U.S. DEPARTMENT OF THE INTERIOR
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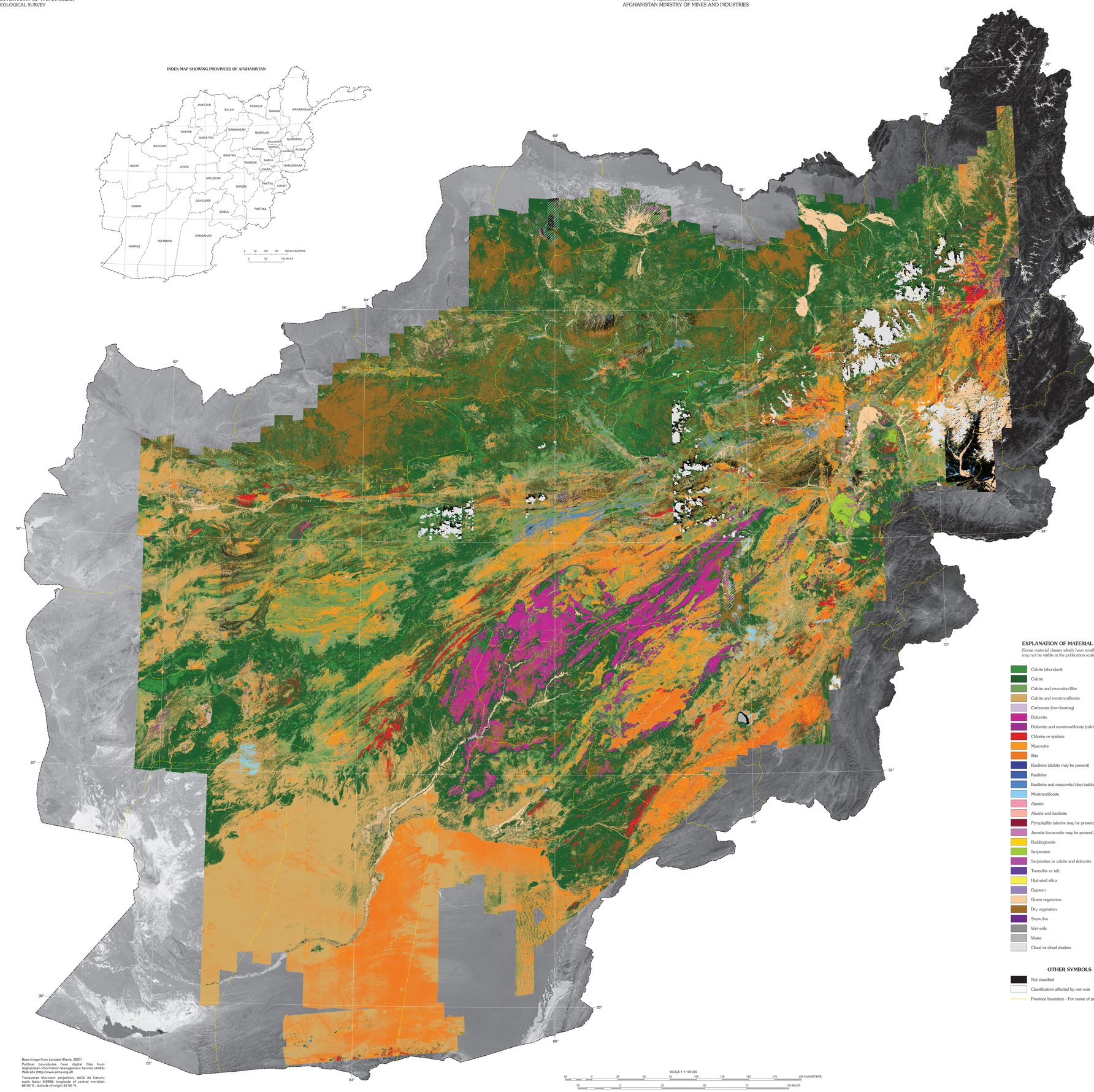
Prepared in cooperation with the
AFGHANISTAN MINISTRY OF MINES AND INDUSTRIES

