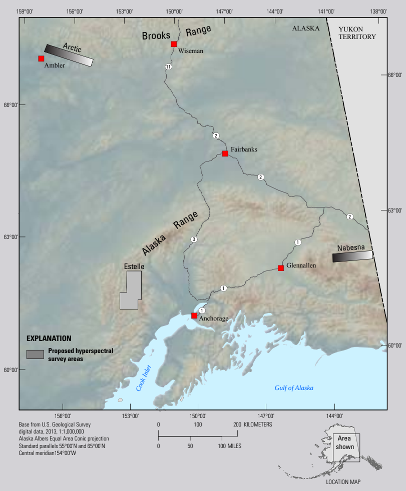
USGS
science for a changing world

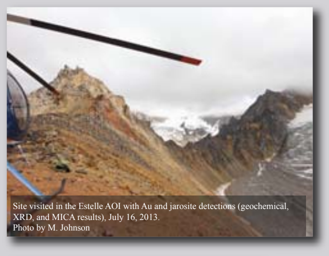
MAPPING SURFICIAL MINERALS AT HIGH LATITUDES: THE USGS 2014 IMAGING SPECTROMETER DATA COLLECTION IN ALASKA

Raymond F. Kokaly[1], Todd M. Hoefen[1], Garth E. Graham[1], Karen D. Kelley[1], Michaela R. Johnson[1], Bernard E. Hubbard[2] and Richard J. Goldfarb[1]
[1]U.S. Geological Survey, Denver, Colorado, USA
[2]U.S. Geological Survey, Reston, Virginia, USA

ABSTRACT

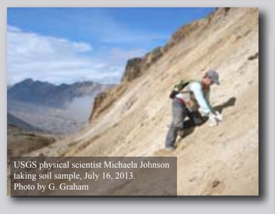
Passive optical remote sensing of high latitude regions faces many challenges including a short acquisition season and poor illumination due to low solar elevation. Additional complications are encountered in the identification of surface minerals for mineral resource characterization because minerals of interest commonly are exposed on steep terrain, further challenging reflectance retrieval and detection of mineral signatures. On shallow slopes and flat terrain, vegetation cover can interfere with or obscure the absorption features of minerals in rock and soil. The USGS is conducting a study to examine the viability of using remote sensing techniques for identification of large-tonnage, base metal-rich deposits in Alaska.




Site visited in the Estelle AOI with Au and jarosite detections (geochemical, XRD, and MICA results), July 16, 2013. Photo by M. Johnson


Spectral measurement, July 15, 2013. Photo by B. Hubbard


Garth Graham and Michaela Johnson calibrating field spectrometer at Island Mountain, July 14, 2013. Photo by B. Hubbard


USGS physical scientist Michaela Johnson taking soil sample, July 16, 2013. Photo by G. Graham


USGS geophysicist Raymond Kokaly measuring calibration site with a field spectrometer. Photo by G. Graham

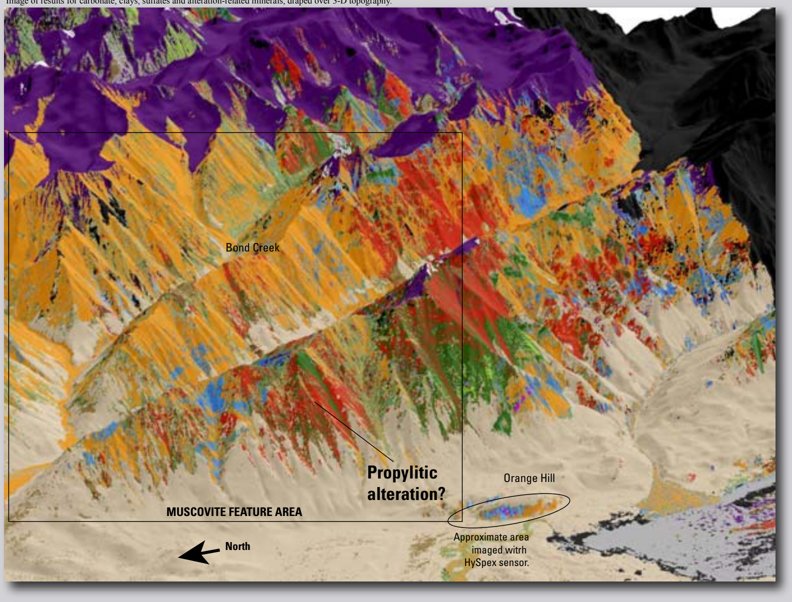
STUDY AREAS OF INTEREST (AOIs)

