The Whole Moon Catalog

A new tool has the potential for making the existing mountain of lunar data both less ponderous and more meaningful

BY JONATHAN EBERHART

"I think," said Michael J. Bielefeld at the recent Lunar Science Conference in Houston, "I can call myself a 'born again' image processor." Bielefeld, who works for Computer Sciences Corp. in Silver Spring, Md., is but one of the hundreds of scientists who have been studying—and contributing to—the vast accumulation of data amassed in recent years on the subject of earth's moon. The problem has been one of excess: too much sheer volume, in too many different formats, analyzed in too many different ways. Everything—altitude measurements, gamma-ray scans, gravitational perturbations—gets looked over at least once or twice, of course. But the important task of looking for correlations among the numerous data sets has become a time-consuming, costly task of formidable proportions. Says one researcher, "It's gotten to where it takes a substantial research grant just to compare A and B."

Bielefeld, however, is also a member of a smaller group of moon-watchers: an informal gathering of about 40 geochemists, geophysicists, astronomers and others known as the La Jolla Consortium. The name, according to Lawrence A. Soderblom of the U.S. Geological Survey, dates from a 1974 meeting in La Jolla, Calif., called by James R. Arnold of the University of California, Isidore Adler of the University of Maryland and others to confront the very problem of "data overkill." It's certainly not the case that everything is already known about the moon, Soderblom says. Rather, it's that what *is* known must be unearthed from an ever-growing pile of sheer numbers.

From the consortium's impetus has now emerged a partial solution. Besides bringing some order out of chaos, it may help remove one of the major objections facing scientists who hope for a return mission to the moon.

In essence, it is a computer technique capable of letting virtually any kind of global or part-global lunar data be readily compared with any other. The output is maps, compiled from diverse sources but presented in identical geographic formats and, if desired, similar or identical color schemes. According to Eric Eliason of the USGS in Flagstaff, Ariz., co-mentor of the system with Soderblom, "There are now about 40 variables [different lunar parameters] in the system, which means that there are '40-factorial' ways to compare them." This represents a number of combinations roughly equal to an 8 followed by 47 zeros, any of which could be punched up virtually on demand. The system's real contribution, however, is not the readily available output—that's characteristic of modern image-processing systems—but the ease with which large or unusual data sets can be adapted for use as input.

Most intercomparative systems for handling spacecraft data are used only with photographs, Eliason says. The tiny dots, or "pixels," making up the picture are each expressed as a number, in binary notation, representing a certain level of brightness. Typical systems, such as those in use with Landsat and Viking, use binary numbers of eight "bits" or less, capable of representing numbers from zero to 255. This means that the "dynamic range" of the picture—the number of discrete steps in its gray scale—can be no greater than 256. (For Viking, the number is only 128 without special processing.)

This is fine for photos, but for many other kinds of data it simply won't do. Lunar altimetry measurements, for example, indicating the distance from the moon's center of mass, are numbers such as 1733.24 kilometers. To preserve the accuracy of the measurement—in other words, to retain all six "significant figures"—would require a binary number of 17 bits, far beyond the capacity of conventional systems. Eliason, therefore, developed "software" that uses 32-bit binary numbers. This also leaves room for special codes to handle data such as gravitational measurements, which often are expressed in positive and negative numbers. The 32-bit numbers take four times the storage capacity and four times the retrieval time of 8-bit numbers, Eliason admits, but the alternative is the laborious task of converting thousands or millions of data points to all-positive numbers, rounding them off and otherwise adapting them to the limitations of a 256-step dynamic range. The resulting map may be rounded off, either for ease of reading or because it also incorporates lower-resolution data, but the scientist will not first have had to rewrite all his measurements to get that result.

