the major tool in exploration over the past half millenium. This newest powerful tool for the modern cartographer could be cost-effectively used to accelerate and correctly discern optimal lunar sites for utilization.

We went to our Moon over 20 years ago with technology that makes our current general technological level seem extremely advanced. Our movement to our nearest planetary neighbor is not a matter of needing superior technology but is one of organizing what we currently know in a superior manner. Using technology that has already been proven and is inexpensive to support, our drive out from Earth has greater potential for success than in developing unproven technology. A universal cartographic database founded on the principles at the center of GIS would become the same helpful tool for exploration that the ancient maps of Herodotos, Ptolemy, and Strabo were to Columbus in his discovery of the "New World" in 1492.

"Discovery is documentation" [12] and, simply, the most useful form of documentation for exploration is the map. This still applies to our future exploration of the Moon as it is applied to historic exploration on Earth. This use of historic maps in exploration has been shown in Henry the Navigator's use of Necho's African map. This map, as described in Herodotos' History, was made in the sixth century B.C. The map described the legendary circumnavigation of Africa sponsored by the Egyptian Necho. This was then used in the fifteenth century A.D. by Henry the Navigator to justify the Portuguese southward exploration in their attempt to follow Necho's described legendary circumnavigation of Africa 2100 years previously.

Our maps of the Moon, whether they be represented on paper or computer screen, will be the human race's most valuable and inexpensive tool in the exploration and conquest of the Moon.

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MÖSSBAUER SPECTROSCOPY FOR LUNAR RESOURCE ASSESSMENT: MEASUREMENT OF MINERALOGY AND SOIL MATURITY.

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Introduction: First-order assessment of lunar soil as a resource includes measurement of its mineralogy and maturity. Soils in which the mineral ilmenite is present in high concentrations are desirable feedstock for the production of oxygen at a lunar base.

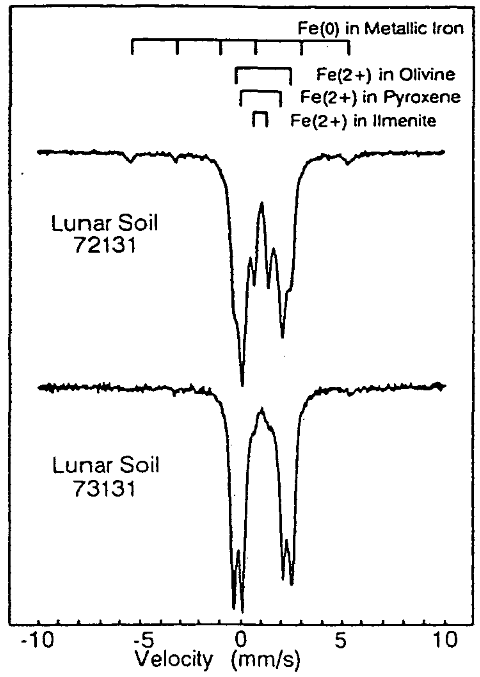

Fig. 1.

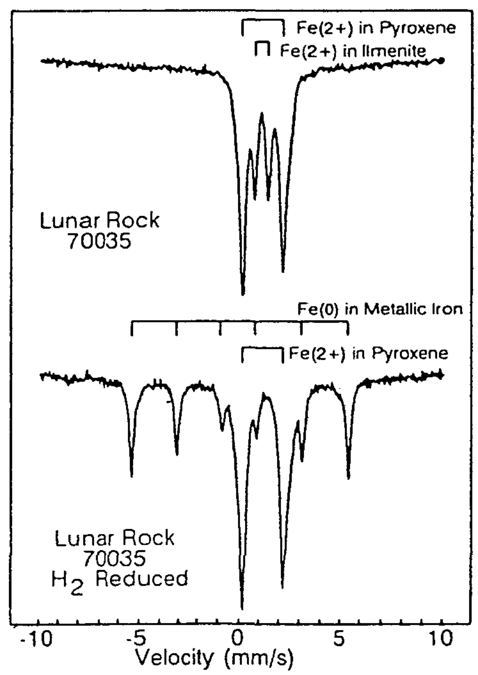

Fig. 2.

The maturity of lunar soils is a measure of their relative residence time in the upper 1 mm of the lunar surface. Increasing maturity implies increasing load of solar wind species (e.g., N, H, and ^{3}He), decreasing mean grain size, and increasing glass content. All these physicochemical properties that vary in a regular way with maturity are important parameters for assessing lunar soil as a resource. For example, ^{3}He can be extracted and potentially used for nuclear fusion. A commonly used index for lunar soil maturity is I_s/FeO,

Fig. 3.

which is the concentration of fine-grained metal determined by ferromagnetic resonance (I_s) normalized to the total iron content (as FeO) [1]. I_s/FeO has been measured for virtually every soil returned by the Apollo and Luna missions to the Moon; values for surface soils are compiled by [2].