Nabesna: Favorability for Cu±Mo-Au porphyry deposits
Arctic: Favorability for polymetallic and precious-metal bearing VMS deposits
Estelle: Favorability for intrusion-related and orogenic gold deposits

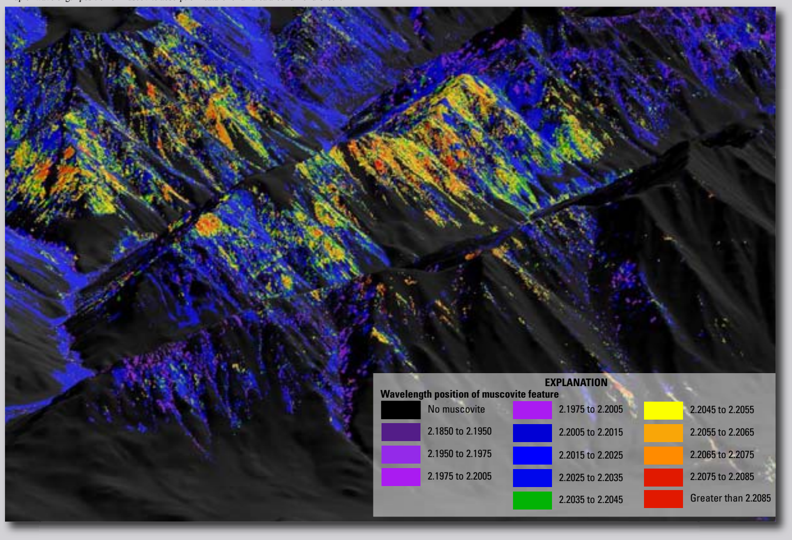
RESULTS: REMOTE SENSING OF SURFACE MINERALS

Reflectance retrieval using the ATCOR-4 software was found to produce better results than ACORN. Preliminary mapping results, showing minerals with absorption features in the 2-micron region of the electromagnetic spectrum, are presented for the area of the Nabesna AOI around the Orange Hill and Bond Creek porphyry prospects in plan view (panel at right) and draped over topography (panel below). These maps display pixel by pixel classifications of the mineral with the strongest spectral signature. Some patterns relate to lithology. For example, more abundant chlorite/epidote classifications occur in areas mapped as greenstone and greenschist facies rocks (southern areas of the rightmost panel). While the Nabesna pluton is characterized by widespread muscovite classification, the Orange Hill and Bond Creek prospect areas are mapped as bearing muscovite with occasional kaolinite and sporadic jarosite and gypsum. Additional gypsum and pyrophyllite zones are mapped to the south. The perspective view (panels below) provide a third dimension to help understand the distribution of minerals within altered rock. For example, chlorite and epidote mapped uphill and to the left of Orange Hill may represent distal propylitic alteration assemblages from the deposit, but still within the Nabesna pluton. Recent field work was conducted in July, 2015, that will examine the relationship of mineral patterns in the HyMap data to ground observations and geochemistry.

Image of results for carbonate, clays, sulfates and alteration-related minerals, draped over 3-D topography.



Map of wavelength position of muscovite absorption feature for an area around Bond Creek.



The wavelength position of the muscovite absorption feature shifts with changing aluminum (Al) composition (Swayze et al., 2014). Shifts in muscovite composition have been used to characterize zones of higher temperature alteration related to metal deposits. Harraden et al. (2013) found the highest gold and copper concentrations within the Pebble deposit to be associated with low AlOH values associated with pyrophyllite and sericite alteration. Additional methods have been developed for the USGS PRISM (Processing Routines in IDL for Spectroscopic Measurements; Kokaly, 2011) software to map muscovite AlOH composition in the HyMap data (panel above).

