U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
Afghan Geological Survey
under the auspices of the U.S. Agency for International Development

OPEN-FILE REPORT 2020–1101
SHEET 2 of 2
USGS Afghanistan Project Product No. 337

INTRODUCTION

In 2007, as part of a collaborative effort, the U.S. Department of State, U.S. Geological Survey, National Aeronautics and Space Administration, Afghanistan Ministry of Mines and Afghan Geological Survey conducted an airborne hyperspectral survey of Afghanistan using the HyMap imaging spectrometer, that measures 128 channels of reflected sunlight at wavelengths between 0.4 and 2.5 microns (µm) (Cocks and others, 1998). Using Material Identification and Characterization Algorithm (MICA) processing techniques, the reflectance spectrum of each pixel of HyMap data was compared and matched to the spectral features of reference entries in a spectral library of minerals, vegetation, water, ice, and snow. Some material classes were created to categorize various suites of minerals that have slightly different compositions but similar spectral signatures. MICA analysis also resulted in a "not classified" determination for a pixel when comparisons with reference spectra produced no viable match (Kokaly, 2011). These data are available for most of Afghanistan and yield useful information about the composition and mineralogy of the upper few millimeters of the Earth's surface.

The results of the spectroscopic analysis are two data sets, one for spectral absorptions that occur at wavelenghts near the 1-µm region and one near the 2-µm region (King and others 2011a). These data sets resulted in the publication of two countrywide maps; the "Surface materials map of Afghanistan: iron-bearing minerals and other materials" (King and others, 2011b), the 1-µm map; and the "Surface materials map of Afghanistan: carbonates, phyllosilicates, sulfates, altered minerals, and other materials" (Kokaly and others 2011), the 2-µm map. These maps depict one of the most comprehensive databases of hyperspectral imagery in the world. In addition, in 2013, a series of 30 hyperspectral surface materials maps were published at a scale of 1:250,000 depicting the 1-µm and 2-µm data.

Maps *A* and *B* show the spatial distribution of selected minerals and other materials that were created by the rescaling and georeferencing of two 1:250,000-scale hyperspectral maps; the "Hyperspectral surface materials map of quadrangle 3568, Pul-e Khumri (503) and Charikar (504) quadrangles, Afghanistan, showing iron-bearing minerals and other materials" (King and others, 2013); and the "Hyperspectral surface materials map of quadrangle 3568, Pul-e Khumri (503) and Charikar (504) quadrangles, Afghanistan, showing carbonates, phyllosilicates, sulfates, altered minerals, and other materials" (Kokaly and others, 2013b). The hyperspectral data for these maps were then clipped to the map extend of the geologic map (sheet 1) in order to relate the hyperspectral data to geologic units, faults, drainage, cultural information, and locations of mineral deposits and ore occurrences identified on the redrafted Soviet map "sheet 1" (Shadchineva and others, 1975). To minimize interference with pixel data, contours were not added; however, shading was maintained to help identify relief. It should be noted that shading will modify the mineral colors as identified in the explanation of material classes. For the Description of Map Units, see sheet 1.

The purpose of sheet 2 was to test the possibility of registering hyperspectral data to redrafted vintage Soviet geologic maps. At the scale of 1:100,000, these maps when combined with geology, shaded relief, and cultural features, provide additional possibilities and application for the hyperspectral data. However, since field verification is not possible, no attempt was made to interpret possible geologic relationships.

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EXPLANATION OF MAP SYMBOLS

- **Contact**
- **Fault**—Dashed where inferred
- **River; ephemeral stream**
- **Province boundary**
- **Road: trail**
- **Town**

Table 1.—Explanation of mineral commodity locations from Shadchinev and others (1975). The table is repeated from sheet 1.

