Chapter 13C. Geohydrologic Summary of the Panjsher Valley Emerald, Iron, and Silver Area of Interest

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13C.1 Introduction

This chapter describes the geohydrology of the Panjsher-Valley emerald-iron-silver area of interest (AOI) in Afghanistan identified by Peters and others (2007) (fig. 13C–1*a*,*b*). The AOI is located in east-central Afghanistan in the Hisa-i-Anwali District in Parwan Province (fig. 13C–1*a*,*b*). The silver and iron subarea covers 111 km^2 (square kilometers) and the emerald subarea covers 125 km^2 in the AOI, which has an area of 956 km^2.

Water is needed not only to process mineral resources in Afghanistan, but also to supply existing communities and the associated community growth that may accompany a developing mining economy. Information on the climate, vegetation, topography, and demographics of the AOI is summarized to provide information on the seasonal availability of, and seasonal demands for, water. The geohydrology of the AOI is described through the use of maps of streams and irrigated areas, and generalized geohydrology and topography. The results of lineament analyses are presented to identify areas where the rock may be more fractured than in other areas, which may be an indicator of high relative water yield and storage in bedrock aquifers.

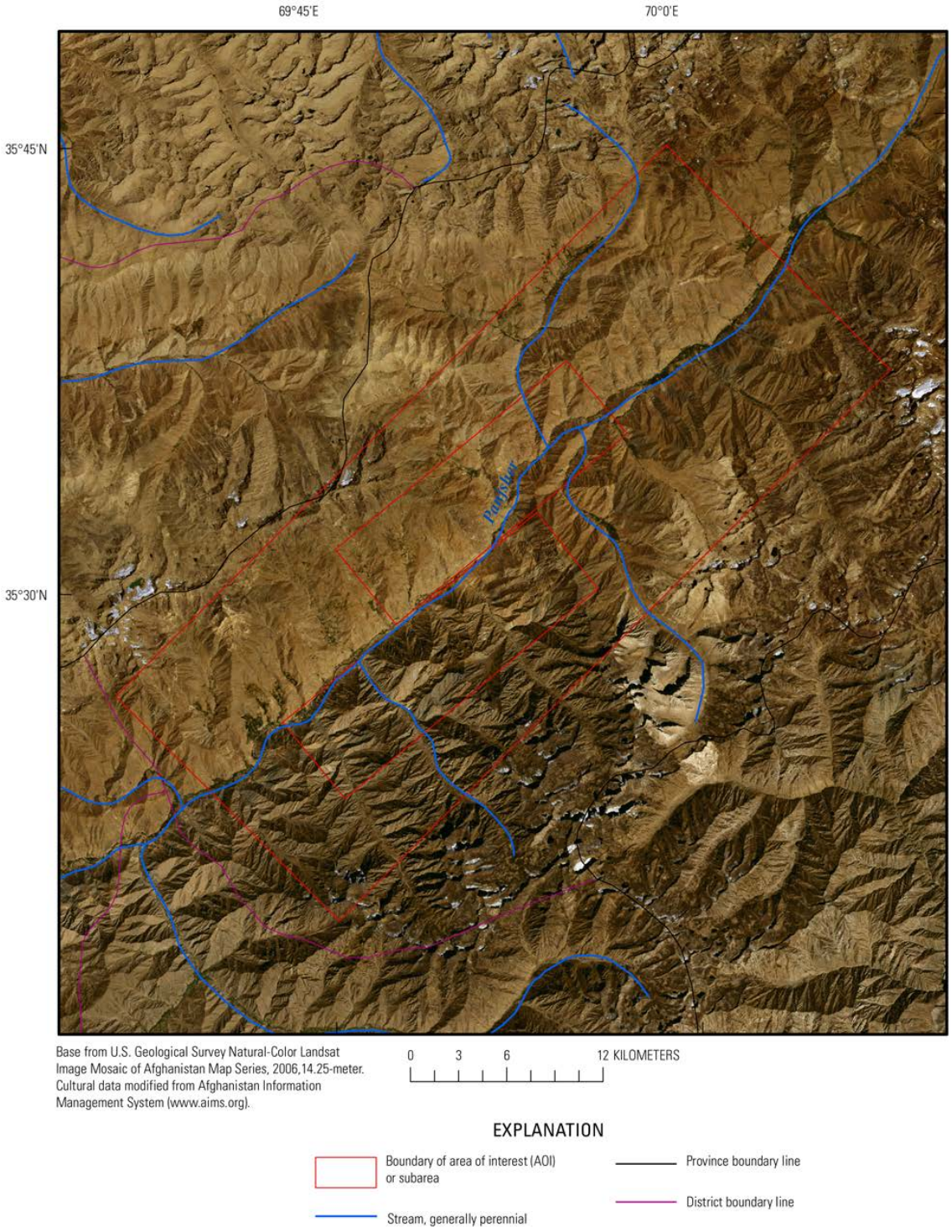
Afghanistan's recent turbulent history has left many of the traditional archival institutions in ruins, and most water-resource and meteorological data-collection activities had stopped by 1980. Recently (2011), nongovernmental organizations (NGOs), foreign government agencies, and the Afghan government have begun water-resource investigations; however, these activities and the amount of data collected are limited. This report summarizes the satellite imagery and climatic, topographic, geologic, surface-water, and groundwater data available. Geohydrologic inferences are made on the basis of an integrated analysis of these data and an understanding of conditions in other areas of Afghanistan.