PLANNED WORK

We are developing a framework for integrating the results from classification of surface mineral composition with other geologic data. The viability of using remote sensing techniques for identification of large-tonnage base metal-rich ores in Alaska will be assessed. The extent of porphyry-related alteration assemblages in the Nabesna AOI, as defined from remotely sensed information, will be examined. Further, the extent of massive sulfide mineralization in the Arctic AOI will be investigated.

We plan to cross-calibrate selected ASTER and WorldView3 (WV3) images, where overlapping with HyMap data. Airborne imaging spectrometer data are very powerful for characterizing mineral composition, however, the expense of acquisition and sparse availability of these data are limiting factors. A cross-calibration/cross-validation with hyperspectral and multispectral data is an approach to lower costs and extend mineral mapping to nearby areas of exposed ground with active resource exploration. The ASTER and WV3 data will be evaluated to extend mineral identifications beyond the area covered by the HyMap data.

U.S. Department of the Interior
U.S. Geological Survey

DATA COLLECTION AND PROCESSING

In July, 2014, approximately 2,000 line kilometers of imagery were collected using the HyMap2 sensor (Cocks et al., 1998) over the Arctic and Nabesna AOIs. The HyMap2 imaging spectrometer measured reflected sunlight in 126 narrow channels spanning the 0.4 to 2.5 micrometer wavelength region of the electromagnetic spectrum. The data were collected at a nominal 6 m ground-instantaneous field of view (GIFOV). Simultaneously with the airborne survey, representative rock and soil samples of geologic units were collected for verification of remote sensing data. In the Arctic AOI, these samples included fresh and altered metavolcanic and metasedimentary host rocks for the Arctic copper-zinc-lead-silver (Cu-Zn-Pb-Ag) volcanogenic massive sulfide (VMS) deposit and the Sunshine and Horse/Cliff VMS prospects. In the Nabesna AOI, sampling focused on altered and unaltered parts of intrusions hosting mid-Cretaceous porphyry copper deposits and mineralized occurrences at Orange Hill, Bond Creek, Baultoff, and Horsfeld. In addition to geologic sampling, field spectra of exposed rocks and soils were collected using an Analytical Spectral Devices (ASD) FieldSpec4 spectrometer (Panalytical, Boulder, Colorado, USA).

IMAGING SPECTROMETER DATA COLLECTION

- HyMap, 126 channels, 0.44 to 2.5 microns, ~6 m pixel
- Digital camera ~30 cm pixel (true color)
- More than 2,000 line km collected in the Nabesna and Artic AOIs
- Concurrent with field work (spectral and geologic sampling)