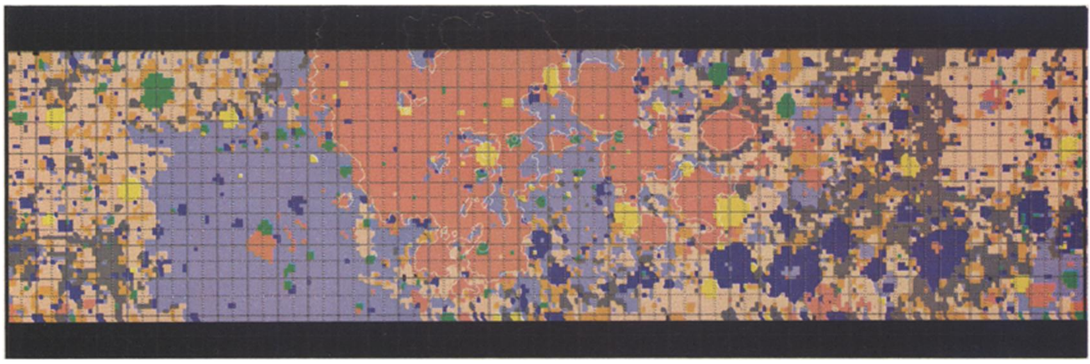
Also, Eliason says, the system is now being refined so that a researcher, having observed an apparent correlation between a pair of maps, can instruct the computer to run an internal analysis to see whether the correlation is statistically valid. If magnesium/silicon ratios, for example, seem to be low in the mare regions and high in the uplands, the computer can scan the data—X-ray measurements and geomorphic typing or altimetry in this case—and report on whether the relationship is true everywhere or tell if and where the reverse is true.

The system can also check the statistical reliability of each individual data point in a set, such as by "weighting" the significance of each point surrounding a point that has already been assigned a value. The results are sometimes startling. Bielefeld's aluminum/silicon data, for example, showed an unclear, "amorphous" distribution until the weighting process revealed the likelihood that the real distribution curve was one with two distinct, separate peaks. An easy check with albedo data already in the system showed that high-albedo (highly reflective) areas corresponded with high aluminum; low albedo with low aluminum. "This," Bielefeld told the Lunar Science Conference, "made a believer out of me."

The system is a powerful tool, potentially capable of opening the way to a virtual "whole moon catalog" of easily accessible, comparative lunar data. But it is just a tool. "Unfortunately," says Christopher T. Russell of the University of California at Los Angeles, "the area of the moon over which such correlative studies can be undertaken with the present data is quite limited." Many of the measurements, notably those made from lunar orbit by Apollo spacecraft, are limited to a rather narrow band of latitudes; furthermore, in comparative measurements, everything is thrown out except where the several data sets overlap. "The coverage here," says Arnold of the gamma-ray data, even without correlations which would restrict it further, "is only about 20 percent of the moon. And in case you miss the message. . . ."

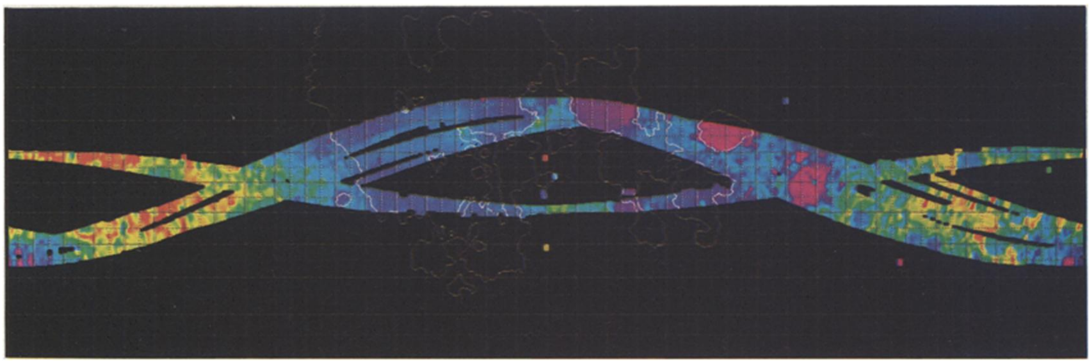
Arnold's message is the Lunar Polar Orbiter, a proposed unmanned satellite