Mineral commodity	Industrial deposit	Non-industrial deposit	Ore occurrence	Location of mineralization
Iron	●		●	●
Manganese				●
Copper			●	●
Lead			●	●
Zinc				●
Tin			●	
Arsenic				●
Silver			●	●
Lithium	●		●	●
Tantalum	●	◎	●	●
Niobium	●	◎	●	●
Ceramic pegmatite			◆	
Muscovite mica			◆	
Talc			◆	
Raw cement material (limestone)	■			
Sand used for casting			■	
Emerald			◆	

For more detailed information of ore occurrence, see annex 2 and 3 of Shadchinev and others (1975).

EXPLANATION OF MATERIAL CLASSES

IRON-BEARING MINERALS AND OTHER MATERIALS

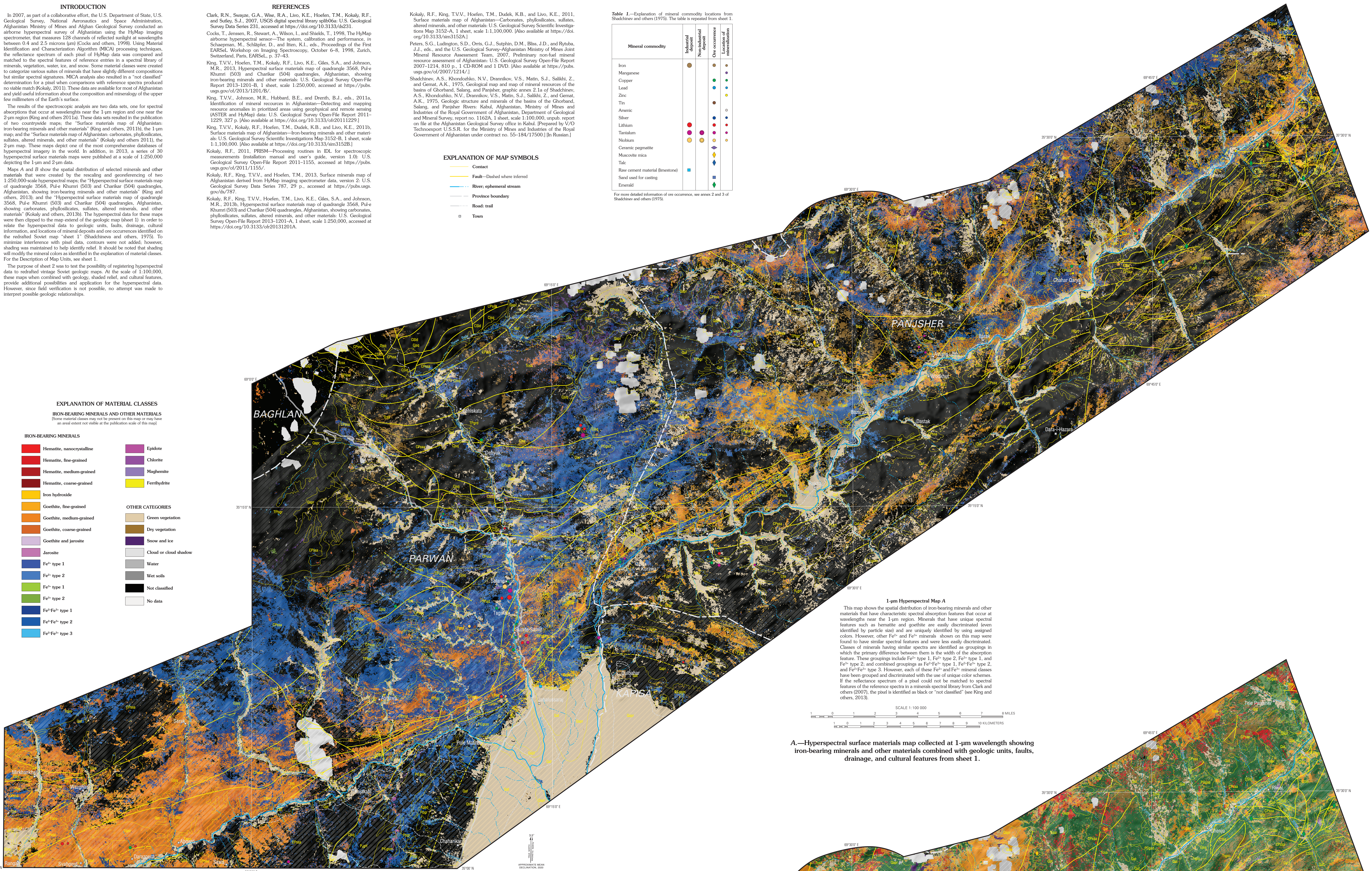
[Some material classes may not be present on this map or may have an areal extent not visible at the publication scale of this map]