13C.1.1 Climate and Vegetation

Climate information for the Panjsher-Valley emerald-iron-silver AOI is based on data generated for the Afghanistan agricultural-meteorological (Agromet) project. Agromet was initiated by the U.S. Agency for International Development and the United Nations Food and Agriculture Organization in 2003 to establish data-collection stations and develop country-wide agrometeorological services. Scientists with the Agromet project are assisting the Afghan Government to collect and analyze agricultural and meteorological data as they relate to crop production, irrigation, water supply, energy, and aviation. The U.S. Geological Survey (USGS) assumed responsibility for the operation of the project in 2005; by the end of August 2010, 87 Agromet stations were recording precipitation data and other parameters. Additionally, the Agromet project receives data from 18 Afghanistan Meteorological Authority (AMA) weather stations. The Agromet project has developed a database that includes data collected at the Agromet stations over the past 6 years (2005–2011), data collected at the AMA weather stations, and historical data collected at weather stations from 1942 to 1993. Data collected as part of the Agromet project are compiled annually by water year (September through August) and are reported in the Afghanistan Agrometeorological Seasonal Bulletin (Seasonal Bulletin) published by the Ministry of Agriculture, Irrigation, and Livestock. Unless otherwise specified, the Agromet data cited in this report are from the agricultural season that extends from 1 September, 2009, to 31 August, 2010.

The observed total precipitation for the 2009–2010 water year for the AOI, as published in the Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 2), ranged from 255 to 300 mm (millimeters). The AOI received 61 to 80 mm of precipitation in February 2010, the month with the greatest precipitation (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 3). The AOI received 34 to 79 mm of precipitation in October 2009, the month with the least precipitation (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 4). The amount of precipitation increases from west to east across the AOI.

a



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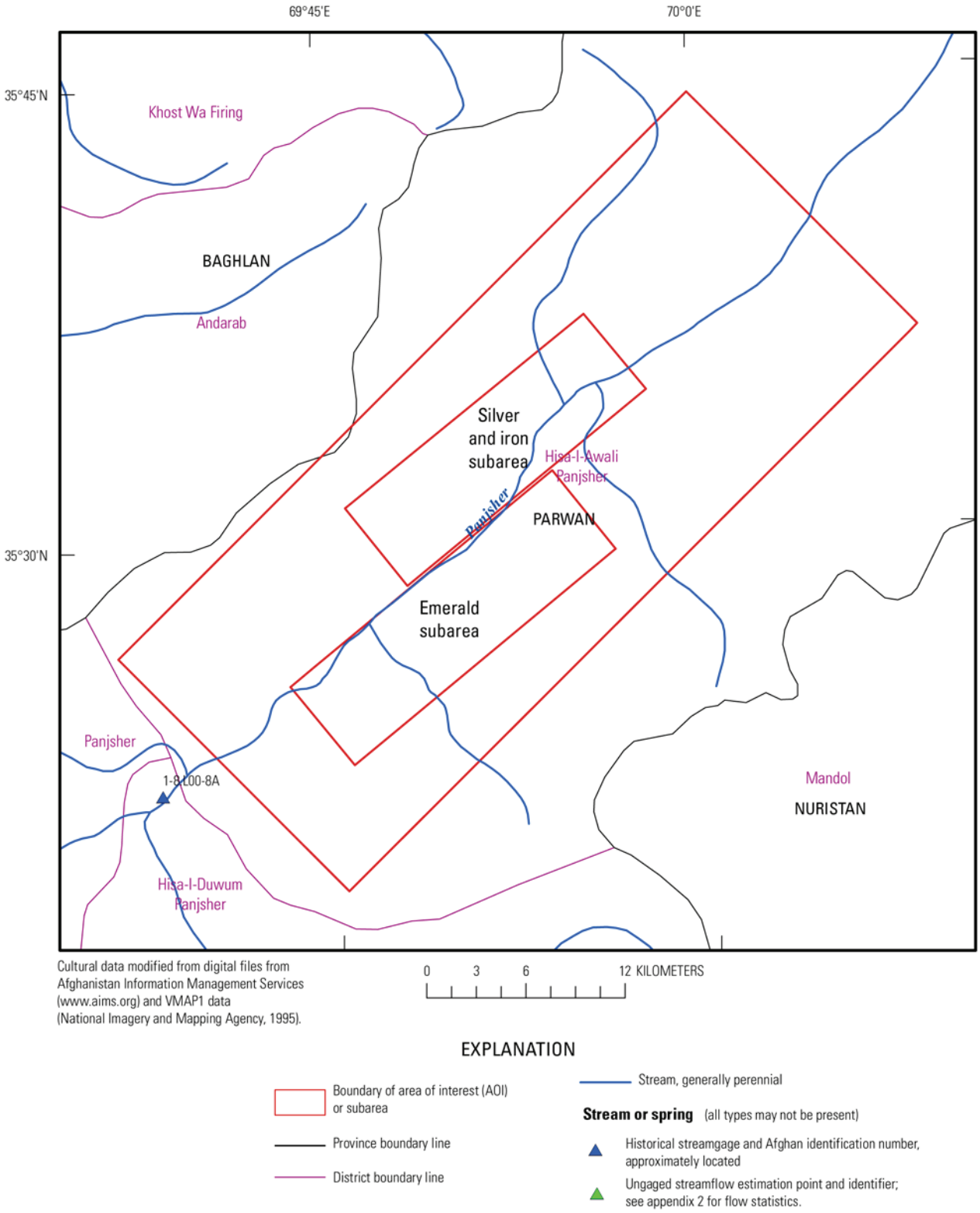

Figure 13C–1. (*a*) Landsat image showing the location of, and (*b*) place names, stream names, and streamgage station numbers in, the Panjsher-Valley emerald-iron-silver area of interest in Afghanistan.

There are no Agromet stations near the AOI for which 2009–2010 water year and long-term average (LTA) precipitation and temperature data are available. Precipitation data for the 2009–2010

water year are available for the Charikar Agromet station. This station is located about 80 km southwest of the center of the AOI at an elevation of about 1,600 m (meters) above sea level (asl). The total amount of precipitation recorded at this station for the 2009–2010 water year was 445 mm. Charikar had 2 snow days during the 2009–2010 water year, 1 each in December and February. Ten cm (centimeters) of snowfall was recorded at this station during the 2009–2010 water year, and 55 cm was recorded the previous water year. The snow-depth map for January 17, 2010 (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 6), indicates that snow depth in the AOI ranged from 10 to 30 cm in January 2010.