Continued on page 302



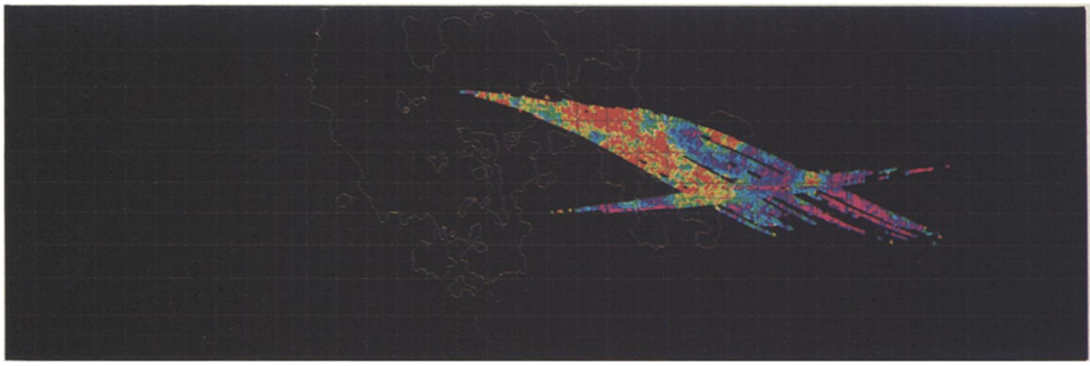
Data: F. El-Baz, D.E. Wilhelm et al.

Generalized geologic map *uses data from a variety of earth-based and moon-orbiting sources to classify the lunar surface (±40° latitude) into relative age groupings. Dark gray—pre-Nectarian; tan—Nectarian basins; orange—Nectarian craters; light blue—Imbrium basins; dark blue—Imbrium craters; red—maria; green—Erastothenian craters; yellow—Copernican craters. This map can be a basis for comparing numerous other single- and multisource measurements.*



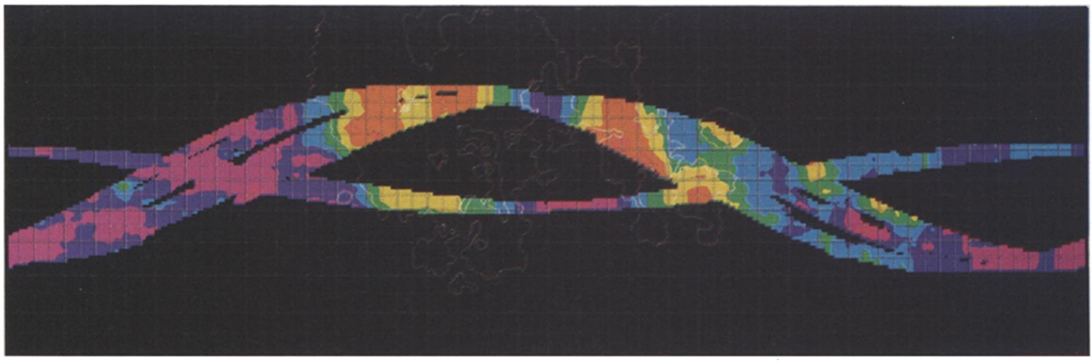
Data provided by W.L. Sjogren

Altimetry map *of the moon's radius relative to its center of mass, measured from lunar orbit using lasers aboard the Apollo 15 and 16 command-service modules. Violet—1,733 kilometers; blue—1,735 km; cyan—1,737 km; green—1,739 km; yellow—1,741 km; red—1,743 km. This enables a variety of comparisons such as elevation vs. geochemistry.*