SCIENTIFIC INVESTIGATIONS MAP 3152–A
USGS Afghanistan Project Product No. 190



DATA SUMMARY

This map shows the distribution of selected carbonates, phyllosilicates, sulfates, altered minerals, and other materials derived from analysis of HyMap imaging spectrometer data of Afghanistan. Using a NASA (National Aeronautics and Space Administration) WB-57 aircraft flown at an altitude of ~15,240 meters (m) or ~50,000 feet (ft), 218 flight lines of data were collected over Afghanistan between August 22 and October 2, 2007 (Kokaly and others, 2008). The grayscale background image, visible in the area of no data around the country's perimeter, is from Landsat Enhanced Thematic Mapper Plus (ETM+) (Davis, 2007).

The HyMap imaging spectrometer measures 128 channels of reflected sunlight at wavelengths between 0.4 and 2.5 µm (Cocks and others, 1998). The HyMap data were converted to apparent surface reflectance using ACORN (Atmospheric CORrection Now) version 6/x software developed by ImSpec LLC), then further empirically adjusted using ground-based reflectance measurements. Each flight line was georeferenced to Landsat base imagery in Universal Transverse Mercator projection (Davis, 2007).

HyMap reflectance data were processed using MICA (Material Identification and Characterization Algorithm), a module of the U.S. Geological Survey PRISM (Processing Routines in IDL for Spectroscopic Measurements) software (Kokaly, 2011). Subsequently, the classified HyMap results were projected to a Transverse Mercator projection and mosaicked, with 23-m pixel spacing. Using MICA, the reflectance spectrum of each pixel of HyMap data was compared to the spectral features of reference entries in a spectral library of minerals, vegetation, water, ice, and snow. For each pixel, MICA determined the reference material having the best matching spectrum. MICA analysis resulted in a "Not classified" determination for a pixel when comparisons with reference spectra produced no viable match (see Kokaly, 2011).

This map shows the spatial distribution of minerals that have diagnostic absorption features in the shortwave infrared wavelengths. These absorption features result primarily from characteristic chemical bonds and mineralogical vibrations. A complementary map showing the distribution of iron-bearing minerals and other materials having diagnostic absorption features at visible and near-infrared wavelengths has also been created (King and others, 2011).

Several criteria, including (1) the reliability of detection and discrimination of minerals using the HyMap spectrometer data, (2) the relative abundance of minerals, and (3) the importance of particular minerals to studies of Afghanistan's natural resources, guided the selection of entries in the reference spectral library and, therefore, guided the selection of mineral classes shown on this map. Minerals occurring abundantly at the surface and those having unique spectral features were easily detected and discriminated. Minerals having similar spectral features were less easily discriminated, especially where the minerals were not particularly abundant and (or) where vegetation cover reduced the absorption strength of mineral features. Thus, some map classes include several minerals having similar spectra, for example, the "Chlorite or Epidote" class. In addition, some identified minerals were grouped to reduce the total number of classes, in order to allow the assignment of discernible map colors.

Complications in reflectance calibration also affected the detection and identification of minerals. Complications arose because of (1) the large magnitude of the imaging spectrometer dataset, which covers an area over 480,000 km^2, (2) surface elevations that range from 280 to 5,642 m (920–18,510 ft), and (3) a protracted data-collection period lasting 43 days. In addition, variations in daily weather, in solar angles, and in airborne dust levels affected reflectance calibrations. In cloud-contaminated areas, it was not possible to completely remove atmospheric effects in the conversion of the data to reflectance because of significant variation in water-vapor content of the atmosphere. As a result, some differences in identified material classes exist between adjacent flight lines that differed in extent of cloud cover. Similarly, minor differences in identified material classes occur between adjacent flight lines having large differences in solar illumination angles (see Kokaly and others (2008) for flight-line data collection times and dates). On October 2, 2007, the last day of data collection, a large dust storm blanketed northern Afghanistan (see Kokaly and others, 2008). No correction for airborne dust, beyond extension of the ground calibration factor, was applied to the data collected along these lines.

