Integrated Multispectral and Hyperspectral Mineral Mapping, Los Menucos, Rio Negro, Argentina, Part I: Landsat TM Reconnaissance and AVIRIS Prospect Mapping

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1. 0 Introduction

The Los Menucos gold district was discovered in 1998 by Arminex, S.A. using regional exploration methods employing Landsat Thematic Mapper (TM) satellite imagery and field investigation (Franco et al., 2000; Gemuts and Perry, 2000; Perry and Gemuts, 2000). This district has the largest significant concentration of advanced argillic, altered Permian ignimbrite and rhyolite assemblages in Argentina. Alteration is related to the intrusion of Triassic-age (?) rhyolite dome complexes below thick Permian-age felsic volcanic rocks. Associated with dome fields are large areas of phreatic breccias and hematite-rich altered oxidized zones. Alteration is characterized by vuggy silica, quartz stockwork, kaolin, and alunite. The region has potential for low-sulfidation style gold mineralization. The Los Menucos region was submitted and selected as a NASA E0-1 collection site during 2000 to evaluate other earth observation sensors, including hyperspectral (airborne AVIRIS and satellite EO-1 Hyperion) as well as multispectral data sets (Landsat 7 Enhanced Thematic Mapper and ASTER imagery). The results of the TM reconnaissance and AVIRIS analysis are presented here. The Hyperion, ETM and ASTER results are presented in a companion paper (Kruse et al., 2002a).

2.0 Landsat TM Reconnaissance

Over 100 sites were predicted as alteration anomalies resulting from digital enhancement of Landsat TM imagery analyzed by Perry Remote Sensing LLC (PRS). These results were used to drive field exploration, and in less than one year, a field crew of six geologists systematically visited and sampled all of these anomalies. Eighty percent of the areas visited exhibited epithermal-style alteration, and five percent were mineralized. The exploration effort led Arminex to assemble 80,000 hectares near the village of Los Menucos and established the area as the first gold district in Rio Negro province. Early in 2000, Rio Tinto Mining & Exploration (RTZ) took an option on the Arminex property and agreed to continue drilling and testing at key prospect areas.

3.0 Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)

The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), flown by NASA/Jet Propulsion Laboratory (JPL) is a 224-channel imaging spectrometer with approximately 10 nm spectral resolution covering the 0.4 – 2.5-μm spectral range. It was flown for the Los Menucos site, Argentina on a Twin Otter aircraft at low altitude on 14-15 February 2001. The AVIRIS dataset consists of 6 overlapping, approximately 2.7km x 30km north-south flightlines, at 3.5m spatial resolution. Each flightline was processed and analyzed separately in reconnaissance mode

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(optimized for the entire dataset, not individual sites). Two spectral ranges were analyzed; 1) 0.4–1.3 μm (iron oxides), and 2) 2.0–2.5 μm (clays, carbonates, etc). Processing consisted of standardized hyperspectral analysis developed by AIG (Boardman and Kruse, 1994; Boardman et al., 1995; Kruse et al., 1996; Kruse et al., 2002b, 2002c; Kruse, 2002) to allow identification and mapping of key alteration minerals. This hyperspectral analysis methodology includes 1) correction of data to apparent reflectance using the ACORN atmospheric correction software (AIG, 2001), 2) linear transformation of the reflectance data to minimize noise and determine data dimensionality, 3) location of the most spectrally pure pixels, 4) extraction and automated identification of endmember spectra, and 5) spatial mapping and abundance estimates for specific image endmembers. A key point of this methodology is the reduction of data in both the spectral and spatial dimensions to locate, characterize, and identify a few key endmember spectra that can be used to explain the rest of the hyperspectral dataset. Once these endmembers are selected, then their location and abundances can be mapped from the original data. These methods derive the maximum information from the hyperspectral data themselves, minimizing the reliance on a priori or outside information. The results were map-corrected and combined into an image mosaic covering an approximately 10km x 30km area covering several key mineral prospects.

The high spatial resolution AVIRIS data allowed identification and mapping of common alteration minerals such as hematite, goethite, kaolinite, dickite, alunite, pyrophyllite, muscovite/sericite, montmorillonite, and calcite. Distinguishing between similar minerals such as kaolinite and dickite was possible because of the high signal-to-noise (SNR) of the AVIRIS sensor. The AVIRIS data pointed out minerals and mineral assemblages that would not have been readily apparent utilizing conventional field mapping methods. In particular, a large zoned hydrothermal system, dominated by several different muscovite species was mapped, and in addition, several previously unknown pyrophyllite occurrences cross-cutting predominant structural trends were detected and mapped.

4.0 Field Verification

AVIRIS mineral maps were used along with the Landsat TM mapping as base maps for field verification. Field reconnaissance was conducted during April 2001 with the assistance of RTZ geologists. Several prospects and other mineralogically interesting areas shown by the AVIRIS mineral maps were visited, the rocks and alteration were examined, and samples were collected utilizing real-time GPS positioning. Over 160 field-spectrometer readings were compiled to generate spectral libraries of key alteration minerals throughout the district. The field reconnaissance and spectral measurements verified the accuracy of the AVIRIS mapping. Known mineralized areas were accurately characterized and several new prospects identified (Kruse et al., 2002c). Spectral libraries were later used to refine AVIRIS results and to apply to EO-1 Hyperion and Landsat/ASTER multispectral evaluation.

5.0 Conclusions

The Los Menucos district provides an excellent case history of a complex epithermal gold system initially identified using satellite imagery and further mapped and explored using hyperspectral imaging systems. The district offers a host of argillic and advanced argillic alteration minerals at the surface, including many which are difficult to visually identify, thus it has proved to be an excellent test area for hyperspectral mapping. The combination of Landsat

TM reconnaissance with detailed AVIRIS mineral mapping provides powerful exploration tools. In the span of three field seasons, the district was explored, mapped, and further refined for sampling and drilling, using remote sensing technology to optimize man-hours in the field.

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