The Dara Panjsheer Agromet station is listed in the Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010) and 2009–2010 water year snowfall data are available. This station could not be accurately located, but it is likely to be near the AOI in the Panjsher River Basin. The snowfall data provide an example of the amount of snowfall that could be received in the higher elevations of the AOI. The Dara Panjsheer Agromet station had a total of 17 snow days in the 2009–2010 water year, distributed as follows: November 2009, 3 days; December 2009, 4 days; January 2010, 1 day; and February 2010, 9 days. The snowfall reported at this station for the 2009–2010 water year was 217 cm. The LTA snowfall for this station is 370 cm.

The "Potential Natural Vegetation" (PNV) described in Breckle (2007) is the vegetation cover that would be present if it had not been modified by human activity. Today, as a result of continued exploitation such as grazing, farming, and deforestation, much of the original natural vegetation is found only in a few remote areas of Afghanistan. The destruction of the natural vegetation has resulted in the degradation and erosion of the soil cover in some areas. Many areas exhibit signs of long-lasting desertification caused by human activity.

Much of the upland surface of the AOI is bedrock outcrop with very thin alluvial cover. The vegetation above about 3,300 m asl in the AOI is classified by Breckle (2007, p. 161 and 178) as "thorny cushions, subalpine and alpine semi deserts and meadows." The *Amygdalus*-Woodlands PNV is mapped in the lower elevations of the AOI. Azonal riverine vegetation likely was present in the stream valleys, but the trees have been harvested for fuel and building materials. Most land suitable for farming has been plowed and planted, especially along major stream valleys and some of the ephemeral tributary stream valleys. Irrigated fields are present in many of the valleys in the AOI (fig. 13C–2).

13C.1.2 Demographics

The population in the Panjsher-Valley emerald-iron-silver AOI is concentrated along the Panjsher River and a few of the tributary streams as mapped by LandScan (Oak Ridge National Laboratory, 2010). The population density along the Panjsher River is as much as 501 to 2,500/km^2 in some areas, but generally ranges from 51 to 500/km^2. Farther from the Panjsher River the population is sparse, with much of the higher, mountainous terrain having no inhabitants, as indicated by the gray shading in figure 13C-3. The population density shown in figure 13C–3 has a pixel resolution of about 1 km^2 (Oak Ridge National Laboratory, 2010).

13C.1.3 Topography and Geomorphology

The topography of the Panjsher-Valley emerald-iron-silver AOI is very mountainous (fig. 13C–4), with a northeast-southwest trend dissected by the Panjsher River in the middle of the AOI (Davis, 2006) (fig. 13C–2). The elevations of the higher mountain peaks within the AOI range from 3,500 to more than 4,500 m asl. One peak just outside the northeast corner of the AOI is 5,809 m asl, and another outside the southwest corner is 5,126 m asl (Bohannon, 2005a, 2005b). The elevation of the Panjsher River valley in the AOI is about 2,800 m asl where it enters the AOI, and 2,100 m asl where it exits. Relief between the valley bottom and flanking mountain ridges ranges from 1,000 to 2,000 m.

The landforms at the higher elevations within and just outside the AOI are dominated by alpine glacial features including arêtes, cirques, cirque lakes, and paternoster lakes. The course of the Panjsher River through the AOI is linear. The tributary streams to the Panjsher River exhibit a rectangular drainage pattern.

