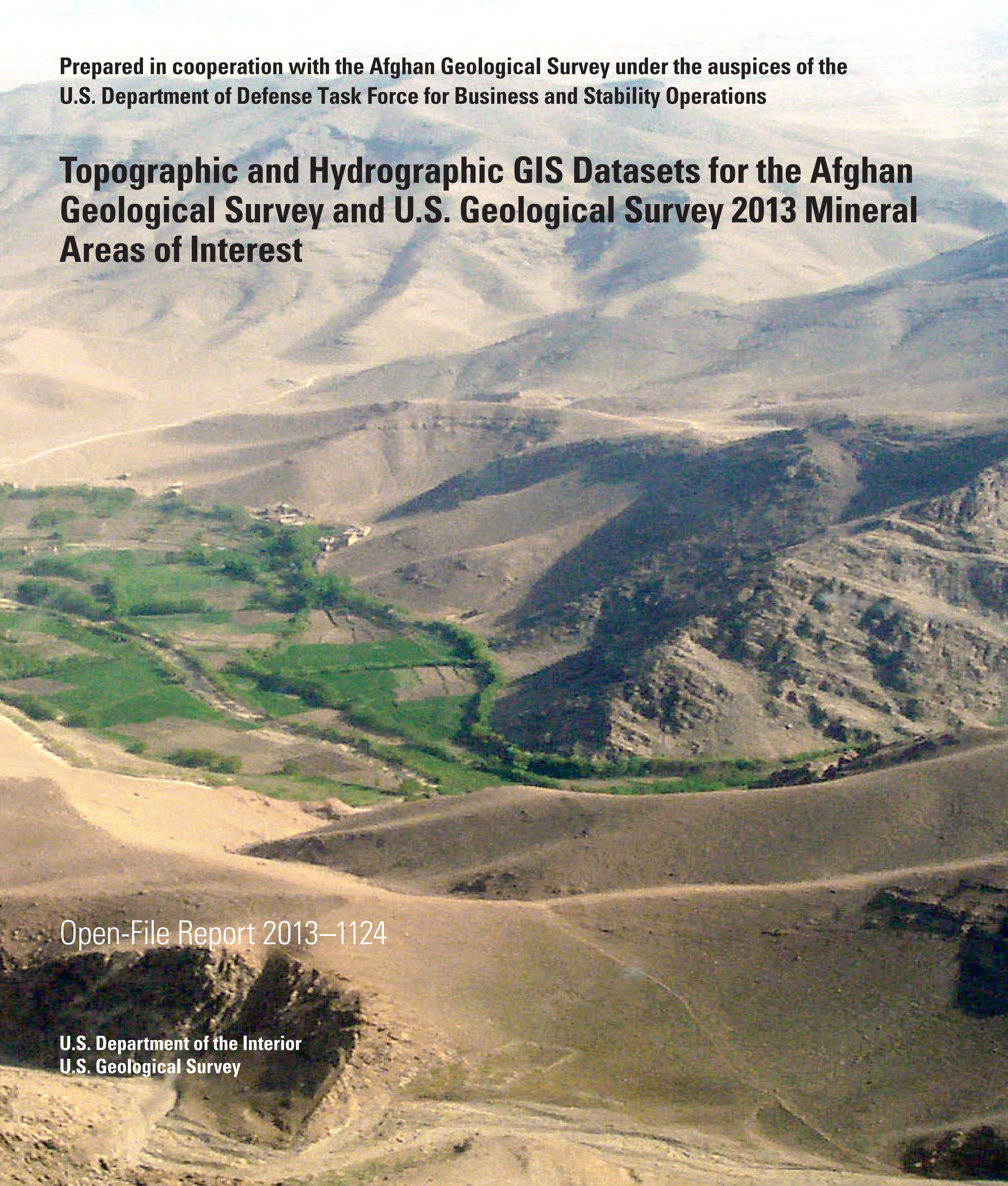

Prepared in cooperation with the Afghan Geological Survey under the auspices of the U.S. Department of Defense Task Force for Business and Stability Operations

Topographic and Hydrographic GIS Datasets for the Afghan Geological Survey and U.S. Geological Survey 2013 Mineral Areas of Interest

Open-File Report 2013–1124

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

Cover: Photo showing mountainous terrain and the alluvial floodplain of a small tributary in the upper reaches of the Kabul River Basin located northeast of Kabul Afghanistan, 2004 (Photograph by Peter G. Chirico, U.S. Geological Survey).

Topographic and Hydrographic GIS Datasets for the Afghan Geological Survey and U.S. Geological Survey 2013 Mineral Areas of Interest

By Brittany N. Casey and Peter G. Chirico

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

U.S. Department of the Interior
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Topographic and Hydrographic GIS Datasets for the Afghan Geological Survey and U.S. Geological Survey 2013 Mineral Areas of Interest

By Brittany N. Casey and Peter G. Chirico

Abstract

Afghanistan is endowed with a vast amount of mineral resources, and it is believed that the current economic state of the country could be greatly improved through investment in the extraction and production of these resources. In 2007, the "Preliminary Non-Fuel Resource Assessment of Afghanistan 2007" was completed by members of the U.S. Geological Survey and Afghan Geological Survey (Peters and others, 2007). The assessment delineated 20 mineralized areas for further study using a geologic-based methodology. In 2011, a follow-on data product, "Summaries and Data Packages of Important Areas for Mineral Investment and Production Opportunities of Nonfuel Minerals in Afghanistan," was released (Peters and others, 2011). As part of this more recent work, geologic, geohydrologic, and hyperspectral studies were carried out in the areas of interest (AOIs) to assess the location and characteristics of the mineral resources. The 2011 publication included a dataset of 24 identified AOIs containing subareas, a corresponding digital elevation model (DEM), elevation contours, areal extent, and hydrography for each AOI. In 2012, project scientists identified five new AOIs and two subareas in Afghanistan. These new areas are Ahankashan, Kandahar, Parwan, North Bamyan, and South Bamyan. The two identified subareas include Obatu-Shela and Sekhab-Zamto Kalay, both located within the larger Kandahar AOI. In addition, an extended Kandahar AOI is included in the project for water resource modeling purposes.

The dataset presented in this publication consists of the areal extent of the five new AOIs, two subareas, and the extended Kandahar AOI, elevation contours at 100-, 50-, and 25-meter (m) intervals, an enhanced DEM, and a hydrographic dataset covering the extent of the new study area. The resulting raster and vector layers are intended for use by government agencies, developmental organizations, and private companies in Afghanistan to assist with mineral assessments, monitoring, management, and investment.

Introduction to 2013 Mineral Areas of Interest

Afghanistan is endowed with a vast amount of mineral resources, located throughout the country. These resources include copper, iron, rubies, emeralds, gold, silver, bauxite, and lithium. The extraction of Afghanistan's mineral resources is considered to be crucial for the country's economic growth, employment, and security development. In 2007, the U.S. Geological Survey (USGS) released the "Preliminary Non-Fuel Mineral Resource Assessment of Afghanistan 2007" (Peters and others, 2007). This assessment was conducted from 2005 to 2007 by the USGS, in conjunction with the Afghan Geological Survey (AGS), and was funded by the U.S. Agency for International Development (USAID). The purpose of this initial study was to identify potential areas of interest (AOIs) and to assess Afghanistan's nonfuel mineral resources as part of an effort to reconstruct the country's economy. Scientists from the USGS and AGS worked to compile data collected during previous assessments on multifarious mineral deposits and estimated possible undiscovered deposits, using a geology-dependent methodology. The preliminary assessment delineated 20 initial mineralized areas for further study (Peters and others, 2007).