Hatched lines identify areas where mineral identification was adversely affected by soil moisture. Material classification in these areas is less accurate due to the distortion of reflectance spectra by the strong absorption of light in the infrared wavelengths by the water in the soil. In some limited areas, the MICA analysis misidentified wet, bright soils as snow, because both are highly reflective in the visible wavelengths but are strongly absorbing at longer wavelengths. Pixels classified initially as snow-covered for land surfaces whose elevation is lower than a threshold elevation of 3,150 m (10,334 ft) were reclassified as wet soils.

The 31 classes in the list of materials represent a necessary compromise between striving for the highly focused level of detail achievable in the best calibrated flight lines, on the one hand, and, on the other hand, seeking identifications that were reliably detected across the entire country and that occurred in large enough areas to be perceptible at a national map scale. Each class name specifies a mineral, or several minerals, whose reflectance spectra match the HyMap data. However, minerals having slightly different chemical compositions may have very similar reflectance spectra. Therefore, the material classes represented on this map should be evaluated giving consideration to the effects of mineral chemical composition on reflectance spectra.

REFERENCES CITED

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., Schläpfer, D., and Iten, K.I., eds., Proceedings of the First EARSeL Workshop on Imaging Spectroscopy, October 6–8, 1998, Zurich, Switzerland: Paris, EARSeL, p. 37–43.

Davis, P.A., 2007, Landsat ETM+ false-color image mosaics of Afghanistan: U.S. Geological Survey Open-File Report 2007–1029, 22 p., available at http://pubs.usgs.gov/of/2007/1029/.

King, T.V.V., Kokaly, R.F., Hoefen, T.M., Dudek, K.B., and Livo, K.E., 2011, Surface materials map of Afghanistan: iron-bearing minerals and other materials: U.S. Geological Survey Scientific Investigations Map 3152-B, one sheet, scale 1:1,100,000. Also available at http://pubs.usgs.gov/sim/3152/B/.

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, available at http://pubs.usgs.gov/of/2011/1155/.

Kokaly, R.F., King, T.V.V., and Livo, K.E., 2008, Airborne hyperspectral survey of Afghanistan 2007; flight line planning and HyMap data collection: U.S. Geological Survey Open-File Report 2008–1235, 14 p., available at http://pubs.usgs.gov/of/2008/1235/.

EXPLANATION OF MATERIAL CLASSES

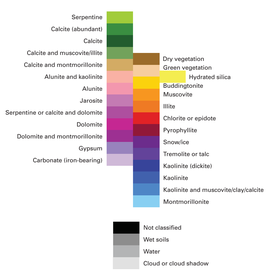
[Some material classes which have small areal extent may not be visible at the publication scale of this map]

- Calcite (abundant)
- Calcite
- Calcite and muscovite/illite
- Calcite and montmorillonite
- Carbonate (iron-bearing)
- Dolomite
- Dolomite and montmorillonite (calcite may be present)
- Chlorite or epidote
- Muscovite
- Illite
- Kaolinite (dickite may be present)
- Kaolinite
- Kaolinite and muscovite/clay/calcite
- Montmorillonite
- Alunite
- Alunite and kaolinite
- Pyrophyllite (alunite may be present)
- Jarosite (muscovite may be present)
- Buddingtonite
- Serpentine
- Serpentine or calcite and dolomite
- Tremolite or talc
- Hydrated silica
- Gypsum
- Green vegetation
- Dry vegetation
- Snow/ice
- Wet soils
- Water
- Cloud or cloud shadow

OTHER SYMBOLS

- Not classified
- Classification affected by wet soils
- Province boundary—For name of province see index map

COLOR COMPARISON CHART



Base image from Landsat (Davis, 2007)
Political boundaries from digital files from Afghanistan Information Management Service (AIMS) Web site (http://www.aims.org.af)

Transverse Mercator projection, WGS 84 Datum; scale factor 0.9996; longitude of central meridian 66°00' E.; latitude of origin 34°00' N.

SCALE 1:1 100 000
25 0 25 50 75 100 125 150 175 200 KILOMETERS
25 0 25 50 75 100 MILES

SURFACE MATERIALS MAP OF AFGHANISTAN: CARBONATES, PHYLLOSILICATES, SULFATES, ALTERED MINERALS, AND OTHER MATERIALS

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