IRON-BEARING MINERALS

- Hematite, nanocrystalline
- Hematite, fine-grained
- Hematite, medium-grained
- Hematite, coarse-grained
- Iron hydroxide
- Goethite, fine-grained
- Goethite, medium-grained
- Goethite, coarse-grained
- Goethite and jarosite
- Jarosite
- Fe^{2+} type 1
- Fe^{2+} type 2
- Fe^{3+} type 1
- Fe^{3+} type 2
- $Fe^{2+}Fe^{3+}$ type 1
- $Fe^{2+}Fe^{3+}$ type 2
- $Fe^{2+}Fe^{3+}$ type 3
- Epidote
- Chlorite
- Maghemite
- Ferrihydrite

OTHER CATEGORIES

- Green vegetation
- Dry vegetation
- Snow and ice
- Cloud or cloud shadow
- Water
- Wet soils
- Not classified
- No data



Topography, hydrography, and shaded relief derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) 30-meter Global Digital Elevation Model (GDEM) data, 2009

Projection and grid: Universal Transverse Mercator (UTM), zone 42 north

World Geodetic System (WGS) 1984 Datum

Cultural data from digital files at the Afghanistan Information Management Services (AIMS), accessed 2015, at http://www.aims.org.af

Hyperspectral imagery from the "Hyperspectral surface materials map of quadrangle 3568, Pul-e Khumri (503) and Charikar (504) quadrangles, Afghanistan, showing iron-bearing minerals and other materials," by King and others (2013), U.S. Geological Survey Open-File Report 2013–1201–B.

1-µm Hyperspectral Map *A*

This map shows the spatial distribution of iron-bearing minerals and other materials that have characteristic spectral absorption features that occur at wavelengths near the 1-µm region. Minerals that have unique spectral features such as hematite and goethite are easily discriminated (even identified by particle size) and are uniquely identified by using assigned colors. However, other Fe^{2+} and Fe^{3+} minerals shown on this map were found to have similar spectral features and were less easily discriminated. Classes of minerals having similar spectra are identified as groupings in which the primary difference between them is the width of the absorption feature. These groupings include Fe^{2+} type 1, Fe^{2+} type 2, Fe^{3+} type 1, and Fe^{3+} type 2; and combined groupings as $Fe^{2+}Fe^{3+}$ type 1, $Fe^{2+}Fe^{3+}$ type 2, and $Fe^{2+}Fe^{3+}$ type 3. However, each of these Fe^{2+} and Fe^{3+} mineral classes have been grouped and discriminated with the use of unique color schemes. If the reflectance spectrum of a pixel could not be matched to spectral features of the reference spectra in a minerals spectral library from Clark and others (2007), the pixel is identified as black or "not classified" (see King and others, 2013).

