Oxygen is a potentially abundant lunar resource vital for life support and spacecraft propulsion. The recent identification by Prospector of ice at the lunar poles has renewed interest in the use of \textit{in situ} oxygen production to supply a future base. Siting a lunar base at any significant distance from the poles, however, would require costly transport of O or its extraction from the local regolith.

Over 20 different processes have been proposed for regolith O extraction \cite{1}. Among the simplest and best studied of these processes is the reduction of oxides in lunar minerals and glass using hydrogen gas. Oxides, predominantly those containing FeO, are first reduced and oxygen is liberated to form water. The water is then electrolyzed to yield oxygen, and the H is recycled to the reactor.

\textbf{Experiments:} Allen et al. \cite{2} reported the results of oxygen extraction experiments on 16 lunar soils and three samples of glassy and crystalline volcanic beads. Each sample was reacted in flowing hydrogen for 3 hr at 1050°C.

\textbf{Figure 1.} Correlation of total O yield with initial Fe\textsuperscript{2+} abundance for 16 reduced lunar soils (triangles) and three reduced volcanic bead samples (circles).

Total O yield correlated strongly to each sample's initial Fe\textsuperscript{2+} abundance (Fig. 1). A linear least squares fit of O yield vs. Fe\textsuperscript{2+} for 16 lunar soils yielded a regression line with a slope of 0.19, an intercept of 0.55 wt\% O and an \( r^2 \) value of 0.87. Oxygen yield did not significantly correlate with the abundance of any element except iron.

Apollo 17 volcanic glass sample 74220, composed predominantly of orange glass beads with an average diameter of 40 \( \mu \)m, contains 17.8 wt\% Fe\textsuperscript{2+}. Reduction of this sample yielded 4.3 wt\% O, well above the regression line defined by the experiments on 16 lunar soils (Fig. 1). Sample 74001, taken >25 cm beneath 74220, is dominated by black crystalline beads, the isochronal equivalent of orange glasses. Reduction of 74001 yielded 4.7 wt\% O, the highest value for any of the samples.

\textbf{Remote Sensing -- Iron Abundance:} These results show that, if the H reduction method is employed, O yield from a lunar soil can be predicted based solely on its Fe abundance. Therefore, it is possible to assess the potential for O production at any location on the Moon for which the soil's Fe concentration is known.

\textbf{Gamma Ray Spectrometry:} Iron was one of several elements measured from orbit during the Apollo 15 and 16 missions, using gamma ray spectrometry \cite{3}. These data cover approximately 20\% of the lunar surface, with spatial resolutions of around 100 km.

An improved gamma ray spectrometer on Prospector is currently mapping the abundances of iron, as well as thorium, potassium, uranium, oxygen, silicon, aluminum, calcium, magnesium and titanium, across almost the entire lunar surface. The resolution element at Prospector's current altitude is 150 x 150 km \cite{4}. Approximately one year of orbital operation will be required to attain statistically meaningful abundances for all elements.

\textbf{Multispectral Imaging:} A technique for Fe assessment based on orbital multispectral imaging has also been developed \cite{5}. This method correlates Fe abundance to a parameter derived from reflectance values at 750 and 900 nm. The authors use data from the Clementine spacecraft to map Fe abundances across nearly the entire lunar surface. These data can support identification of iron-rich regions as small as a few hundred meters across at any location on the Moon.

\textbf{Data Correlation:} Clark and McFadden \cite{6} attempted to correlate Clementine multispectral iron determinations with data from the Apollo gamma ray spectrometer. Within the limited areas of the lunar surface covered by both data sets they found good
agreement for most of the nearside but significant deviations at some farside locations. Publication of the entire Prospector data set will allow such comparison across nearly the entire Moon. Iron abundances determined by gamma ray spectroscopy can be used to calibrate and refine the multispectral determinations. These data, with high spatial resolution, can then be used with increased confidence to locate small areas of particularly high Fe abundance.

Remote Sensing – Volcanic Bead Deposits:
Lunar dark mantle deposits (DMDs), composed of glassy and crystalline volcanic beads, have been studied using telescopic and Apollo orbital photography [7]. Recent Clementine multispectral imagery has been employed to determine the precise extent, crystallinity and thickness of several DMDs [8,9].

The volcanic beads in each DMD vary in the amount of crystallinity, with dark patches at the Sinus Aestuum site having the highest concentration of crystallized beads and the Aristarchus Plateau DMD dominated by glasses [9]. All the other DMDs fall between these two extremes because they represent intermediate mixtures between the glasses and crystallized beads and have also undergone more mixing with the surrounding soils.

The DMDs are recognized by their low albedo, and their crystallinity is judged by analogy to the Apollo 17 orange and black glasses. However, these are not the only types of volcanic glass beads recognized on the Moon. Delano [10] identified 25 compositionally distinct types of glass beads in lunar soils. Thin section colors range from green and yellow to orange and red to black, depending on TiO$_2$ content and crystallinity.

No deposits of light-toned volcanic glass, analogous to the DMDs, have been recognized on the lunar surface, and the source vents for most of the 25 glass types are unknown. The combination of TiO$_2$ concentration data from gamma ray spectrometry, combined with multispectral imaging, holds the promise of identifying lunar “light mantle deposits” and locating their eruptive sources.

Volcanic bead deposits represent large volumes of unconsolidated, submillimeter material. Iron-rich beads have been shown to produce more O when reacted with H than other lunar soils. Thus, the deposits could be excellent locations for future lunar bases, both in terms of their scientific potential and their feasibility for maintaining a human presence on the Moon. A recent study by Coombs et al. [11] recommended two sites on the Aristarchus plateau for a future lunar outpost, based on a combination of resource extraction potential and geologic interest.