Because the technique is sensitive to both oxidation state and mineralogy, iron Mössbauer spectroscopy (FeMS) is a viable technique for *in situ* lunar resource assessment. Its utility for mineralogy is apparent from examination of published FeMS data for lunar samples [e.g., 3–5]. From the data published by [5], we can infer that FeMS data can also be used to determine soil maturity. We discuss here (1) the use of FeMS to determine mineralogy and maturity and (2) progress on development of a FeMS instrument for lunar surface use.

Mineralogy and Maturity: Figure 1 shows FeMS spectra for two Apollo 17 soils, 72131 and 73131. Even by visual inspection, the two soils have very different proportions of the ferrous-bearing minerals pyroxene, olivine, and ilmenite. From peak areas, the percentages of total iron associated with each of those mineralogies are 66, 15, and 16 for 72131 and 57, 39, and 4 for 73131. Thus, a Mössbauer spectrometer on a lunar rover could be used to prospect for ilmenite-rich soil horizons (deposits).

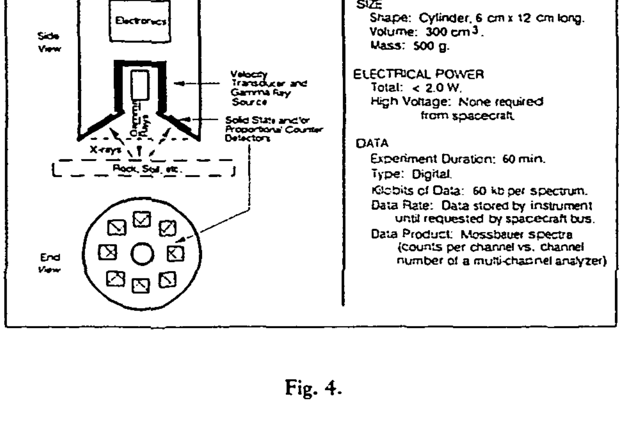

Fig. 4.

A reason for finding ilmenite deposits is shown in Fig. 2, which presents FeMS spectra for a crushed lunar rock (70035) both before and after reduction by hydrogen. The only two iron-bearing mineralogies present in the untreated rock are ilmenite and pyroxene, with 23% of the total Fe in the ilmenite. After H_2 reduction, there is no evidence in the FeMS spectra for ilmenite. Only metallic iron and pyroxene are present, which implies that reduction of ferrous iron in ilmenite is kinetically favored over that in pyroxene. The 36% area for Fe metal does indicate, however, that some of the ferrous iron in pyroxene has been reduced to metal.

In Fig. 3, we plot the excess area near zero velocity, which is a measure of the concentration of superparamagnetic Fe metal (sp-Fe^0), as a function of the maturity index I_s/FeO for nine lunar samples. The area for sp-Fe^0 was calculated using the procedure of [5] except that no attempt was made to correct for saturation effects. A linear correlation is present, which demonstrates that maturity data can be derived from Mössbauer measurements.

Instrument Development: The current status of development of our backscatter Mössbauer spectrometer (BaMS) is described by [6]. A schematic of the instrument, together with specifications, is given in Fig. 4. The instrument has low mass, low volume, low power consumption, and low data transfer rate. We have built and fully tested the velocity drive. Operation in backscatter mode means that no sample preparation is required. The instrument can be placed on a lander or rover or used at a lunar base.

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GAMMA RAY AND NEUTRON SPECTROMETER FOR THE LUNAR RESOURCE MAPPER. C. E. Moss, R. C. Byrd, D. M. Drake, W. C. Feldman, R. A. Martin, M. A. Merrigan, and R. C. Reedy, Los Alamos National Laboratory, Los Alamos NM 87545, USA.

One of the early Space Exploration Initiatives will be a lunar orbiter to map the elemental composition of the Moon. This mission will support further lunar exploration and habitation and will provide a valuable dataset for understanding lunar geological processes. The proposed payload will consist of the gamma ray and neutron spectrometer discussed here, an X-ray fluorescence imager [1], and possibly one or two other instruments. The spacecraft will have a mass of about 1000 kg including fuel, be built on a fast schedule (about three years), and have a low cost (about $100 M including launch). Launch is tentatively scheduled for April 1995.

Most gamma rays used to map lunar elements are in the energy range of 0.2–8 MeV. The proposed gamma ray detector will contain an n-type germanium crystal that is ≈70% efficient [relative to a 7.62-cm-diameter × 7.62-cm-length NaI(Tl) scintillator]. N-type is used because it is much less susceptible to radiation damage than p-type germanium. Because a Stirling cycle cooler will be used, the crystal will be mounted using techniques commercially developed in recent years for operating germanium detectors on vibrating platforms. A segmented cesium iodide [CsI(Na)] anticoincidence shield on the sides and back of the germanium crystal