In 2011, the USGS, in cooperation with the AGS and U.S. Department of Defense Task Force for Business and Stability Operations (TFBSO), released the "Summaries of Important Areas for Mineral Investment and Production Opportunities of Nonfuel Minerals in Afghanistan" (Peters and others, 2011). This product is the result of the nonfuel mineral resource assessments of Afghanistan conducted from October 2009 through September 2011. As part of this work, geologic, geohydrological, and hyperspectral studies were carried out in the AOIs to assess the location and characteristics of the mineral resources. A total of 24 nonfuel mineral AOIs were identified for further mineral investigation and possible production opportunities (fig. 1). The goal of the summary and corresponding datasets was to attempt to minimize risk for investors and developers and to assist the Afghanistan Ministry of Mines (AMM) in the bidding process and in adherence to commercial development procedures. With the aid of geographic information system (GIS) datasets, including geologic, geophysical, and hyperspectral and remotely

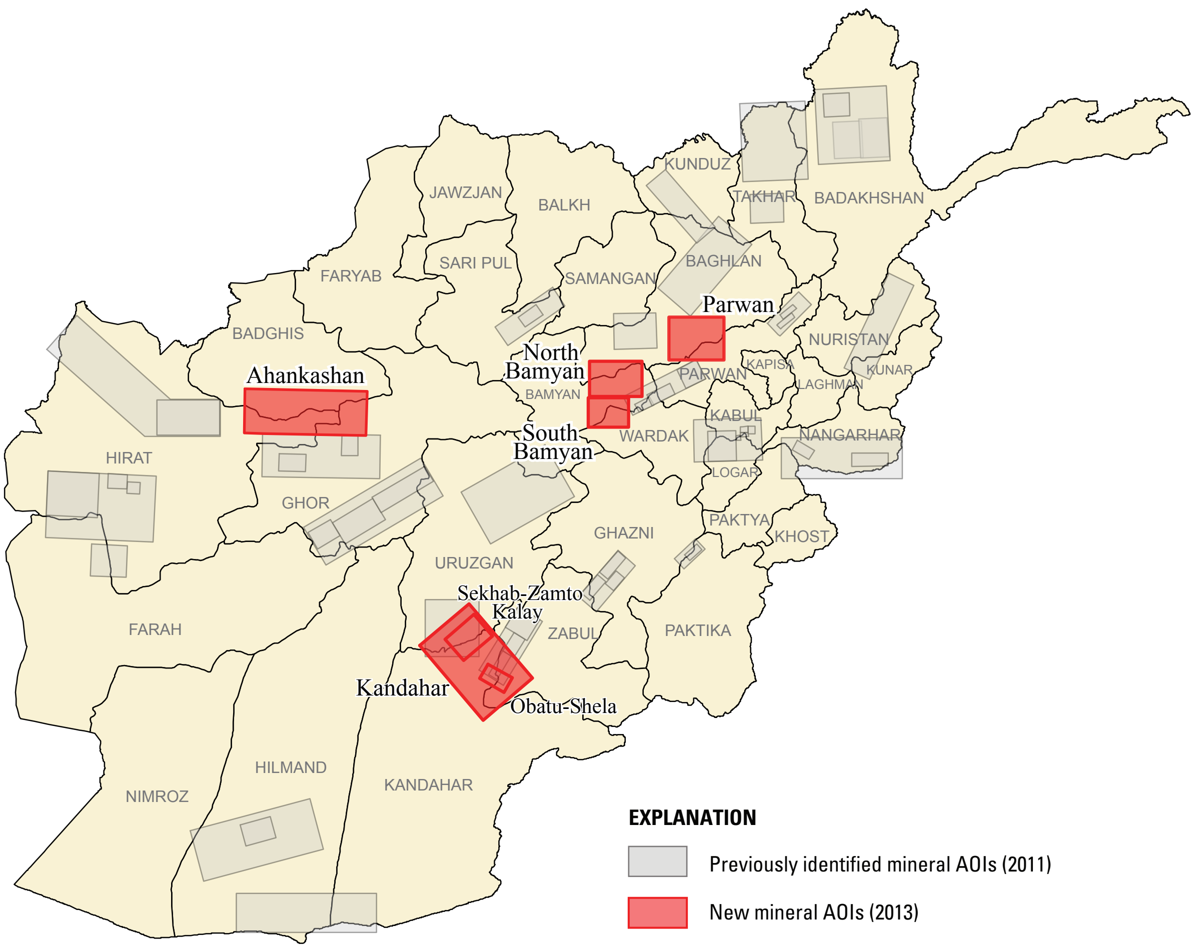

Figure 1. Previously identified mineral areas of interest (AOIs) and newly identified mineral AOIs in Afghanistan.

sensed imagery data, possible and probable mineral resource areas can be more efficiently identified and evaluated. The data package released in 2011 contains 20 to 50 relevant digital data layers, depending on the area, including digital elevation models (DEMs), elevation contours, extent of each AOI, and hydrographic datasets. The published report also includes topographic and hydrographic GIS datasets published by the USGS in 2010 (Chirico and Moran, 2011).

In 2012, project scientists located five new AOIs and two subareas in Afghanistan: Ahankashan, Kandahar, North Bamyan, South Bamyan, and Parwan, and Kandahar subareas Obatu-Shela and Sekhab-Zamto Kalay (fig. 1). The dataset produced as part of this study includes a collection of folders, each representing a specific AOI, and is a continuation of the data package produced for the 24 previously collected AOIs published in 2011 by the USGS (Chirico and Moran, 2011). Each folder contains the extent of the AOI and its subareas, various elevation contours, a DEM, and a hydrographic dataset of the corresponding AOI or subarea; all data are organized into feature vector and raster datasets. The purpose of this dataset is to gather and process publicly available DEMs to complete GIS functions to improve the accuracy and usability of the datasets and to provide layers that can be used cartographically in a visually appealing manner. The completion of such processes renders the datasets more useful to private and government agencies in mineral exploration, mineral resource assessments, and natural resource management.

Study Area

The study area includes the five new mineral AOIs, plus the two subareas identified in 2012, and an extended Kandahar AOI for use by the University of Kansas in their effort to identify the relationship between water, culture, and landscapes that are interconnected by traditional and ancient water supply systems. The names of the individual AOIs reflect the provinces they include, though they typically encompass portions of multiple provinces; alternately, they are named after topographic features, such as Ahankashan Mountain. The Ahankashan AOI is located in northwestern Afghanistan. The northern portion of the AOI is located in the province of Badghis, while the southern portion is located in the provinces of Hirat and Ghor (fig. 2). The Kandahar AOI is located in southeastern Afghanistan. The northern corner of the AOI is located in the Uruzgan province and the southern section is split between the Kandahar province to the west and the Zabul province to the east (fig. 3). Within the Kandahar AOI, two subareas were identified based on known laterite prospects that were previously mapped out by Soviet and Afghan scientists and later reinterpreted by the USGS using remotely sensed imagery. The Sekhab-Zamto Kalay subarea is located in the northern half of the Kandahar AOI. The northern section of the subarea is located in the Uruzgan province and the southern section stretches into the Kandahar province (fig. 4). The Obatu-Shela subarea is located in the southern half of the Kandahar AOI. The northwestern half falls within the Kandahar province while the southeastern half is located in the Zabul province (fig. 5). The Bamyan AOI is situated in north-central Afghanistan and is separated into the North Bamyan and South Bamyan AOIs. The North Bamyan AOI was identified based on hyperspectral data anomalies and the South Bamyan AOI was delineated based on previous geologic information. The North Bamyan AOI spans Baghlan province in the north and Bamyan province in the south (fig. 6), while the South Bamyan AOI spans Bamyan province in the north and the province of Wardak in the south (fig. 7). The Parwan AOI is located in northeastern Afghanistan, encompassing the provinces of Baghlan in the north and Parwan in the south (fig. 8). The AOIs were identified according to the specific mineral resources located within each area. Gold and copper are found in Ahankashan and Parwan, and bauxite is found in Kandahar as well as laterite in the two subareas of Kandahar. North Bamyan and South Bamyan are located in the center of diverse mineral deposits including iron, clay and gypsum, phosphate, barite and rare earth elements, gold, and copper. The extended Kandahar AOI is located in southeastern Afghanistan (fig. 9). It spans from the Farah province in the west through the Helmand province, Uruzgan province, Kandahar province, and into Zabul province in the east.

