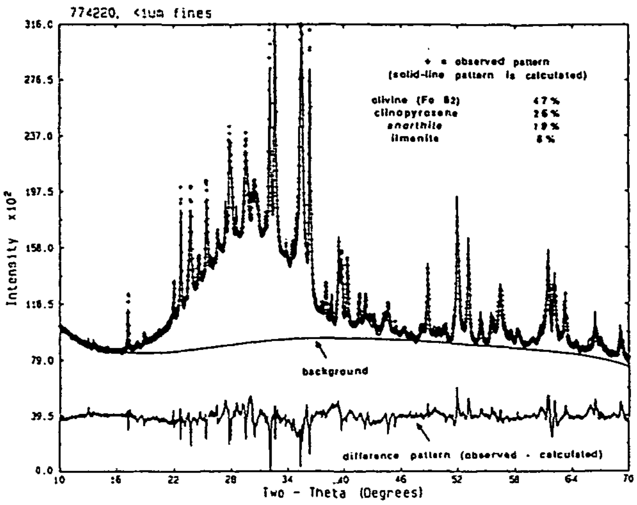

Fig. 1.

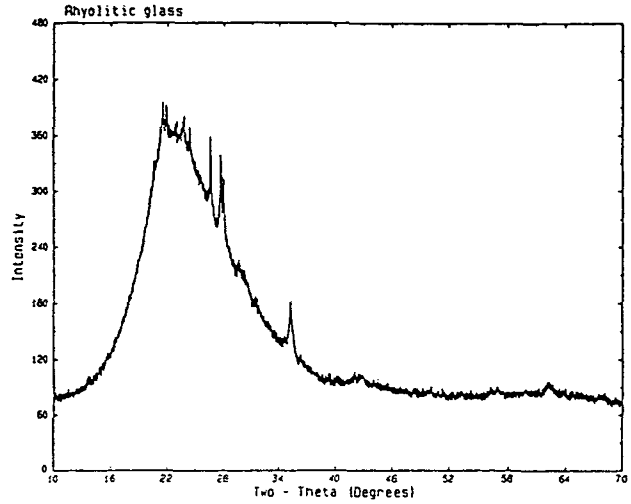

Fig. 2.

those detectable by XRF, particularly for elements lighter than Mg. However, XRF methods are valuable for obtaining full major-element abundances with high precision. Such data, collected in parallel with quantitative mineralogy, permit unambiguous determination of both mineral and chemical abundances where concentrations are high enough to be of resource grade.

Collection of both XRD and XRF data from a single sample provides simultaneous chemical and mineralogic information. These data can be used to correlate quantitative chemistry and mineralogy as a set of simultaneous linear equations, the solution of which can lead to full characterization of the sample. The use of Rietveld methods for XRD data analysis can provide a powerful tool for quantitative mineralogy [3] and for obtaining crystallographic data on complex minerals [4]. Rietveld methods applied to the XRD data will provide (1) enhanced accuracy for quantitative mineralogy, (2) a capability for crystal-chemical characterization of unstable minerals (e.g., the questionable lunar occurrences of lawrencite, $FeCl_2$ [5]) in their natural environment, and (3) a capability to recognize and characterize previously unknown minerals.

Ultimately, Rietveld methods can be used to determine glass abundances where the sample contains a particular type of glass. This approach will be most useful in the exploration of pyroclastic glass deposits. Figure 1 shows an XRD pattern obtained from the <1-μm fraction of pyroclastic sample 74220,19, obtained by settling in Freon. This pattern was collected from 17 mg of material. Rietveld analysis was used to obtain the abundances of crystalline constituents (normalized to 100%) as well as the olivine Mg/Fe ratio. When similar data are obtained on pure splits of the pyroclastic glass, then abundances of this glass (represented by the amorphous bulge between 17° and 46° 2Θ) can be determined. Other glasses, either known or exotic, can be modeled from diffraction data. Figure 2 illustrates the very different amorphous diffraction character of terrestrial rhyolitic glass in comparison with the basaltic pyroclastic glass of 74220 in Fig. 1. With appropriate library diffraction data, a wide variety of glasses and minerals can be determined quantitatively in lunar materials.

References: [1] McKay D. S. et al. (1991) *LPSC XXII*, 881–882. [2] Hawke B. R. et al. (1989) *LPSC XX*, 389–390. [3] Vaniman D. T. (1991) *LPSC XXII*, 1429–1430. [4] Vaniman D. et al. (1991) *Clay Min. Soc. 28th Ann. Mtg.*, 157; [5] Taylor L. A. et al. (1973) *Proc. LSC 4th*, 829–839.