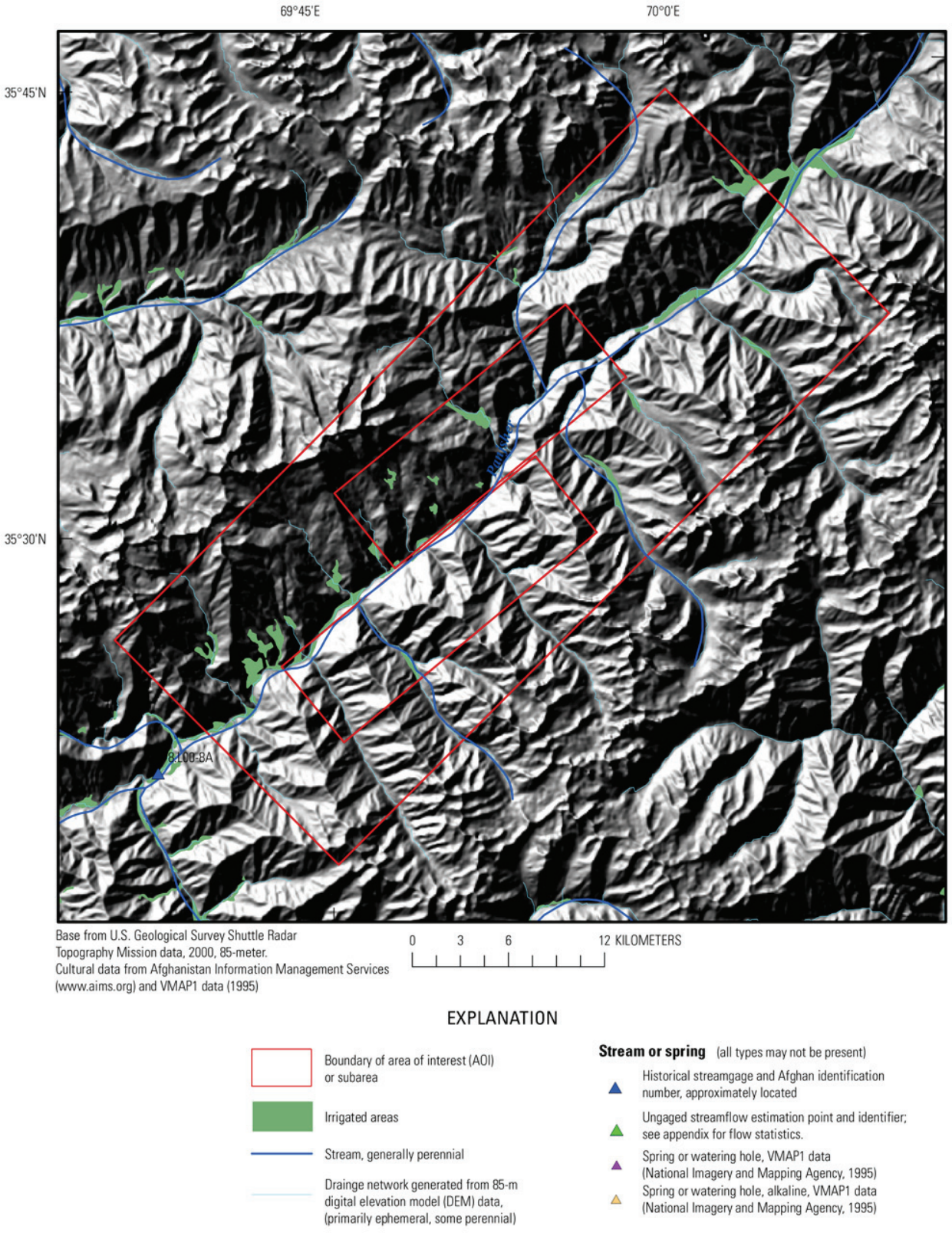

Figure 13C–2. Historical streamgage locations, digitally generated drainage network, and irrigated areas in the Panjsher-Valley emerald-iron-silver area of interest in Afghanistan.

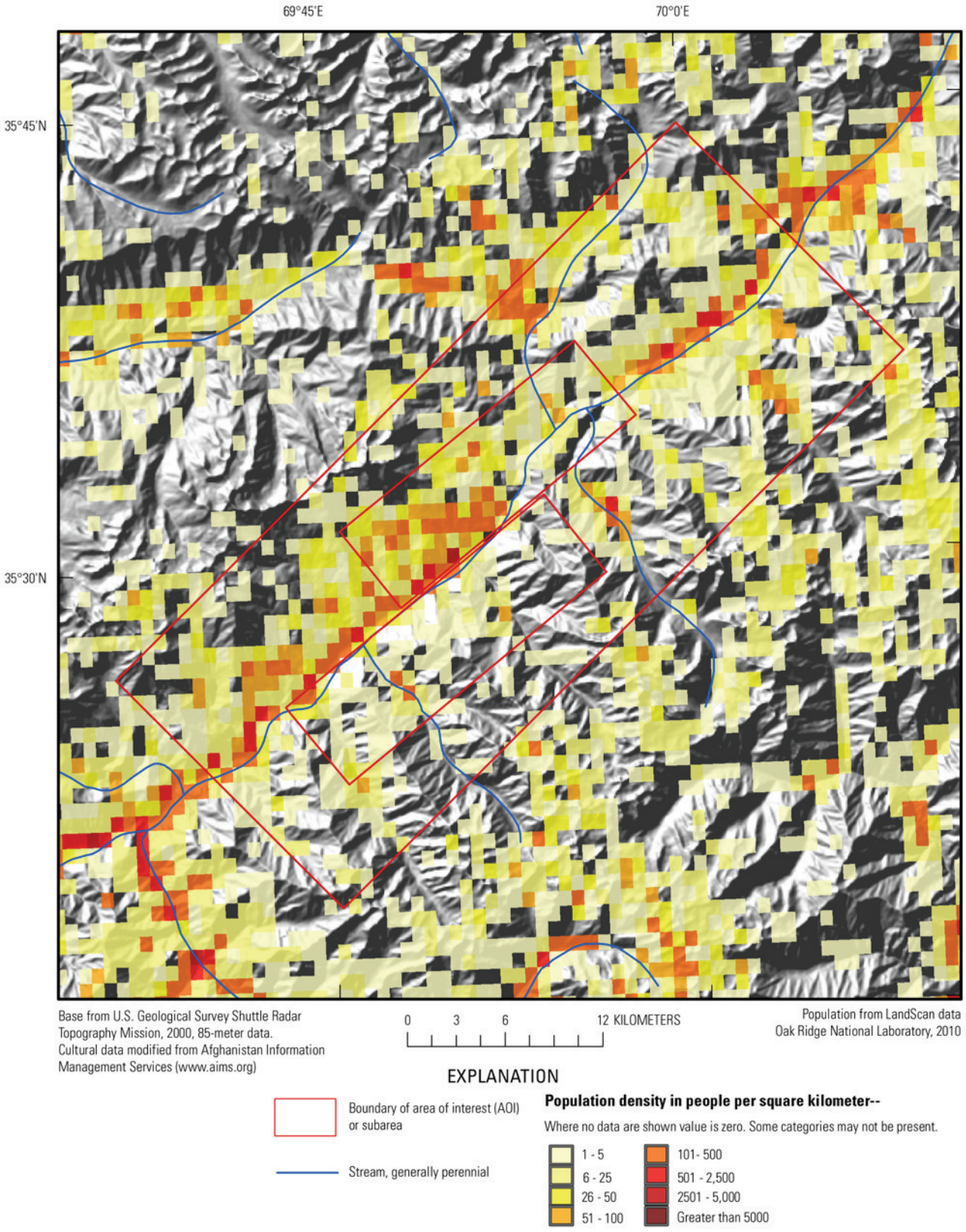

Figure 13C–3. Population density of the Panjsher-Valley emerald-iron-silver area of interest in Afghanistan.