Afghanistan's climate is classified as semi-arid continental with extensive dry seasons and periods of extreme drought. Generally, Afghanistan's average annual precipitation falls between 300 millimeters (mm) and 400 mm per year, with lower elevations typically receiving 100 mm per year and higher elevations receiving up to 4000 mm per year. The majority of the country's precipitation occurs during the winter months in the form of snowfall. Consequently, a large portion of the country's stream systems are fed by snowmelt in the spring and early summer months. Due to the dry climate and irregular seasonal precipitation, Afghanistan contains many ephemeral stream channels. Afghanistan also contains extensive irrigation canal systems, particularly in the Kandahar and Helmand provinces, which are used to reroute stream flowpaths to agricultural areas.

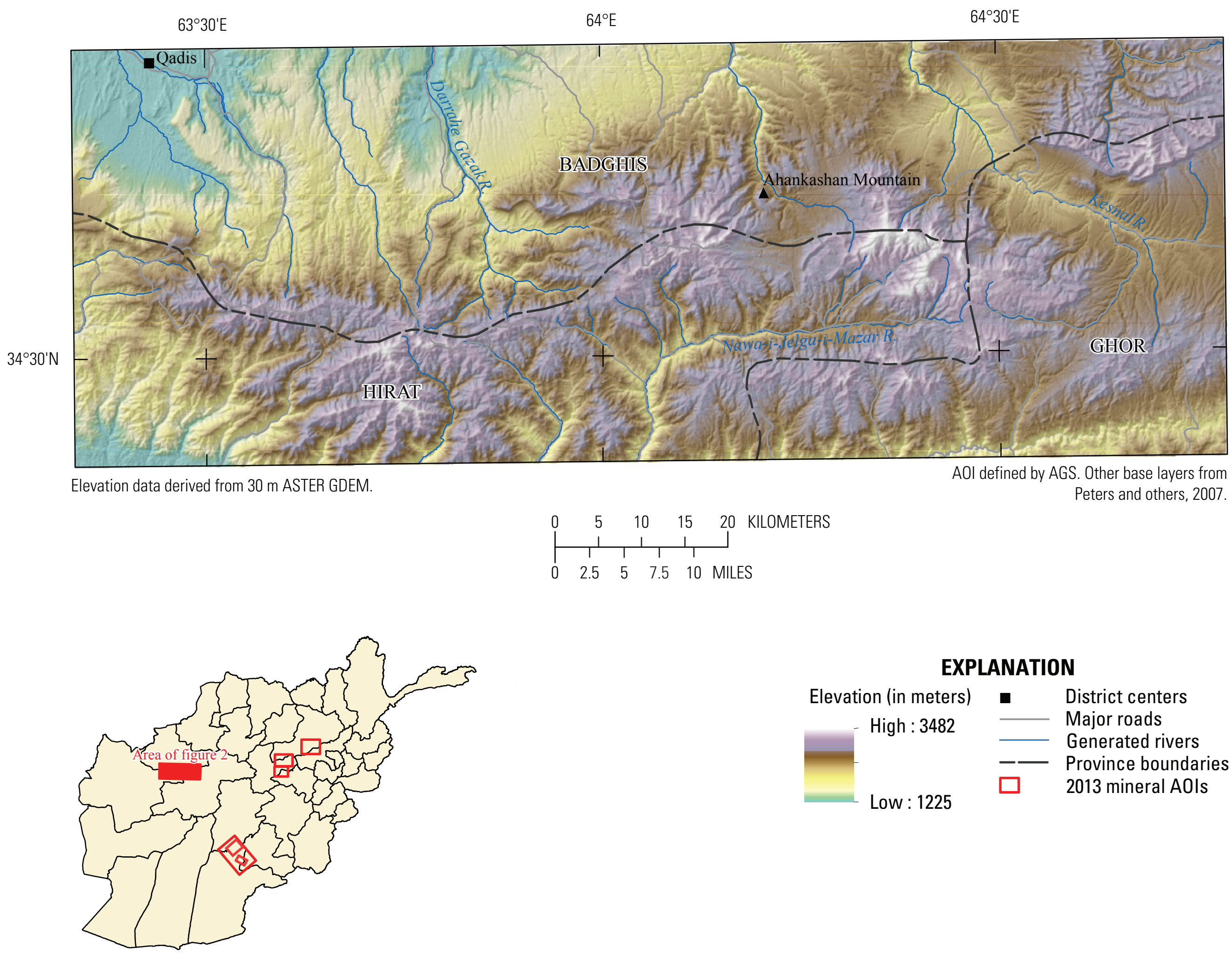

Figure 2. The areal extent and location of the Ahankashan mineral AOI in Afghanistan.

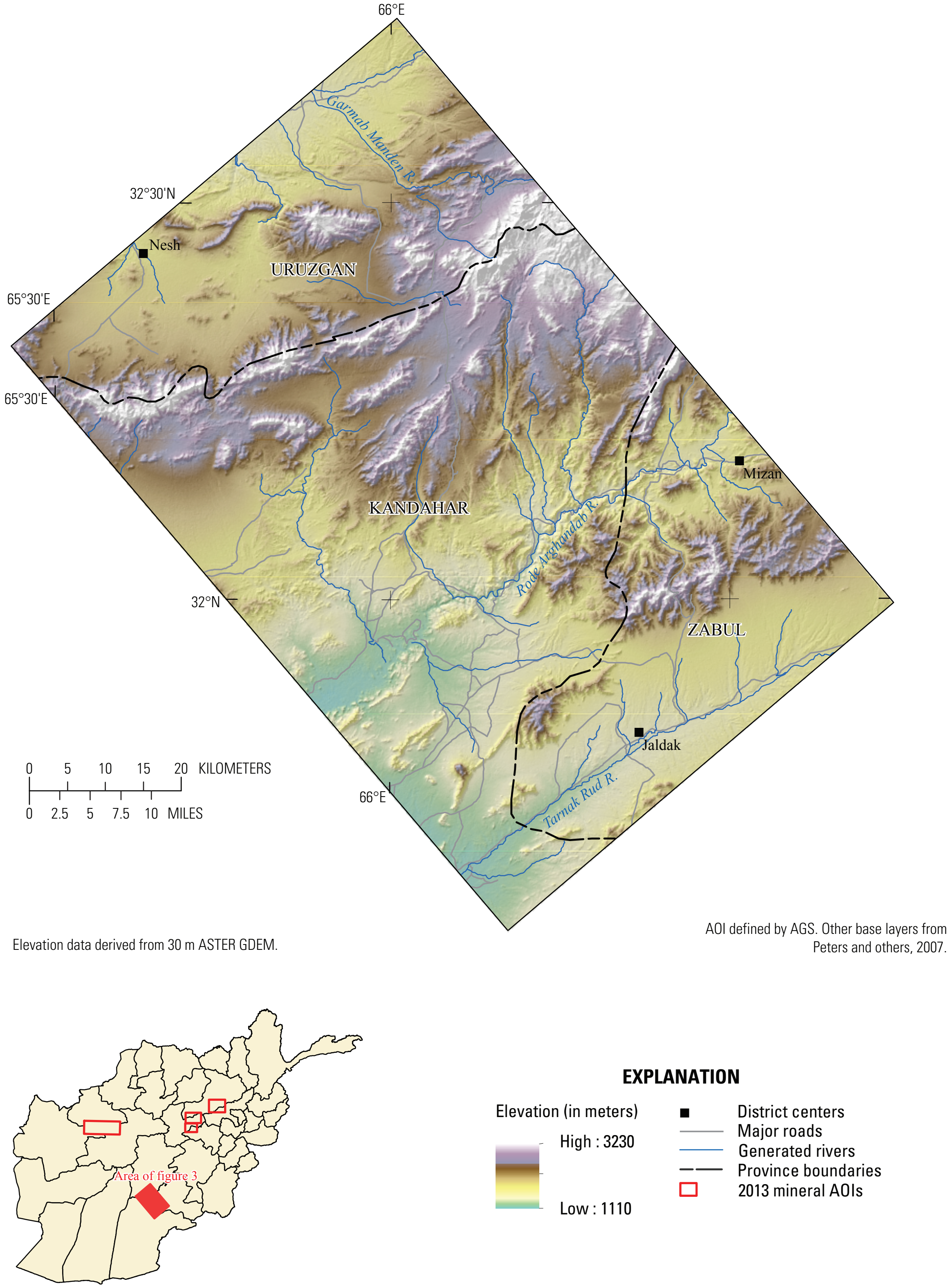

Figure 3. The areal extent and location of the Kandahar mineral AOI in Afghanistan.