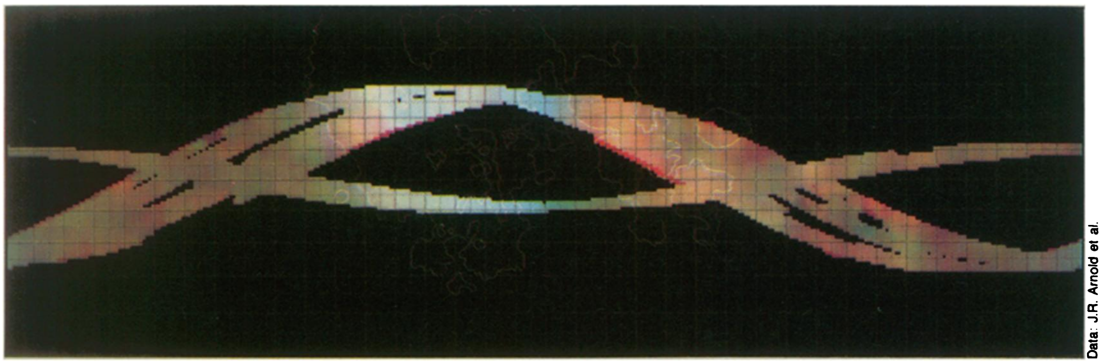
Ratio data: M.J. Bielefeld et al.

Magnesium/aluminum *ratio variations, mapped from orbit by X-ray fluorescence spectrometers aboard Apollo 15 and 16. Violet—0.6; blue—0.75; cyan—0.90; green—1.05; yellow—1.20. In the area covered, Mg/Al ratios are generally high in the maria, low in the uplands, although the eastern maria show some slightly lower ratios than do the western ones.*



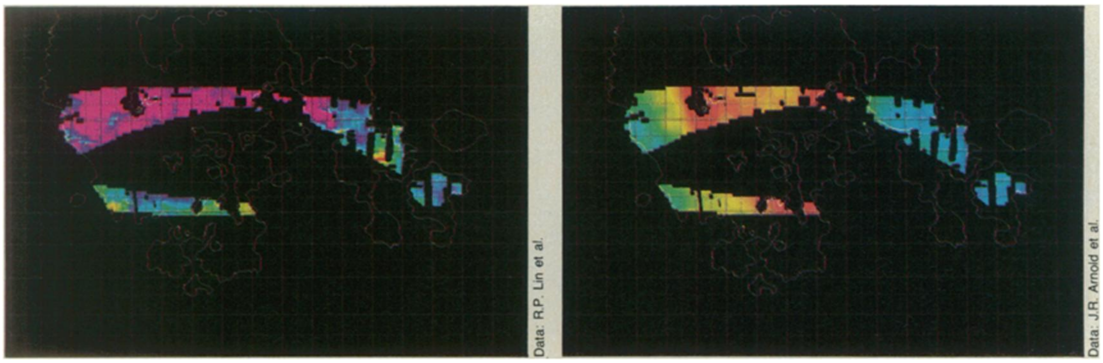
Data: J.R. Arnold et al.

Iron concentrations *produce most of the variations (although titanium and other elements have lesser effects) in this Apollo 15-16 map of gamma-ray emissions over a wide, high-energy band from 2.75 to 8.60 MeV. Violet—19.6 to 19.8 counts per second; blue—19.8 to 20.0; cyan—20.0 to 20.2; green—20.2 to 20.4; yellow—20.4 to 20.6; red—20.6 to 20.8.*



Data: J.R. Arnold et al.