SCALE 1:100 000

1 0 1 2 3 4 5 6 7 8 MILES

1 0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

***A.*—Hyperspectral surface materials map collected at 1-µm wavelength showing iron-bearing minerals and other materials combined with geologic units, faults, drainage, and cultural features from sheet 1.**

EXPLANATION OF MATERIAL CLASSES

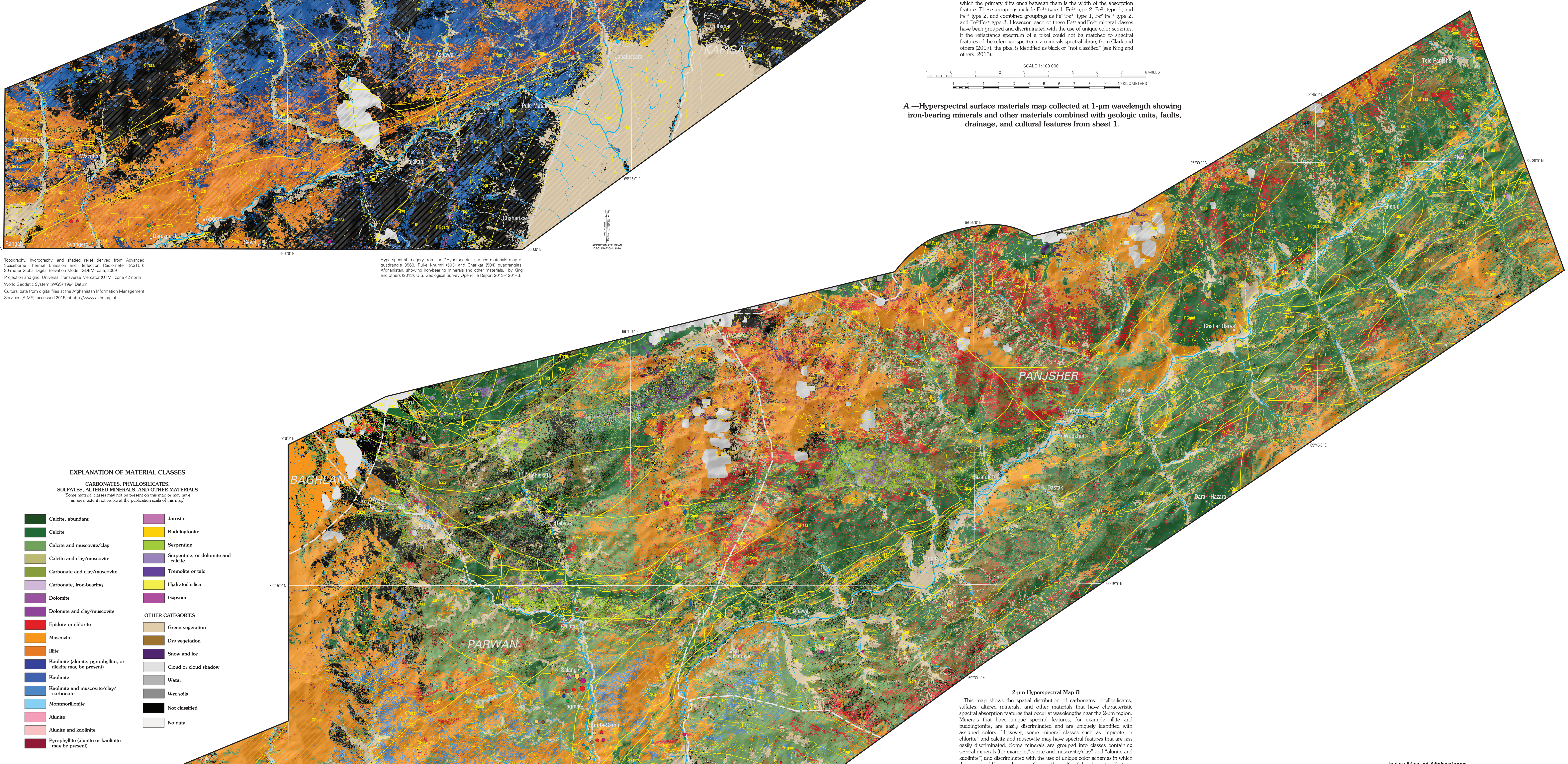
CARBONATES, PHYLLOSILICATES, SULFATES, ALTERED MINERALS, AND OTHER MATERIALS

[Some material classes may not be present on this map or may have an areal extent not visible at the publication scale of this map]