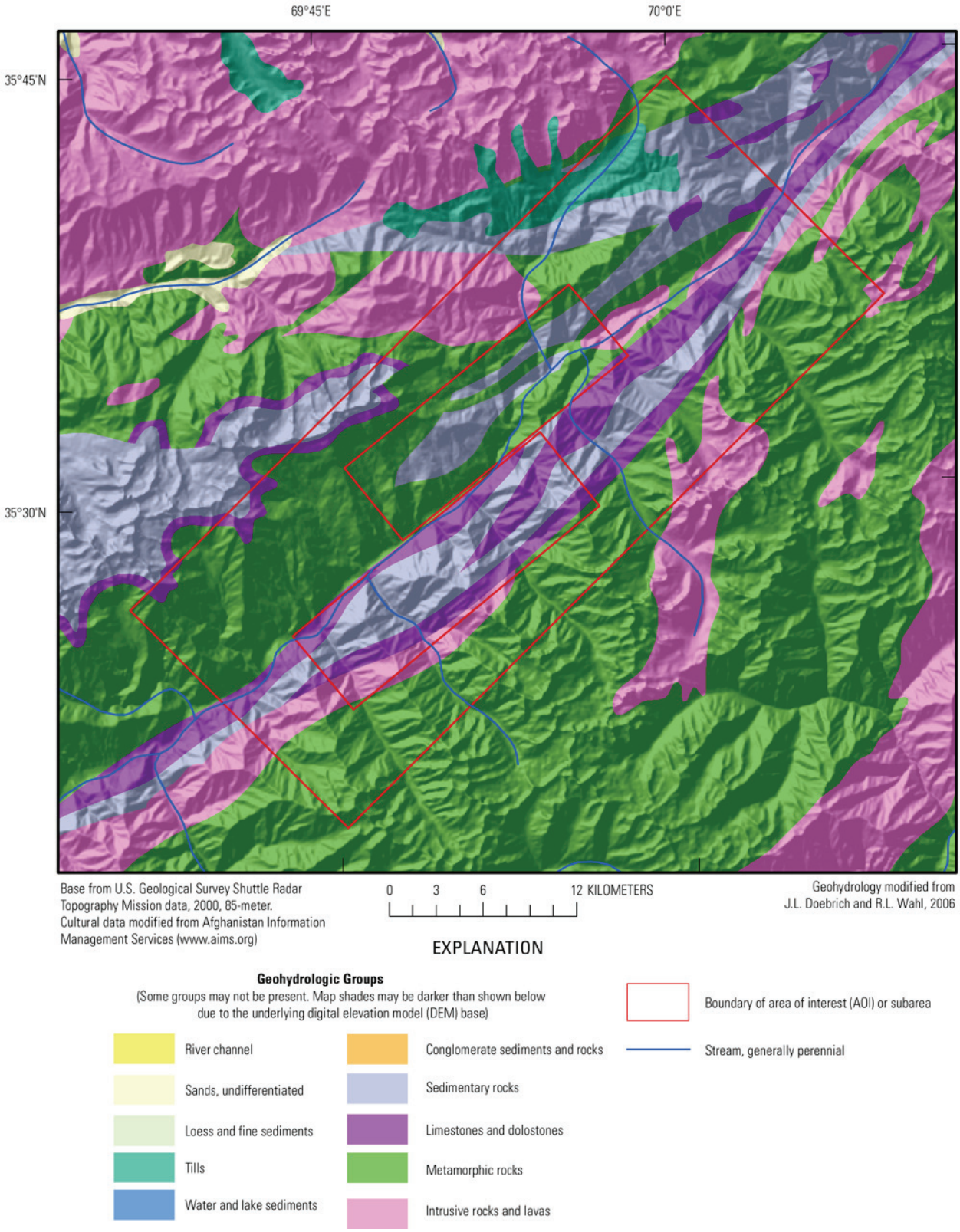

Figure 13C–4. Topography and generalized geohydrology of the Panjsher-Valley emerald-iron-silver area of interest in Afghanistan.

13C.2 Geohydrology

The geohydrology of Afghanistan has been described in general terms by Abdullah and Chmyriov (1977, book 2). As defined in their "Geology and mineral resources of Afghanistan," the Panjsher-Valley emerald-iron-silver AOI is in the "Central Afghanistan Hydrogeological Folded Region that occupies the central part of the country with a predominantly mountain climate." The outcrops and near-surface rocks in the AOI can be grouped according to their physical and hydraulic properties. The generalized geohydrology of the AOI is shown in figure 13C–4 with the underlying topography to allow examination of the geohydrology in the context of relief. Figure 13C–5 shows the generalized geohydrology without topography for a clearer depiction of the geohydrologic units. Generalized geohydrologic groups were created from a country-wide geologic coverage (Doebrich and Wahl, 2006) by combining sediments and rocks into major sediment- or rock-type groups of similar hydrologic characteristics. The geohydrologic groups in the AOI, ranked from high to low relative hydraulic conductivity (Freeze and Cherry, 1979, table 2.3), are "tills; limestones and dolostones; sedimentary rocks; metamorphic rocks; and intrusive rocks and lavas" (figs. 13C–4, 13C–5). Metamorphic rocks form much of the higher elevations in the AOI and probably receive substantial snowfall. Faults mapped in this AOI may have formed the Panjsher River valley and some of the ephemeral stream valleys (figs. 13C–4 and 13C–5). Doebrich and Wahl (2006) used geologic maps at a scale of 1:250,000, modified from Russian and Afghan Geological Survey (AGS) mapping, to generate the country-wide geologic coverage. The 1:250,000-scale geologic maps that cover this AOI are provided by Lindsay and others (2005a, 2005b).

A band of sedimentary rocks, limestones and dolostones, and intrusive rocks and lavas crops out along the southeast side of the Panjsher River valley in the AOI (fig.13C–4). The maximum width of this 48-km-long band is about 7 km. The position of the sedimentary rocks and limestones and dolostones geohydrologic groups in and adjacent to the bottom of the Panjsher River valley could enhance the infiltration of surface water. The outcrop of the till in the north corner of the AOI appears to be primarily covering hillslopes (fig. 13C–4). Where this unit occurs in the stream-valley bottom, it could form an aquifer of limited extent.