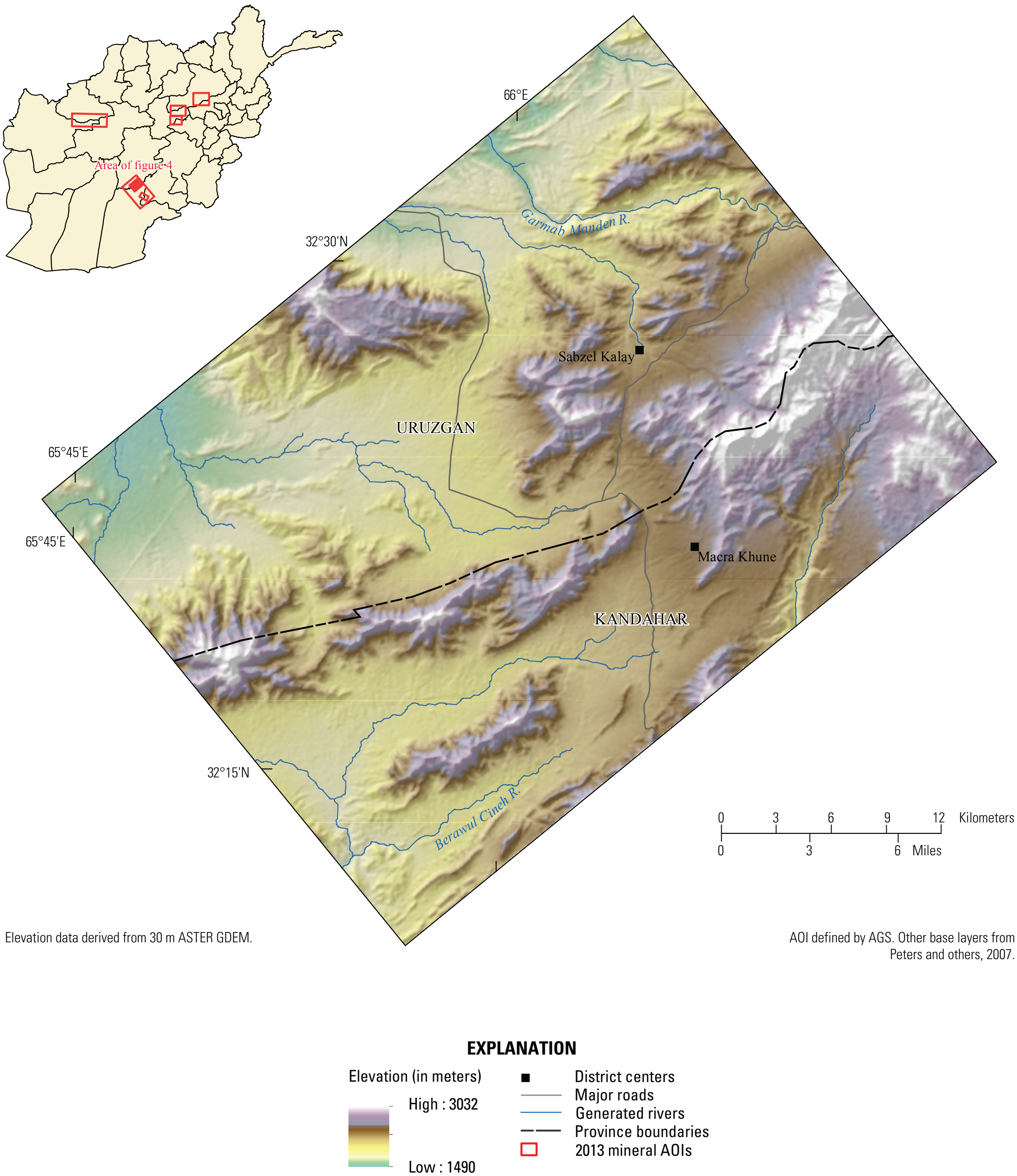

Figure 4. The areal extent and location of the Sekhab-Zamto Kalay subarea mineral AOI in Afghanistan.

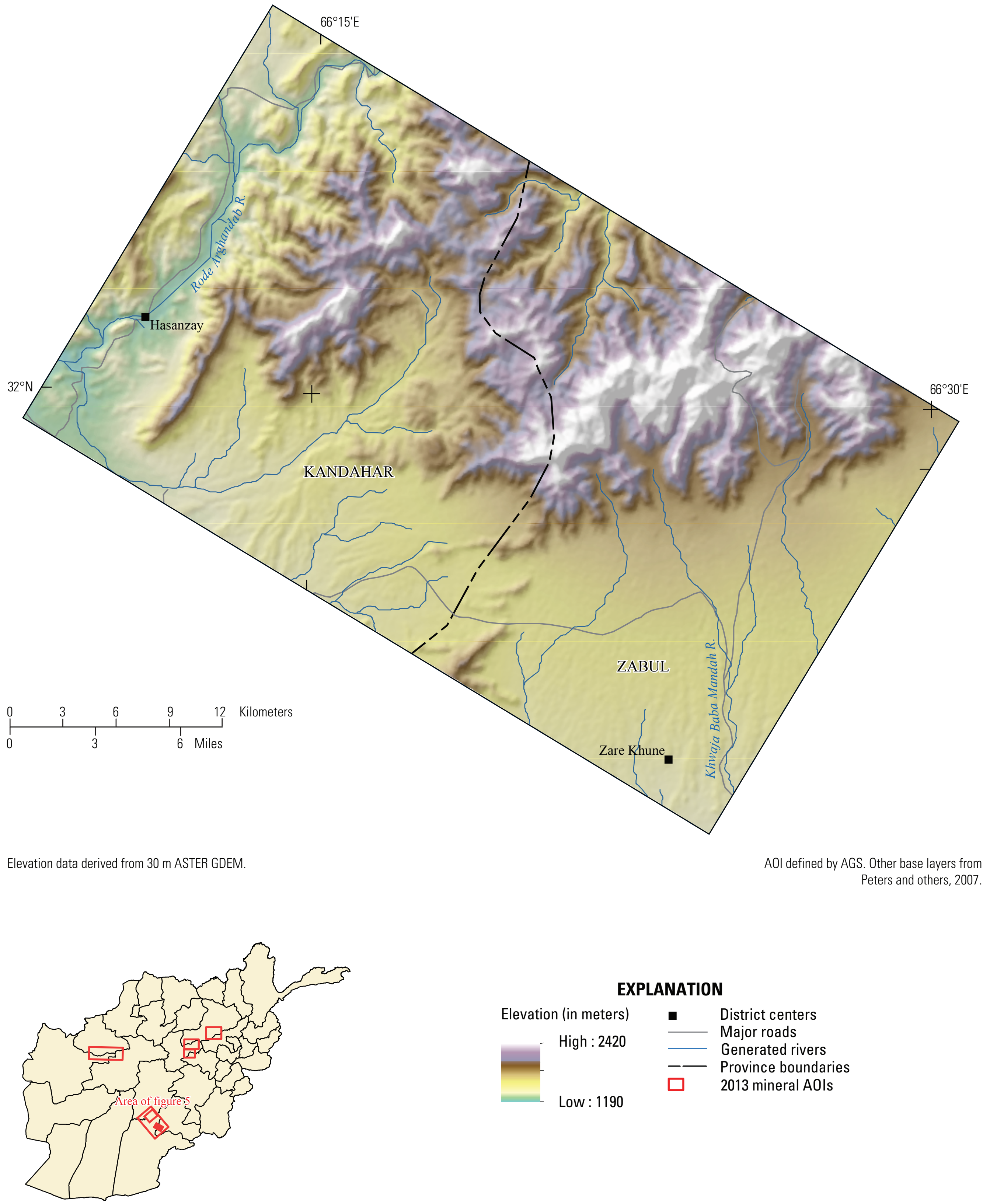

Figure 5. The areal extent and location of the Obatu-Shela subarea mineral AOI in Afghanistan.