Piper Navajo

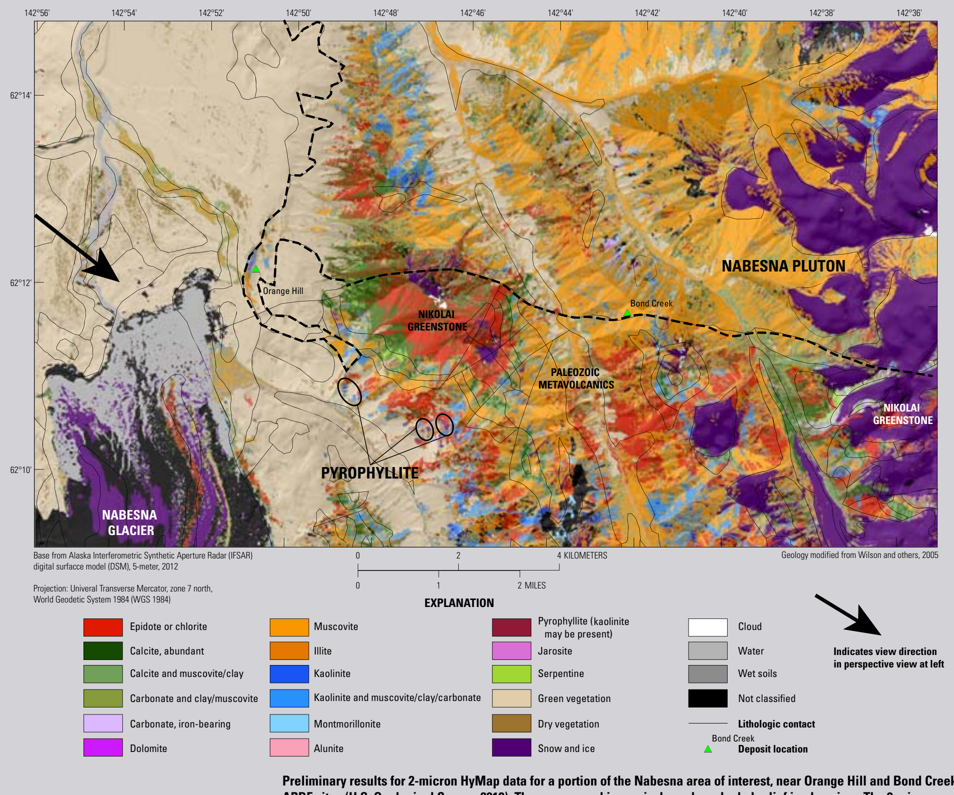

USGS geologist Garth Graham in the Brooks range. Photo by T. Hoefen


Ridge above Bond Creek, Wrangell-St. Elias National Park. Photo by R. Kokaly


HyMap imaging spectrometer

The HyMap2 data were converted from radiance to reflectance using a multistep calibration process (Kokaly, et al., 2013). First, the radiance data were converted to apparent surface reflectance using radiative transfer codes. Two different programs were examined, Atmospheric CORrection Now (ACORN) version 6lx (ImSpec LLC, Palmdale, California, USA) and ATCOR-4 (ReSe Applications, Zurich, Switzerland). ATCOR-4 data were further adjusted using ground-based reflectance measurements from a calibration site.

Reflectance images were processed using the Material Identification and Characterization Algorithm (MICA), a program written in Interactive Data Language (IDL; ExelisVIS, Boulder, Colorado, USA). MICA is a module of the USGS PRISM (Processing Routines in IDL for Spectroscopic Measurements) software (Kokaly, 2011). The MICA analysis identifies the dominant mineral content in each pixel of imaging spectrometer data by comparing its reflectance spectrum to a reference spectral library of minerals, vegetation, water, and other materials.

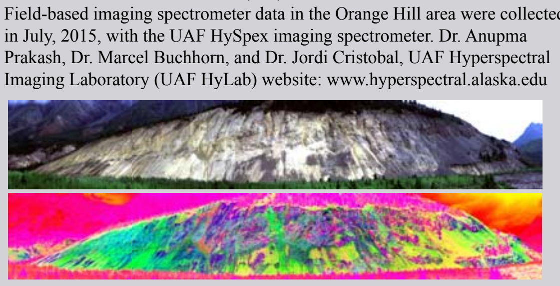


Preliminary results for 2-micron HyMap data for a portion of the Nabesna area of interest, near Orange Hill and Bond Creek ARDF sites (U.S. Geological Survey, 2012). The upper panel image is draped on shaded relief in plan view. The 2-micron and muscovite feature images in the left panels are draped over 3-D topography (DEM) (view direction is indicated by arrow).

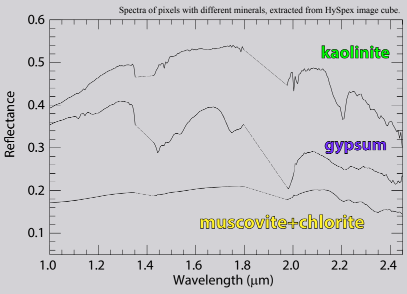
COLLABORATORS

UNIVERSITY OF ALASKA FAIRBANKS (UAF)

Field-based imaging spectrometer data in the Orange Hill area were collected in July, 2015, with the UAF HySpex imaging spectrometer. Dr. Anupma Prakash, Dr. Marcel Buchhorn, and Dr. Jordi Cristobal, UAF Hyperspectral Imaging Laboratory (UAF HyLab) website: www.hyperspectral.alaska.edu


HySpex images of Orange Hill. The top image is a true-color composite from the Visible-Near InfraRed (VNIR) sensor, ~6.5 cm pixel size. The bottom image is a false-color composite from the ShortWave InfraRed (SWIR) sensor, ~29 cm pixel size.