13C.2.1 Surface Water

A network of major, mostly perennial streams, modified from AIMS (Afghanistan Information Management Services, 1997) and VMAP1 (National Imagery and Mapping Agency, 1995), is shown in figure 13C–2. A network representing likely ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 13C–2. Names of major streams and identification numbers for any streamgages and ungaged streamflow estimation sites in the Panjsher-Valley emerald-iron-silver AOI are shown in figure 13C–1*b*.

The Panjsher River at Omarz streamgage station (Afghan identification number 1-8.L00-8A) is the nearest to the AOI. This station is located about 3.5 km (kilometers) southwest of AOI (figs. 13C–1*b* and13C–2). This station is at an elevation of 2,010 m asl and has a drainage area of 2,240 km^2 and a period of record that extends from 1 October, 1962, to 20 February, 1963, and 25 June, 1963, to 30 September, 1980 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.015 $m^3/s/km^2$ (cubic meters per second per square kilometer). The seasonal timing of maximum and minimum monthly streamflow is high flows in the late spring and summer and low flows in winter. A statistical summary of monthly and annual mean streamflows for this station is presented in table 15C-2. Statistical summaries of streamflow data for all available historical gages in Afghanistan can be accessed at *http://afghanistan.cr.usgs.gov/water.php.*

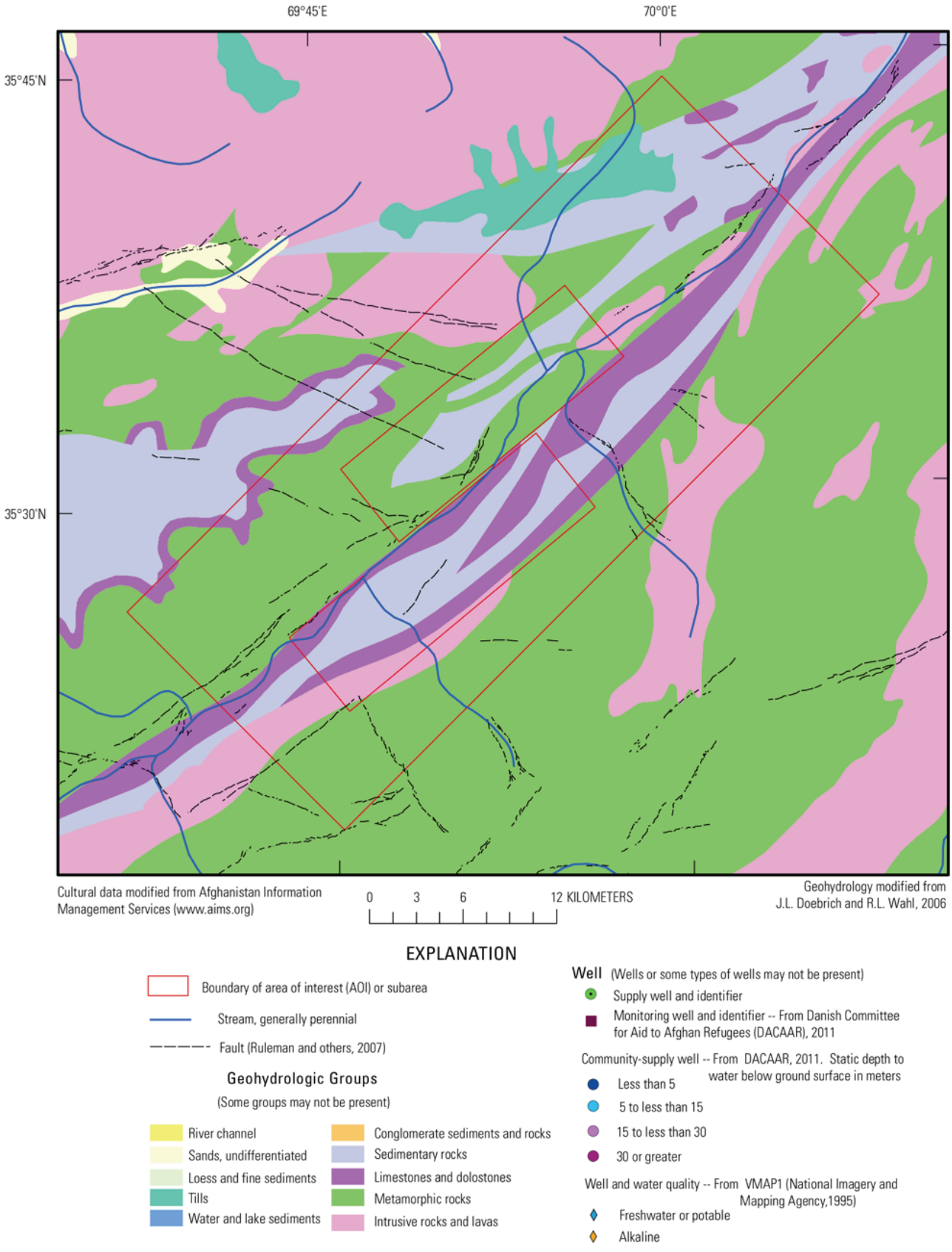

Figure 13C–5. Generalized geohydrology and mapped faults in the Panjsher-Valley emerald-iron-silver area of interest in Afghanistan.