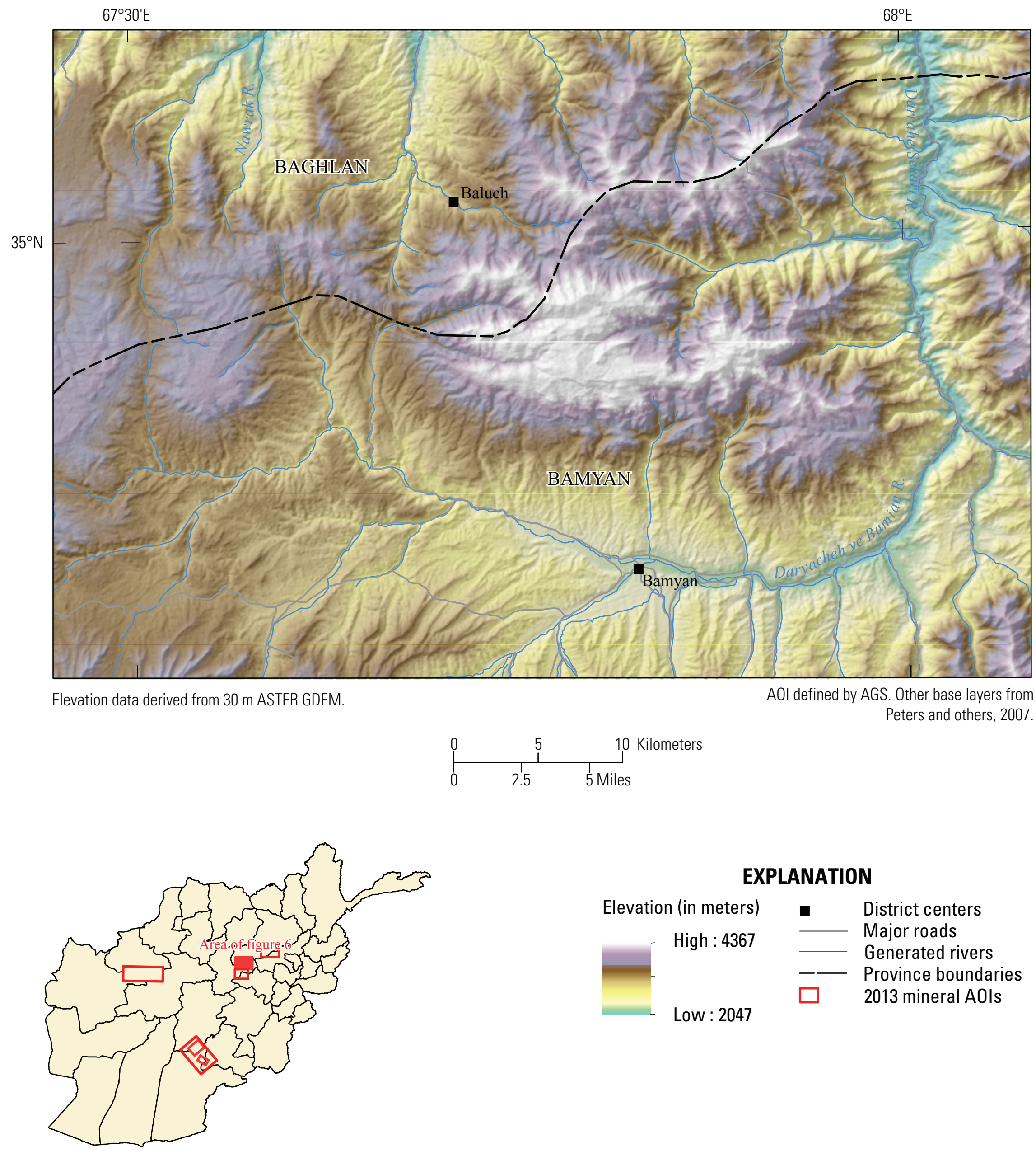

Figure 6. The areal extent and location of the North Bamyan mineral AOI in Afghanistan.

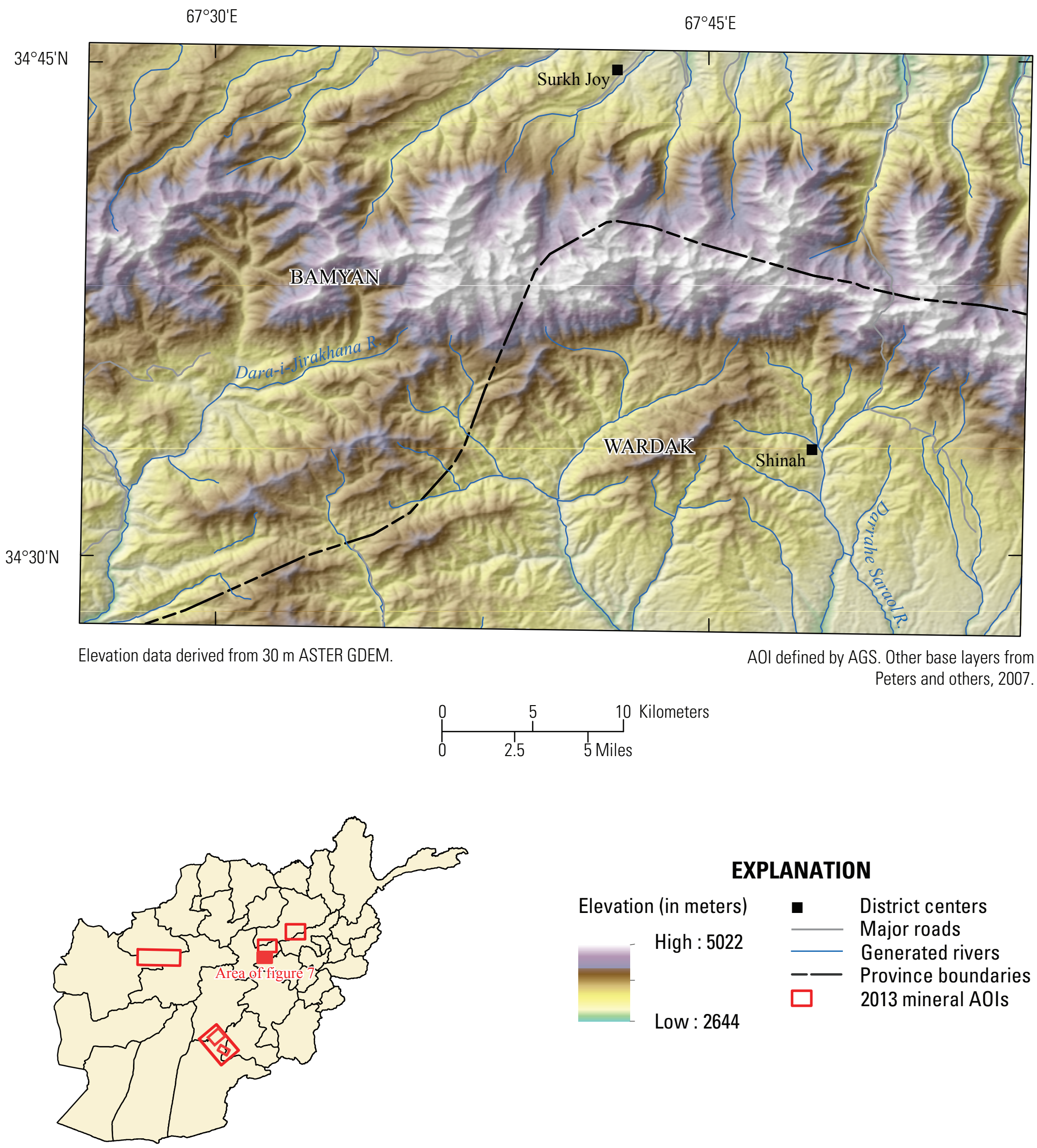

Figure 7. The areal extent and location of the South Bamyan mineral AOI in Afghanistan.

