes in the field.

More than half of the POGO measurements were eliminated, but a rich harvest remained for mapping: 393,452 observations, taken at 7-second (about 50-kilometer) intervals along a given orbit, resulting in about 15 observations for every square degree of surface to be covered. From this mass of numbers, already a map of sorts, the overall magnetic field of the earth itself—"the magnetism associated with magnetic compasses and magnetic north," Regan observes—then had to be subtracted.

Graphically plotted by a computer, the resulting data, at long last, produced the map. The sharp-edged contours, emphasized further by eight shades of color, make the features of the "magnetic earth" seem clear and well-defined. Yet the unimaginably tiny variations that comprise the map are in fact elements in what is probably the subtlest portrait of the planet ever made.

Subtle, but real. The variations in the map seem to have little to do with the outlines of the continents, but some of them do represent variations in the material in the earth's crust. "We are quite confident that most of the anomalies are actually related to significant differences in the upper 50 kilometers of the earth," says Regan. "In particular, we suspect that areas showing the greatest range in magnetic anomalies on the map will turn out to be areas that have experienced the most intense geotectonic activity, such as crustal movement, faulting and volcanism, in the past."

The so-called "Bangui anomaly" in Africa, for example, shows up clearly on the map (it was one of the first magnetic crustal anomalies to be discovered from satellite observations), and lies over the



from P. J. Wyllie, *The Dynamic Earth: Textbook in Geoscience*, John Wiley

Illustrations: Regan et al/ JGR/ © AGU 1975

Map compared with magnetic Africa from Cosmos 49 (5° averaged squares, 4-gamma contours) and POGO data (1°, 2-gamma).

tectonic uplift zone between the Chad basin to the north and the Congo basin to the south. The Indian peninsula appears as a magnetic "high" against a long, Asian "low," consistent with the theory that the peninsula represents a continental plate that is pushing against and sliding under a larger Asian plate, creating the Himalayas in the process.

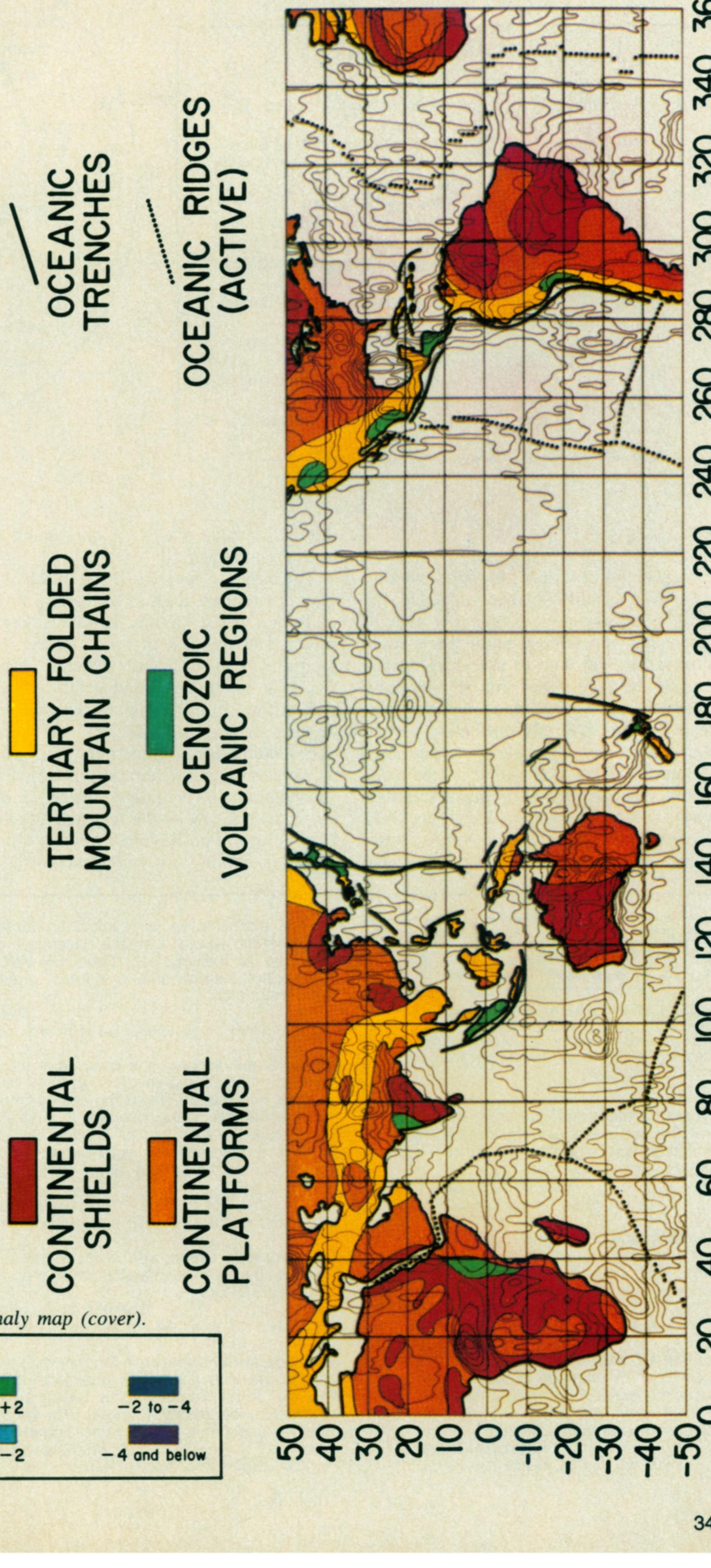
Not all of the map's features, however, are so easily explained. "Some of the other striking anomalies on the map," says Regan, "may be caused by faulty instrument readings, magnetic noise or computer problems. We are now working to investigate the validity and better define the extent of each anomaly. For example, much of the north-south linearity of the anomalies on the map appears to be related to the direction of the satellite orbits and perhaps to errors in determining the exact location of the satellite's position at the time of each measurement."

Some features are simply mysteries. A wide band of magnetic highs spans the entire United States from the mid-Pacific coast to the Pennsylvania border, yet there is no known structure to readily account for it. An intense low fills the Gulf of Mexico, extending to Brazil. "The positive belt and the . . . low over the Gulf . . . are certainly intriguing, and are undoubtedly related to the formation of our continent," Regan says, "but we just have not done enough analysis at this point to venture any firm explanation." Why is the Atlantic peppered with strong highs and lows while the Pacific basin is basically a magnetically bland bowl, broken by little more than the pair of anomalies where the Hawaiian Islands intersect the Emperor Seamount chain?

Additional study of the map should aid researchers in a variety of efforts aimed at understanding the structure of the outer layers of the planet, perhaps even by showing them where to look for physical signs of tectonic activity. (Such signs could indicate valuable mineral deposits, although the magnetic map is far from being a guide to prospectors.)

For still greater accuracy, Regan says, measurements will have to be made from orbits lower than those of the POGO satellites. Among the numerous projects being considered by the National Aeronautics and Space Administration is one known as MAGSAT, which would carry an improved magnetometer over the planet at altitudes as low as 200 kilometers, half the height of a low POGO pass. □

Global tectonic map combined with magnetic anomaly map hints at correlations.



BELOW: Color key for basic magnetic anomaly map (cover).