Table 15C–2. (on following page) Statistical summary of monthly and annual mean streamflows for the Panjsher River at Omarz streamgage station (Afghan identification number 1-8.L00-8A) (Olson and Williams-Sether, 2010).
[m^3/s, cubic meters per second]

1-8.L00-8A PANJSHER RIVER AT OMARZ

Month	Maximum		Minimum		Mean			
	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Standard deviation (m^3/s)	Coefficient of variation	Percentage of annual streamflow
October	15.8	1970	7.90	1972	11.9	2.05	0.17	2.95
November	12.4	1973	7.51	1972	9.50	1.55	0.16	2.36
December	10.7	1973	.04	1975	7.96	1.35	0.17	1.98
January	9.11	1970	5.27	1979	6.85	1.18	0.17	1.71
February	8.72	1970	5.05	1975	6.46	0.92	0.14	1.61
March	10.0	1971	5.55	1975	7.45	1.32	0.18	1.86
April	23.7	1971	10.5	1977	16.3	4.12	0.25	4.05
May	92.4	1971	32.1	1977	50.1	18.1	0.36	12.5
June	190	1973	89.2	1971	131	28.5	0.22	32.5
July	153	1969	34.7	1971	95.8	33.3	0.35	23.9
August	75.5	1969	24.0	1974	40.3	13.2	0.33	10.0
September	27.6	1969	11.9	1971	18.5	3.72	0.20	4.60
Annual	**43.7**	**1969**	**24.5**	**1977**	**33.5**	**5.80**	**0.17**	**100**

13C.2.2 Groundwater

There are no NGO-installed water-supply wells in the Panjsher-Valley emerald-iron-silver AOI according to a database maintained by DACAAR (Danish Committee for Aid to Afghan Refugees, 2011). However, there are likely to be dug wells completed in unconsolidated sediments near the Panjsher River. Some sections of the Panjsher River valley may contain tens of meters of coarse-grained, unconsolidated sediments, and therefore there is potential for recharge from induced infiltration from the river. Wells in such areas may be able to supply considerable water to local users or for mining-related activities. No information is available about groundwater resources in the bedrock aquifers of the AOI. Where fracture zones are present, there may be the potential for limited groundwater availability from bedrock aquifers. No information is available about the quality of groundwater in the unconsolidated or bedrock aquifers.

13C.2.3 Lineament Analyses

Lineaments are photolinear features that could be the result of underlying zones of high-angle bedrock fractures, fracture zones, faults, or bedding-plane weaknesses. Lineament analyses of the Panjsher-Valley emerald-iron-silver AOI (B.E. Hubbard, T.J. Mack, and A.L. Thompson, unpub. data, 2011) were conducted using DEM and natural-color satellite imagery (fig. 13C–6) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 13C–7*a*, *b*). Lineament identification and analysis have long been used as a reconnaissance tool for identifying areas in carbonate bedrock environments where groundwater resources are likely to be found (Lattman and Parizek, 1964; Siddiqui and Parizek, 1971). Lineament analysis is increasingly used to identify areas of high relative well yields in other bedrock settings, including crystalline bedrock (Mabee, 1999; Moore and others, 2002). The lineaments shown in figure 13C–6 were delineated visually, whereas those in figure 13C–7 were delineated using an automated process and on the basis of the multispectral characteristics of the land surface (B.E. Hubbard, T.J. Mack, and A.L. Thompson, unpub. data, 2011). Water wells in bedrock aquifers generally are most productive where boreholes are located in areas of highly fractured bedrock. Numerous lineaments in the AOI follow the northeasterly structural pattern. Some lineaments follow drainage patterns (fig. 13C–2) and may represent areas with a pattern of conjugate fracturing in the bedrock. The presence of a conjugate pattern is supported by the trends of mapped faults in the AOI (fig. 13C–5). Areas where lineament density is high, such as in the silver and iron subarea and the emerald subarea (figs. 13C–6, 13C–7*a*, 13C–7*b*), potentially are areas where

bedrock fractures are more prevalent than in other areas of the AOI. Lineaments provide an indication of areas that warrant further investigation for optimal bedrock water-well placement. Lineaments may also indicate areas of preferential flow and storage of groundwater, and areas with a high density of lineaments may indicate high secondary porosity. Any lineament analyses, including those presented in this investigation, need to be corroborated by field investigations and additional data to confirm the nature of the lineaments and their relation to water-filled bedrock fracture zones.