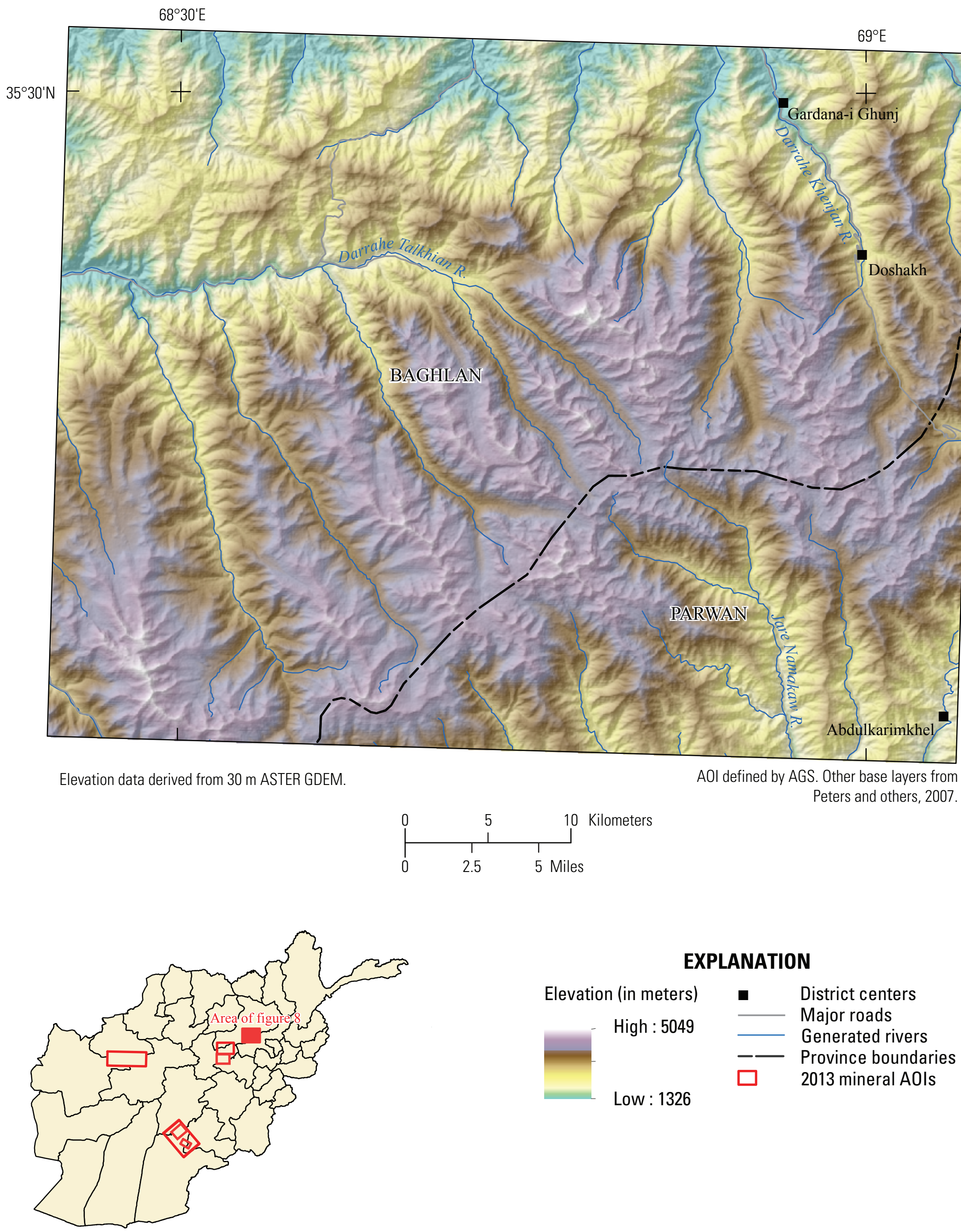

Figure 8. The areal extent and location of the Parwan mineral AOI in Afghanistan.

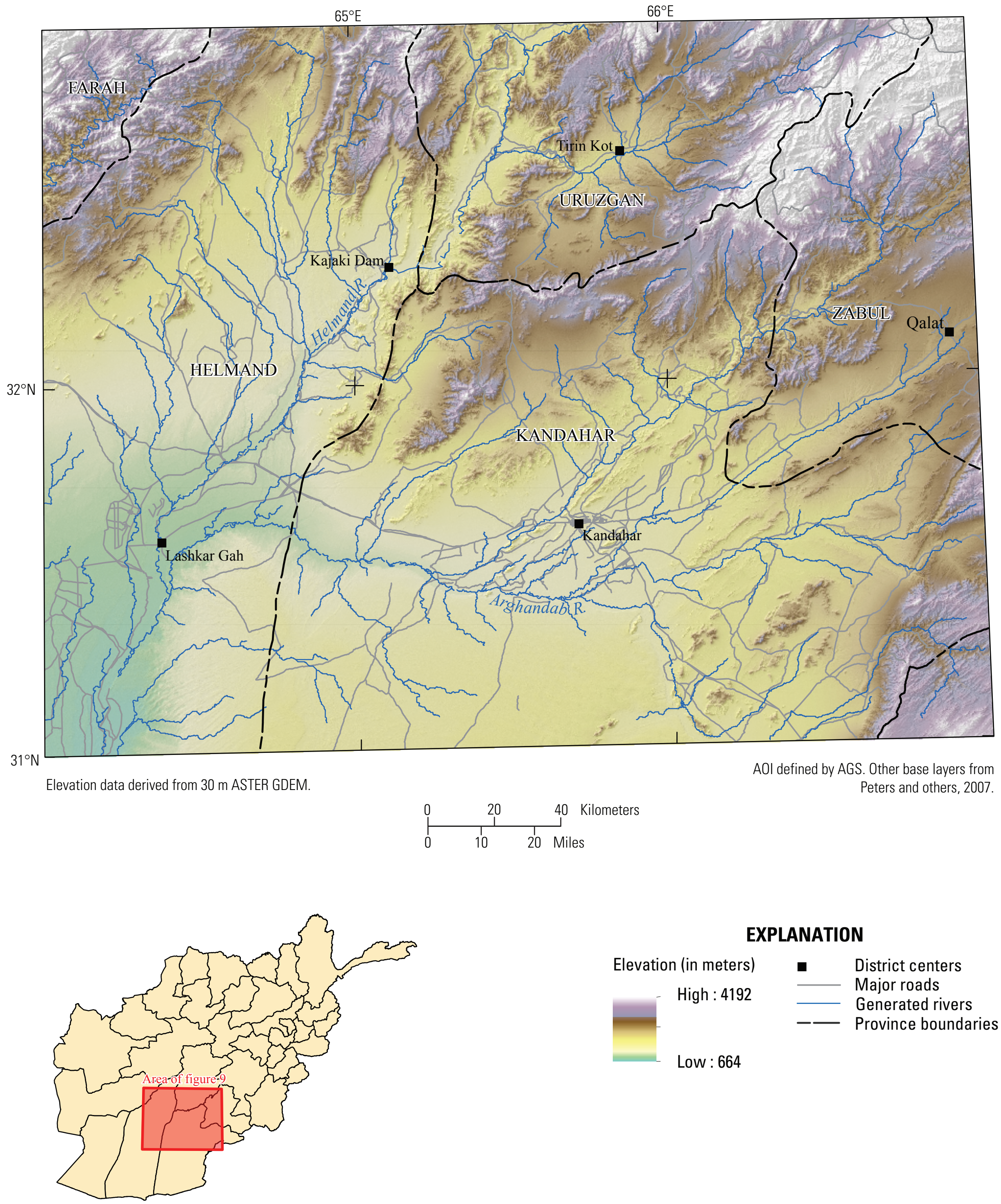

Figure 9. The areal extent and location of the extended Kandahar AOI in Afghanistan.