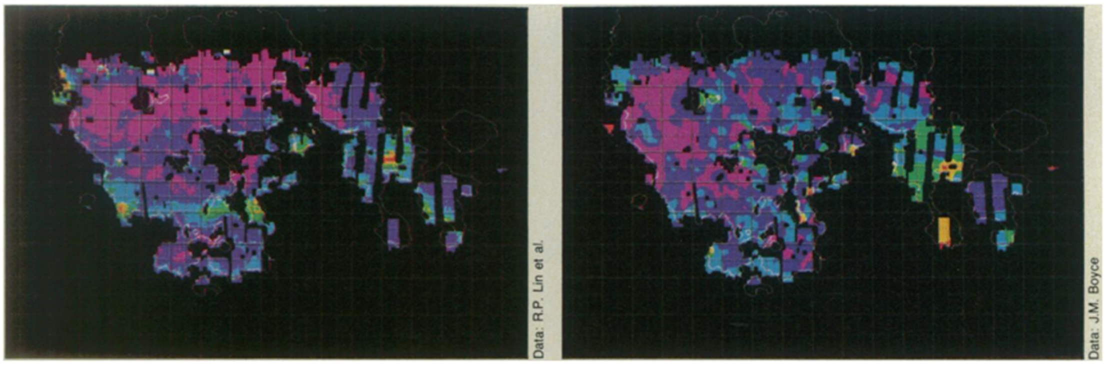
***Three-in-one gamma-ray map** blends colors to show three variables simultaneously, an approach heretofore limited primarily to reflectance data (see cover). Blue represents iron (2.75 to 8.60 MeV), using the same data as the bottom map on p. 301. Green indicates summed emissions from uranium, potassium and thorium (0.55 to 2.75 MeV). Red shows thorium alone in a narrow band (2.53 to 2.675 MeV) that overlaps the summed channel. Thus, purple represents equal brightness of iron and thorium in their respective bands, yellow represents equal iron and U-K-Th, white areas are high in all three bands, etc.*



Data: R.P. Lin et al.

Data: J.R. Arnold et al.

***Remnant magnetism** (left) **vs. radioactivity** (right) of the frontside maria. Only mare areas covered by both data sets are shown. Remnant magnetism is based on electron scattering recorded by the Apollo 15 and 16 subsatellites. Radioactivity is derived from the uranium-potassium-thorium data referred to in the above caption. In both images, violet represents low values, increasing through blue, green, yellow and red. The eastern maria (Crisium, Tranquillitatis, Fecunditatis and Serenitatis), generally older than the western ones (Imbrium, Procellarum, Humorum, Nubium), are also generally more highly magnetized but about 20 percent lower in radioactivity. This may reflect a longer thermal evolution in areas with greater radionuclide concentrations.*



Data: R.P. Lin et al.

Data: J.M. Boyce

***Remnant magnetism** (left) **vs. age** (right) of mare provinces compares the above electron-scattering data with relative ages estimated from small-crater morphologies. Same color scheme as above, with low values (violet) representing weak magnetism and young ages. The general correlation suggests that the lunar magnetic field was decaying during the period of mare emplacement.*

that would circle the moon in a pole-crossing path so that the entire lunar surface would pass beneath it. The probe would carry a host of magnetic, X-ray, gamma-ray, visual, multispectral and other sensors to provide the first broad-based global data bank about the moon. Its advocates have been having a hard time finding sympathetic ears in Congress for such a mission, what with the Rangers, Surveyors, Lunar Orbiters (nonpolar and primarily photographic) and Apollos that have gone before.

One reason has been that the existing mountain of lunar data has yet to be fully analyzed, and the Lunar Polar Orbiter would add to the load. The system of Soderblom and Eliason, however, combined with the cooperative approach being pursued by the members of the La Jolla Consortium, suggests to some researchers that, in the words of one Lunar Science Conference attendee, "the mish-mash wouldn't have to be a mish-mash after all."

This is not to say that the system is the automatic solution to everyone's lunar research problems. The principal scientists in spacecraft programs often work for years before their data are in hand, and some are understandably reluctant to share the results for others to analyze. But the time may come—if it hasn't already—when some such centralized approach may be the only way for major scientific explorations to get off the ground. Indeed, says Eliason, the system is already being tried out for use in certain studies of the earth. □