- Calcite, abundant
- Calcite
- Calcite and muscovite/clay
- Calcite and clay/muscovite
- Carbonate and clay/muscovite
- Carbonate, iron-bearing
- Dolomite
- Dolomite and clay/muscovite
- Epidote or chlorite
- Muscovite
- Illite
- Kaolinite (alunite, pyrophyllite, or dickite may be present)
- Kaolinite
- Kaolinite and muscovite/clay/carbonate
- Montmorillonite
- Alunite
- Alunite and kaolinite
- Pyrophyllite (alunite or kaolinite may be present)
- Jarosite
- Buddingtonite
- Serpentine
- Serpentine, or dolomite and calcite
- Tremolite or talc
- Hydrated silica
- Gypsum

OTHER CATEGORIES

- Green vegetation
- Dry vegetation
- Snow and ice
- Cloud or cloud shadow
- Water
- Wet soils
- Not classified
- No data



Topography, hydrography, and shaded relief derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) 30-meter Global Digital Elevation Model (GDEM) data, 2009

Projection and grid: Universal Transverse Mercator (UTM), zone 42 north

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Hyperspectral imagery from the "Hyperspectral surface materials map of quadrangle 3568, Pul-e Khumri (503) and Charikar (504) quadrangles, Afghanistan, showing carbonates, phyllosilicates, sulfates, altered minerals, and other materials," by Kokaly and others (2013b), U.S. Geological Survey Open-File Report 2013–1201–A.

2-µm Hyperspectral Map *B*

This map shows the spatial distribution of carbonates, phyllosilicates, sulfates, altered minerals, and other materials that have characteristic spectral absorption features that occur at wavelengths near the 2-µm region. Minerals that have unique spectral features, for example, illite and buddingtonite, are easily discriminated and are uniquely identified with assigned colors. However, some mineral classes such as "epidote or chlorite" and calcite and muscovite may have spectral features that are less easily discriminated. Some minerals are grouped into classes containing several minerals (for example,"calcite and muscovite/clay" and "alunite and kaolinite") and discriminated with the use of unique color schemes in which the primary difference between them is the width of the absorption feature. If the reflectance spectrum of a pixel could not be matched to spectral features of reference spectra in a minerals spectral library from Clark and others (2007), the pixel is identified as black or "not classified" (see Kokaly and others, 2013b).

SCALE 1:100 000

1 0 1 2 3 4 5 6 7 8 MILES

1 0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

***B.*—Hyperspectral surface materials map collected at 2-µm wavelength showing carbonates, phyllosilicates, sulfates, altered minerals, and other materials combined with geologic units, faults, drainage, and cultural features from sheet 1.**

Index Map of Afghanistan

Area of this report is shown with green fill. The map area includes parts of the provinces that are outlined in red.

Sheet 2—Hyperspectral surface materials maps

Geologic and Mineral Map (Modified from the 1975 Original Map Compilation by A.S. Shadchinev and Others) and Hyperspectral Surface Materials Maps of the Ghorband, Salang, and Panjsher River Basins; Kapisa, Panjsher, Parwan, and Baghlan Provinces, Afghanistan

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2020

For sale by U.S. Geological Survey, Box 25286, Denver Federal Center, Denver, CO 80225; http://store.usgs.gov; 1–888–ASK–USGS (1–888–275–8747)

Suggested citation: Stettner, W.R., Koroleva, N.E., Masonic, L.M., and Shields, D.A., comps., 2020, Geologic and mineral map (modified from the 1975 original map compilation by A.S. Shadchinev and others) and hyperspectral surface materials maps of the Ghorband, Salang, and Panjsher River Basins; Kapisa, Panjsher, Parwan, and Baghlan Provinces, Afghanistan: U.S. Geological Survey Open-File Report 2020–1101, 2 sheets, scale 1:100,000, https://doi.org/10.3133/ofr20201101.

ISSN 2331–1258 (online)
https://doi.org/10.3133/ofr20201101