Introduction to the Extended Kandahar Water Resource Area of Interest

In 2010, a group of experts from the University of Kansas began collaboration on a project titled "Modeling Cultural Landscapes and Water Resources: A Case Study in Afghanistan," funded by the U.S. Army Research Office. The goal of the project is to identify the relationship between water, culture, and landscapes that are interconnected by traditional and ancient water supply systems. The study focuses on an ancient form of irrigation still widely implemented in Afghanistan today, known as karez water systems. Karezes are typically constructed within alluvial fan aquifers in mountainous regions and consist of numerous hand-dug wells that extend down and connect in a system of underground tunnels, tapping into the water table. Gravity works to move the water from the mother well (the first well in the series), through the access shafts, and out the surface canals to designated locations downslope. The models constructed using this information will be used in the prediction and simulation of climate change and precipitation shifts on karezes, as well as to provide support for the environmental security of the Kandahar area and the preservation of an ancient technology and unique cultural way of life (The University of Kansas, 2012).

The project began with the inventorying of known karez systems in Afghanistan and identifying them as active versus inactive. The researchers used Google Earth imagery, for official use only (FOUO) high resolution orthorectified aerial photography, and LiDAR optical remote sensing data from the BuckEye program of the U.S. Army Geospatial Center. Imagery was obtained for the years 2004–11. The initial results of this study displayed a decrease in the amount of active karezes as compared to the previously recorded numbers and produced an improved method for locating and quantifying active versus inactive karezes using a combination of remote sensing data and GIS.

As a continuation of the project, researchers from the University of Kansas are constructing a working GIS and high resolution models of landscapes in Afghanistan to inventory and display surface and ground water systems. To assist with this component of their analysis, the USGS is providing a data package consisting of the extent of the AOI, various elevation contours, a DEM, and a hydrographic dataset, organized into feature vector and raster datasets of the extended Kandahar AOI in southeastern Afghanistan (fig. 9). These data will be used to aid in the locating and modeling of karez water systems.

Methodology

The dataset constructed as part of this study required the acquisition of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) data. Several processes were run on the ASTER GDEM data to produce viable and effective GIS layers. Manual processes were also completed to create derivative elevation contours and hydrographic layers. Each layer developed throughout the GIS processes was clipped to match the extent of its corresponding AOI or subarea. This was done to eliminate excess information, reduce file size, and improve processing time, as well as to enhance cartographic design aspects of the end product. All data and GIS processes conducted throughout the creation of this dataset were completed using the Environmental Systems Research Institute's (ESRI) ArcMap 10.0 GIS software.

Digital Elevation Model

The ASTER GDEM data were obtained from the National Aeronautical and Space Administration's (NASA) Earth Observing System Data and Information System (EOSDIS) server and consists of 30-m resolution elevation data. The ASTER GDEM data are publicly available online through the NASA portal. ASTER GDEM data for each new AOI were acquired by defining the geographic location of the AOI on the NASA server and downloading the individual tiles. The tiles are presented on a one cell by one cell basis; therefore, numerous tiles were required to provide complete coverage of the AOIs. After the required tiles were downloaded, they were merged to create a single, continuous ASTER GDEM dataset for each study area using the mosaic command in the raster toolset in ArcGIS version 10.0.

Data Extraction and Modification

DEM Dataset Construction

Several processes were run on the DEMs to derive advantageous, functional, and aesthetically appealing data. The DEM data as downloaded include pixels displayed in integer format, rounded to the nearest meter. To improve functionality, the DEMs were converted from 16 bit signed (integer) to 32 bit floating point data using the copy raster command in the raster toolset in ArcGIS version 10.0. Floating point representation is a data type that supports decimal storage in pixels, allowing for a greater level of elevation detail to be stored. Conversion to a floating point representation is important for the calculation of focal statistics, as it prevents the rounding of pixel values and improves the accuracy of the output datasets. This process allows for hydrological flowpaths and elevation contours to be displayed as smooth lines, rather than lines that appear pixelated with sharp angles. After the DEMs were converted to floating point format, they were projected into their corresponding Universal Transverse Mercator (UTM) zones based on their geographic location using the project raster command in the projections and transformation toolset in ArcGIS. Bilinear resampling was used to determine new cell values, based on the average values of surrounding cells. A focal mean was then generated for the DEM data of each AOI, using a 5×5 cell neighborhood. The focal mean is calculated for individual cells based on the average value of surrounding cells. The focal mean was calculated twice to ensure a smoother, less pixelated DEM.

Elevation Contour Dataset Construction

Elevation contours were generated at increments of 100, 50, and 25 m for each AOI and subarea. The elevation contours within the AOIs or subareas were manually edited to remove contours which had been generated around false topographic features as a result of errors in the DEM values.

Hydrographic Dataset Construction

A series of hydrographic functions was applied to the output of the second focal mean calculation to determine hydrological flowpaths. It is important to note that hydrological flowpaths differ from streampaths in that they do not necessarily contain water. Due to Afghanistan's dry climate, and the fact that the majority of streams are fed by spring snowmelt, numerous streams are ephemeral and some only contain water every few years. The hydrological flowpaths also include ancient flowpaths that may no longer function as streams, as well as flowpaths carved into exposed rock surfaces. The raw raster elevations were processed to remove drainage imperfections, referred to as "sinks." Identification of flow direction and flow accumulation was performed on the DEMs, based on the work of Jenson and Domingue (1988). The flow direction is determined by the direction of the steepest cell value to the most gentle cell value in the raster dataset. Specifically, the distance is calculated between cell centers. When many cell centers contain the same descent value, the neighborhood is enlarged until the steepest descent is found. The flow accumulation correlates to the amount of water that would flow through each cell, based on the amount of precipitation that falls on the surface upslope from each cell, not taking into consideration precipitation that was intercepted, evaporated, or absorbed into groundwater. This action forces the flow out of only one cell in a neighborhood. Cells with high flow accumulation values are areas of concentrated flow which may be used to identify stream channels. If the flow accumulation is equal to zero, it can be used to identify ridges.

Flowpaths were then reclassified from the flow accumulation, based on the work of Tarboton and others (1991). The DEM was reclassified to include an upstream contributing area with a threshold of greater than 1,500 pixels. The exact number of pixels selected per AOI was determined by a variable methodology which employed Landsat imagery and the visual interpretation of flowpaths. Using the reclassified DEM, the stream order was determined for the hydrographic channels in each AOI. Stream ordering is a method of identifying and classifying types of streams based on their number of tributaries. To develop stream orders in this study, the Strahler method was applied (Strahler, 1964). Strahler's process for quantitatively analyzing a river system network assigns a value to the different stream segments within the channel system, based on their upslope flowpaths. In this method, a stream order of 1 corresponds to segments with no channelized water flow upstream. These are the smallest and shortest stream segments in the network. To get a stream order of 2, there must be two first-order streams intersecting, while stream order 3 is obtained through the intersection of two second-order streams, and so on. This system of numbering continues until every segment in the system has been assigned a value.