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LUNAR LAVA TUBE SENSING. Cheryl Lynn York, Bryce Walden, Thomas L. Billings, and P. Douglas Reeder, Lunar Base Research Team, Oregon L[5] Society, P.O. Box 86, Oregon City OR 97045-0007, USA.

Large (≥300-m-diameter) lava tube caverns appear to exist on the Moon and could provide substantial safety and cost benefits for lunar bases. Over 40 m of basalt and regolith constitute the lava tube roof and would protect both construction and operations. Constant temperatures of -20°C reduce thermal stress on structures and machines. Base designs need not incorporate heavy shielding, so lightweight materials can be used and construction can be expedited [1,2]. Identification and characterization of lava tube caverns can be incorporated into current precursor lunar mission plans. Some searches can even be done from Earth.

Earth-based sensing of major near-surface (200-m-deep) lunar lava tubes and their entrances at 25-m resolution may be possible using Earth-penetrating radar (EPR) interferometry [3]. From lunar orbit 1-m EPR resolution should be achievable. Radar, lidar, and optical and infrared imaging might spot an entrance candidate from lunar orbit without using power-intensive EPR. Lava tube entrances can also be found directly by surface explorers (human or machine). Multifunctional kinetic penetrators and high-resolution seismic arrays may detail likely sites. Any search for lunar ice or other captured volatiles should include sheltered lava tube entrances and skylights (spot roof collapses).

Interior volume mapping to 10-cm resolution should be possible using lidar, microwave, or optical imaging from a platform moving along the length of the cavern. Floor and ceiling detail in optical or lidar data could be evaluated for lunar geoscience and possible

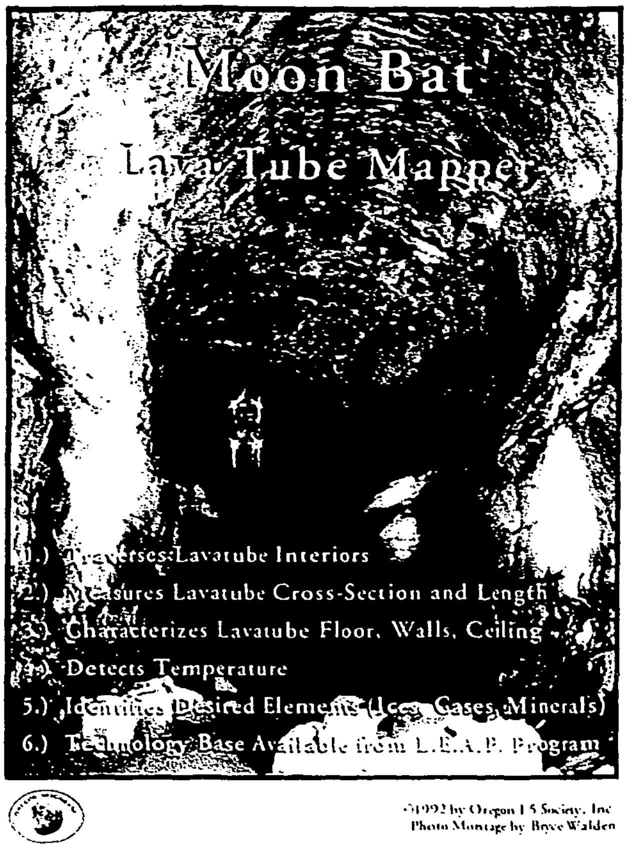

Fig. 1.

lunar base engineering use. Dust and other deposits in a lunar cave may be identified and mapped in a variety of ways although lunar lava tube caverns may be relatively dust free. Sensors used for surface exploration are suitable in lava tubes, including IR and UV spectrometers, lasers, vapor detectors, probes, optical spectrometers and imagers, and neutron activation analysis, although some of these sensors require a "light" source. A hovering rover, which we have christened a "Moon Bat," could lift off from a surface lander and fly into and through a lava tube cave. Based on present and near-future SDIO Light Exo-Atmospheric Projectile (L.E.A.P.) technology, the "Moon Bat" could gather data rapidly while "on the fly" and its rockets could provide a light source.

Specific recommendations for lunar lava tube search and exploration are (1) an Earth-based radar interferometer, (2) an EPR orbiter, (3) kinetic penetrators for lunar lava tube confirmation, (4) a "Moon Bat" *hovering rocket vehicle, and (5) the use of* other proposed landers and orbiters to help find lunar lava tubes.

References: [1] Oberbeck V. R. et al. (1969) *Modern Geology, 1*, 75–80. [2] Hörz F. (1985) In *Lunar Bases and Space Activities of the 21st Century* (W. W. Mendell, ed.), 405–412, LPI, Houston. [3] Billings T. L. (1991) *J. Brit. Interplanet. Soc., 44*, 255–256.