Spectra of pixels with different minerals, extracted from HySpex image cube.



DIGITALGLOBE (DG)

DG, a provider of satellite remote sensing data, will collect WorldView3 (WV3) multispectral satellite data over the Nabesna AOI in summer of 2015.

ALASKA DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS (ADGGS)

USGS and ADGGS are cooperating to define additional hyperspectral projects in Alaska (Steve Masterman, Melanie Werdon, and Larry Freeman)

NOVA COPPER, INC. (NC)

NC, a mineral exploration company, provided detailed company geologic maps and opened their exploration camp in support of our 2014 field work in the Arctic AOI.


Dr. Marcel Buchhorn with the HySpex sensor at Orange Hill, July 2015. Photo by Charlie Phillips.

PRODUCTS

Cole, C.J., Johnson, M.R., and Graham, G.E., 2015, Advanced Land Observing Satellite (ALOS) Phased Array Type L-Band Synthetic Aperture Radar (PALSAR) mosaic for the Kahiltna terrane, Alaska, 2007–2010: *U.S. Geological Survey Scientific Investigations Map, 1 sheet, scale 1:1,000,000*, http://dx.doi.org/10.3133/sim3323.
Kokaly, R.F., and Skidmore, A.K. (in press). Plant phenolics and absorption features in vegetation reflectance spectra near 1.66 μm. *International Journal of Applied Earth Observation and Geoinformation*. http://www.sciencedirect.com/science/article/pii/S0303243415000112
Johnson, M.R., Graham, G.E., Hubbard, B.E., and Benzel, W.M., 2015, Geospatial compilation of results from field sample collection in support of mineral resource investigations, Western Alaska Range, Alaska, July 2013: U.S. Geological Survey Data Series 943, 12 p., http://dx.doi.org/10.3133/ds943.

REFERENCES

Cocks, T., Jenssen, R., Stewart, A., Wilson, I., and Shields, T., 1998, The HyMap airborne hyperspectral sensor—The system, calibration and performance, in Schaepman, M., Schlapfer, D., and Itten, K.I., eds., Proceedings of the 1st EARSeL Workshop on Imaging Spectroscopy, 6-8 October 1998, Zurich: Paris, EARSeL, p. 37–43.
Harraden, C.L., McNulty, B.A., Gregory, M.J., and Lang, J.R., 2013, Shortwave infrared spectral analysis of hydrothermal alteration associated with the Pebble Porphyry copper-gold-molybdenum deposit, Iliamna, Alaska: Economic Geology, v. 108, p. 483–494.
Kokaly, R.F., 2011, PRISM: Processing routines in IDL for spectroscopic measurements (installation manual and user's guide, version 1.0): U.S. Geological Survey Open-File Report 2011–1155, 432 p.
Kokaly, R.F., King, T.V.V., and Hoefen, T.M., 2013, Surface mineral maps of Afghanistan derived from HyMap imaging spectrometer data version 2: U.S. Geological Survey Data Series 787, 29 p., http://pubs.usgs.gov/ds/787/.
Swayze, G.A., Clark, R.N., Goetz, A.F.H., Livo, K.E., Breit, G.N., Kruse, F.A., Sutley, S.J., Snee,L.W., Lowers,H.A., Post,J.L., Stoffregen, R.E., and Ashley, R.P., 2014, Mapping advanced argillic alteration at Cuprite, Nevada, using imaging spectroscopy. Economic Geology, v. 109, no. 5: 1179-1221.
U.S. Geological Survey, 2012, Alaska Resource Data File (ARDF), digital data, accessed September 25, 2014, at http://ardf.wr.usgs.gov/.
Wilson, F.H., Labay, K.A., Shew, N.B., Preller, C.C., Mohadjer, Solmaz, and Richter, D.H., 2005, Preliminary integrated geologic map databases for the United States : digital data for the geology of Wrangell-Saint Elias National Park and Preserve, Alaska: U.S. Geological Survey Open-File Report 2005-1342.

Presented at International Geoscience and Remote Sensing Symposium (IGARSS) 2015, Milan, Italy, July 29, 2015.