Identifying stream orders is important in modeling efforts because of the generalized characteristics that can be seen in each stream order, which can aid in the determination of the location of mineral deposits by following flow patterns. The Strahler method is a widely implemented and accepted method of stream ordering which allows for simple and consistent stream comparisons to be completed in multiple locations over an extended period of time. For example, if a known mineral is located near a stream, its path can be followed downstream until sampling and fieldwork reveal the location of alluvial deposits, usually located in higher order stream. Order numbers are directly proportional to the size of the contributing watershed, to channel dimensions, and to stream discharge measurements for each individual stream segment. The larger the stream order, the greater the number of upslope streams or channels that feed into it. There is no channelized water flow from anywhere else, and the order 1 flows are dominated by overland flow of water. Meanwhile, larger stream orders represent larger vector stream lines with connections to various other streams within the network. The arid climate in Afghanistan prevents constant streamflow yearlong in various areas, resulting in the ephemeral nature of many streams. It is necessary to include ephemeral streams in the model because they can still hold importance when considering deposit movement due to spring snowmelt and ancient stream systems.

The stream order raster dataset was then converted to a shapefile. The resulting shapefile was manually edited using 30-m resolution Landsat imagery to correct the geographic locations of the stream networks. The vector polylines were then simplified to generate smoother lines through the removal of excess vertices.

Watersheds were delineated using order 3 and higher streams. To generate those watersheds, the stream order raster derived in the above step was reclassified to exclude stream orders 1 and 2. This reduces the number of small streams and generates larger, more significant watersheds as well as reducing the likelihood of including ephemeral stream watersheds.

Subarea Dataset Construction

The elevation contours, DEM, and hydrographic dataset for the two subareas located within the Kandahar AOI, subareas Obatu-Shela and Sekhab-Zamto Kalay, were constructed by clipping processed data from the larger Kandahar AOI to the extent of the individual subareas. These subareas were delineated within the Kandahar AOI because of their potential for containing laterite deposits, whereas the remainder of the AOI principally contains bauxite deposits. Because the subareas are contained within the extent of the larger Kandahar AOI, it was not necessary to generate topographic and hydrographic datasets separately for them.

Projection

The datasets are provided in two coordinate systems, Universal Transverse Mercator (UTM) coordinate system and geographic coordinate system (GCS), for convenience purposes. Both coordinate systems use the World Geodetic System of 1984 (WGS 1984) datum. The AOIs are projected into different UTM zones according to their geographic locations. Afghanistan is divided into UTM Zones 41N, 42N, and 43N. The Ahankashan AOI is projected to zone 41N, while the North Bamyan, South Bamyan, Parwan, and Kandahar AOIs and the Obatu-Shela and Sekhab-Zamto Kalay subareas are projected into zone 42N. The extended Kandahar AOI is projected into zone 41N because the majority of the AOI falls in zone 41N, though a small portion does fall within zone 42N.

Dataset Organization

Each of the five new mineral AOIs, two subareas, and extended Kandahar AOI have corresponding folders containing the associated raster or vector datasets and metadata files, in extensible markup language (.xml) format and text file (.txt) format. Within each folder are four additonal subfolders: “Area_Extent,” “DEM,” “Elevation_Contours,” and “Hydrography.” The Area_Extent folder contains the AOI’s areal extent shapefile. The “DEM” folder contains two raster layers, the ASTER GDEM, and the hillshade layers. The Elevation_Contours folder contains three more folders: “100m,” “50m,” and “25m.” Each of these folders contains a shapefile of the corresponding elevation contours. The Hydrography folder contains the streams and watershed shapefiles. The two subarea folders are located within the “Kandahar” folder. Lastly, a folder entitled “AOI_Maps” is included and contains a map of each of the five individual AOI study areas and two subareas, in Adobe Portable Document File (.pdf) format.

Results

The resulting dataset includes various layers useful for assisting with natural resource assessments, monitoring, and management, as well as water resource modeling. These layers include a DEM, which has been processed to easily depict elevation data; a hillshade raster, for aesthetically appealing map construction; three elevation contour layers, constructed at intervals of 100, 50, and 25 m; a layer containing an outline of the mineral areas; a streams layer, with individual stream orders identified; and a watersheds layer, displaying the watersheds for streams of order 3 and higher. These layers were created for each of the five new mineral AOIs, the two subareas, and the extended Kandahar AOI. The flowpaths were designed to be used with maps at a scale of 1:100,000 to 1:50,000. The accuracy of model flowpaths has not been validated for scales falling outside of this range.

Tables 1 and 2 describe the general characteristics of the study areas using basic statistics and areal measurements for comparison purposes. Table 1 lists the elevation data, while table 2 lists the results of the stream order classification for each AOI. Table 2 shows that the maximum identified stream order in the AOI was a stream order of 6. Kandahar contains the lowest mean elevation, 1,633.37 m, and the smallest relief in elevation, 2,118.95 m. Kandahar has the highest abundance of order 6 streams as compared to the other AOIs. Parwan contains the largest elevation relief, 3,722.62 m, and South Bamyan contains the highest mean elevation, 3,516.71 m. Parwan and South Bamyan are similar in average elevation and highest elevation, though South Bamyan has a relief of only 2,378.41 m. Neither Parwan nor South Bamyan, with their high elevations and steep reliefs, include any stream order 6 streams. The Obatu-Shela subarea includes 16 stream order 6 streams and no stream order 5 streams, which is a result of the clipping process. The stream order 5 streams that merge to form the stream order 6 streams fall outside of the subarea's extent.

Table 1. Area and the lowest and highest elevation points for each individual mineral area of interest.

[km^2, square kilometer; m, meter; STD, standard deviation]

	Area (km^2)	Lowest Elevation (m)	Highest Elevation (m)	Mean Elevation (m)	Relief (m)	STD
Ahankashan	6,472.28	1,224.62	3,482.25	2,430.02	2,257.63	421.58
Kandahar	7,580.04	1,111.45	3,230.4	1,633.37	2,118.95	317.8
Parwan	2,828.42	1,326.14	5,048.76	3,352.38	3,722.62	771.67
North Bamyan	2,215.79	2,046.61	4,366.68	3,110.66	2,320.07	371.73
South Bamyan	1,427.19	2,644.04	5,022.45	3,516.71	2,378.41	446.91
Obatu-Shela	561.72	1,189.51	2,420.54	1,582.68	1,231.43	233.11
Sekhab-Zamto Kalay	1,304.57	1,489.62	3,032.06	1,938.52	1,542.44	260.66

Table 2. The number of vector stream segments, classified into stream orders 1–6, in each individual mineral area of interest (not a representation of distance, not linear kilometers).

[km^2, square kilometer]

	Area (km^2)	Stream order 1	Stream order 2	Stream order 3	Stream order 4	Stream order 5	Stream order 6
Ahankashan	6,472.28	2,926	1,346	743	463	211	39
Kandahar	7,580.04	1,687	784	435	225	156	84
Parwan	2,828.42	1,535	670	424	331	36	0
North Bamyan	2,215.79	761	340	210	125	81	37
South Bamyan	1,427.19	496	247	146	44	28	0
Obatu-Shela	561.72	119	52	31	2	0	16
Sekhab-Zamto Kalay	1,304.57	329	152	84	70	0	0

Summary

The hydrological flowpaths and elevation contour datasets presented in this report were created based on the processing of the ASTER GDEM data and were evaluated against Landsat imagery. No fieldwork has been completed to date to verify the locations and distribution of the dataset-derived streams or channels relative to the actual streams or channels on the ground. Because there are currently no ground data available, the derived hydrographic datasets and their corresponding stream orders will be useful in estimating stream parameters and characteristics within the AOIs and subareas through remote sensing. Specific hydrologic characteristics, such as velocity differences between low order and high order streams, which influence sediment accumulation, accompany different stream orders, and developing an understanding of these characteristics can increase the efficiency of modeling and predicting the location and characteristics of mineral resources in Afghanistan. This information may further reduce risk to government agencies, developmental organizations, and private companies by providing a narrower margin of error in mineral management, assessment, and exploration efforts.

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