TERRESTRIAL CASE STUDIES OF ILMENITE EXPLORATION AND LUNAR IMPLICATIONS. S.C. Feldman and H.A. Franklin (Bechtel Corp., San Francisco, CA 94119)

INTRODUCTION. The Space Exploration Initiative (SEI) includes space resource utilization as one of the four architectures to achieve U.S. goals in space. Space resource utilization will make use of lunar resources to support long term activities on the lunar surface. Lunar ilmenite and regolith are two of the materials that can be mined and processed for lunar oxygen production. During this investigation, several sources were reviewed to assess terrestrial exploration methods used for locating ilmenite resources. These sources included published reports on terrestrial ilmenite exploration methods, analytical methods, case histories, chemical and physical properties, and associations with other minerals. Using a terrestrial analog and considering the differences between terrestrial and lunar environmental conditions, rocks, and minerals, exploration methods and analytical instruments can be recommended for a lunar orbiter and lander for assessing lunar resources.

IMPORTANCE OF EXPLORATION IN RESOURCE PRODUCTION. To produce a resource, such as oxygen from ilmenite, exploration is needed to gather information about the quantity and quality of the ore, the associated major, minor, and trace elements, and the depth and distribution of the deposit. These data contribute to mine planning and process plant design. Without them the life of the mine cannot be accurately predicted.

On the Earth, the initial exploration cost is extremely low compared with development and expansion costs, but provides the foundation for the operation. The same would be true for the Moon.

TERRESTRIAL CASE HISTORIES. Twelve terrestrial case histories were reviewed to gain insight into ilmenite exploration on the Moon. All exploration case histories follow the same pattern. They begin with a model, use remote geophysical techniques, define regional sampling sites from the model and geophysics, narrow down the area of exploration based on the preceding work, collect more samples and cores, and perform laboratory analyses of samples. An important part of this process is the collection of samples to determine the correctness of the model. Surface and core samples are collected in areas expected to contain both high and low concentration of the commodity to test the model. After samples are analyzed and the area of mineralization is defined, reserves are calculated to determine the cost/benefit ratio, the necessary capacity of the processing plant, and the life of the mine. Table 1 summarizes the exploration methods used for locating terrestrial ilmenite resources. These methods are reviewed with respect to the petrology, chemistry, and mineral associations of the terrestrial and lunar environments.

The number of samples collected and the size of the area of exploration in the case histories also have implications for lunar mining.

Table 1
Exploration methods for terrestrial ilmenite resources.

- Develop model
- Define area of resources
  - Mapping
    - Geologic
    - Topographic
  - Geophysics
    - Magnetic
    - Seismic
    - Radiometric
    - Electrical
    - Gravity
  - Sampling
    - Surface samples
    - Cores
  - Laboratory analysis
    - Grain size analysis
    - Chemical analysis
    - Mineralogical analysis
    - Magnetic separation
    - Magnetic susceptibility
    - Light/heavy mineral separation
    - Resistivity
    - Induced polarization
- Calculate reserves

DISCUSSION. NASA's Office of Exploration is planning two orbiting missions to the Moon. The orbiting missions are referred to as the Lunar Scout Program and will provide a basis for lunar exploration. The instruments to be flown on these missions are an X-ray fluorescence spectrometer, a gamma ray spectrometer, an imaging spectrometer, and the High Resolution Stereo Camera. The spatial resolution of chemical data gathered will be on the order of 10's of kilometers or more. Mineralogical data will have a spatial resolution of 80 to 180 m. Analytical instruments for surface missions to the Moon have been proposed for the Artemis Lunar Lander. The data needs for ilmenite exploration should to be examined together with the proposed orbiter and lander instrument requirements if ilmenite is a resource of interest for lunar oxygen production.