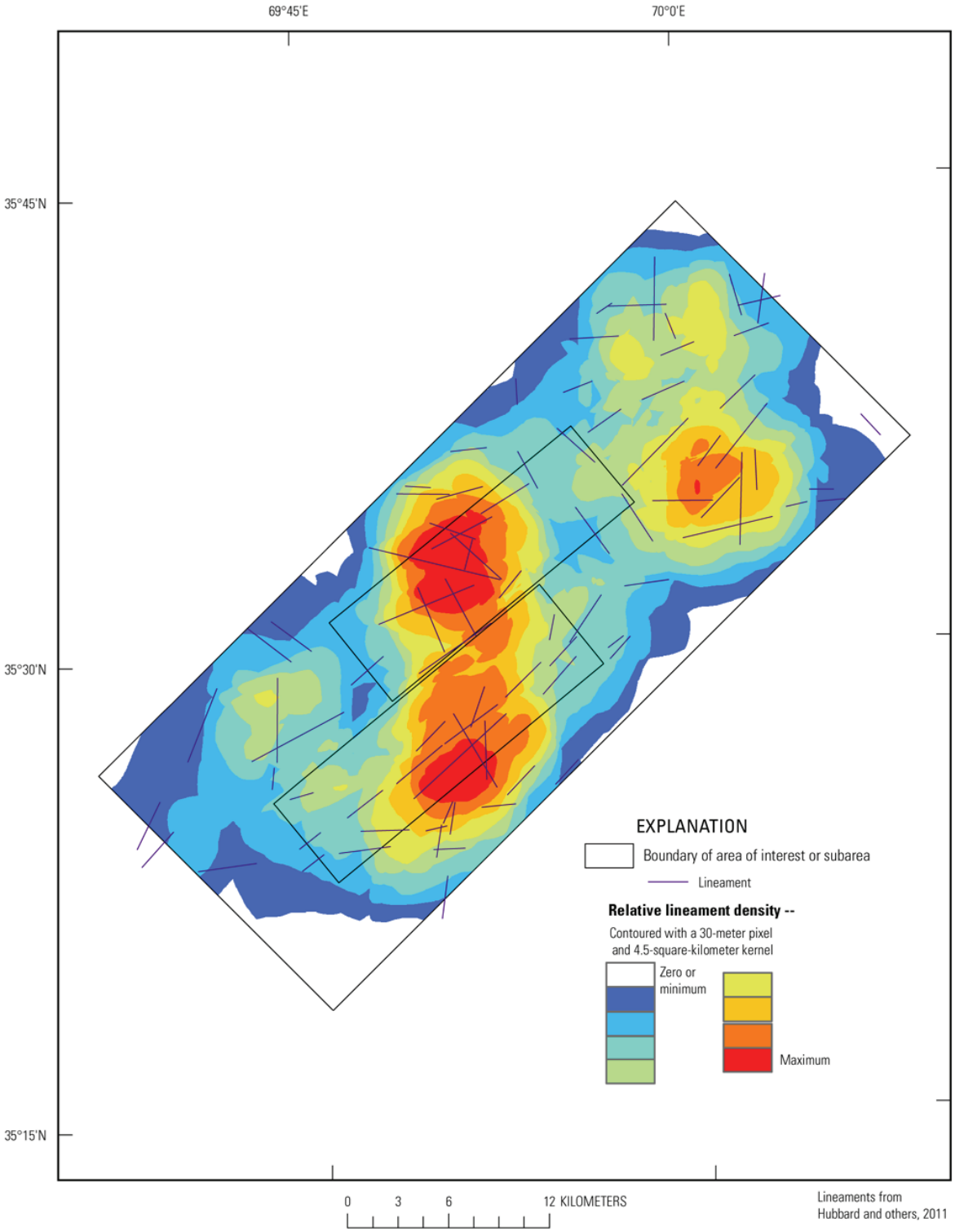

Figure 13C–6. Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the Panjsher-Valley emerald-iron-silver area of interest in Afghanistan.

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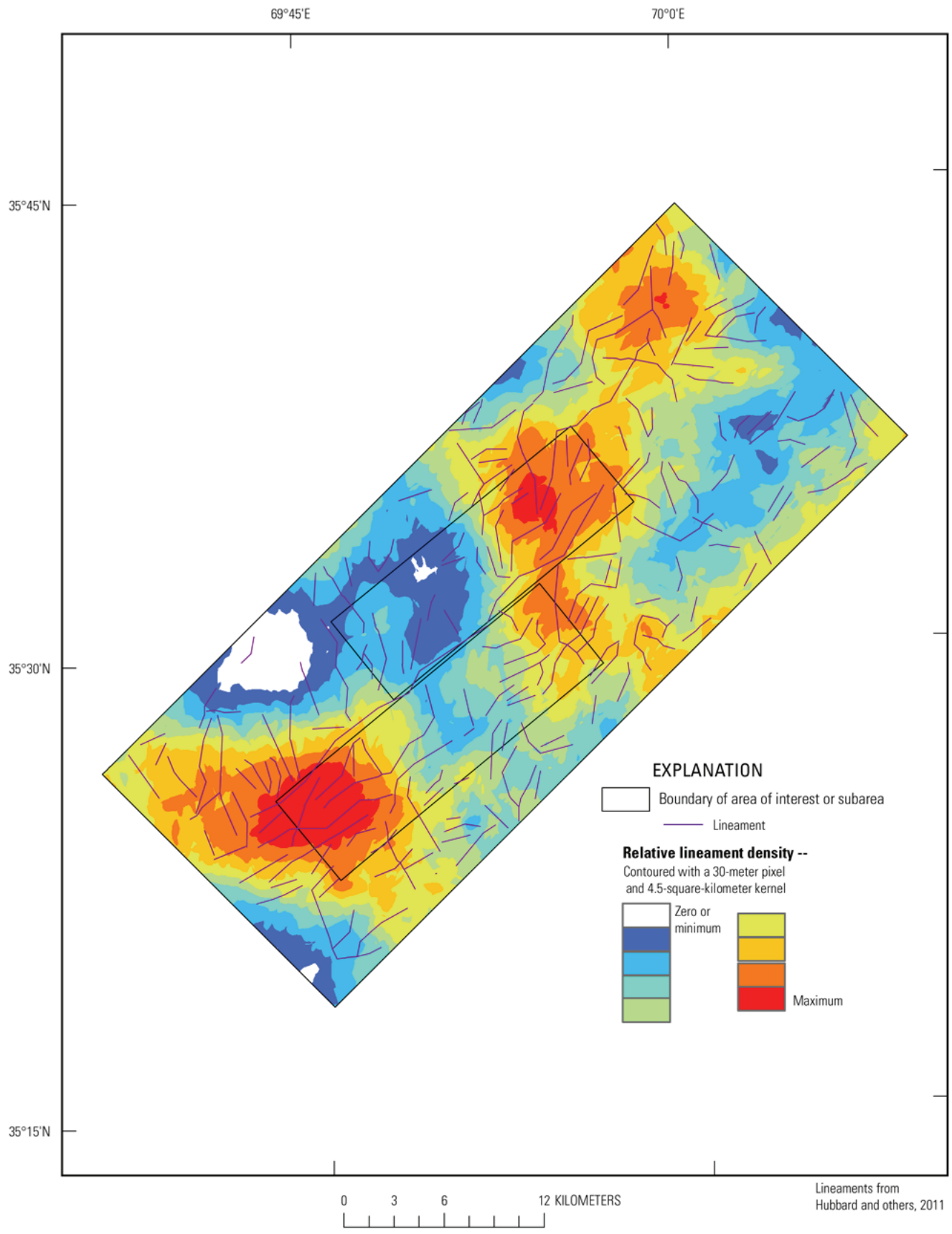
69°45'E
70°0'E
35°45'N
35°30'N
35°15'N
EXPLANATION
Boundary of area of interest or subarea
Lineament
Relative lineament density --
Contoured with a 30-meter pixel
and 4.5-square-kilometer kernel
Zero or
minimum
Maximum
0
3
6
12 KILOMETERS
Lineaments from
Hubbard and others, 2011

b

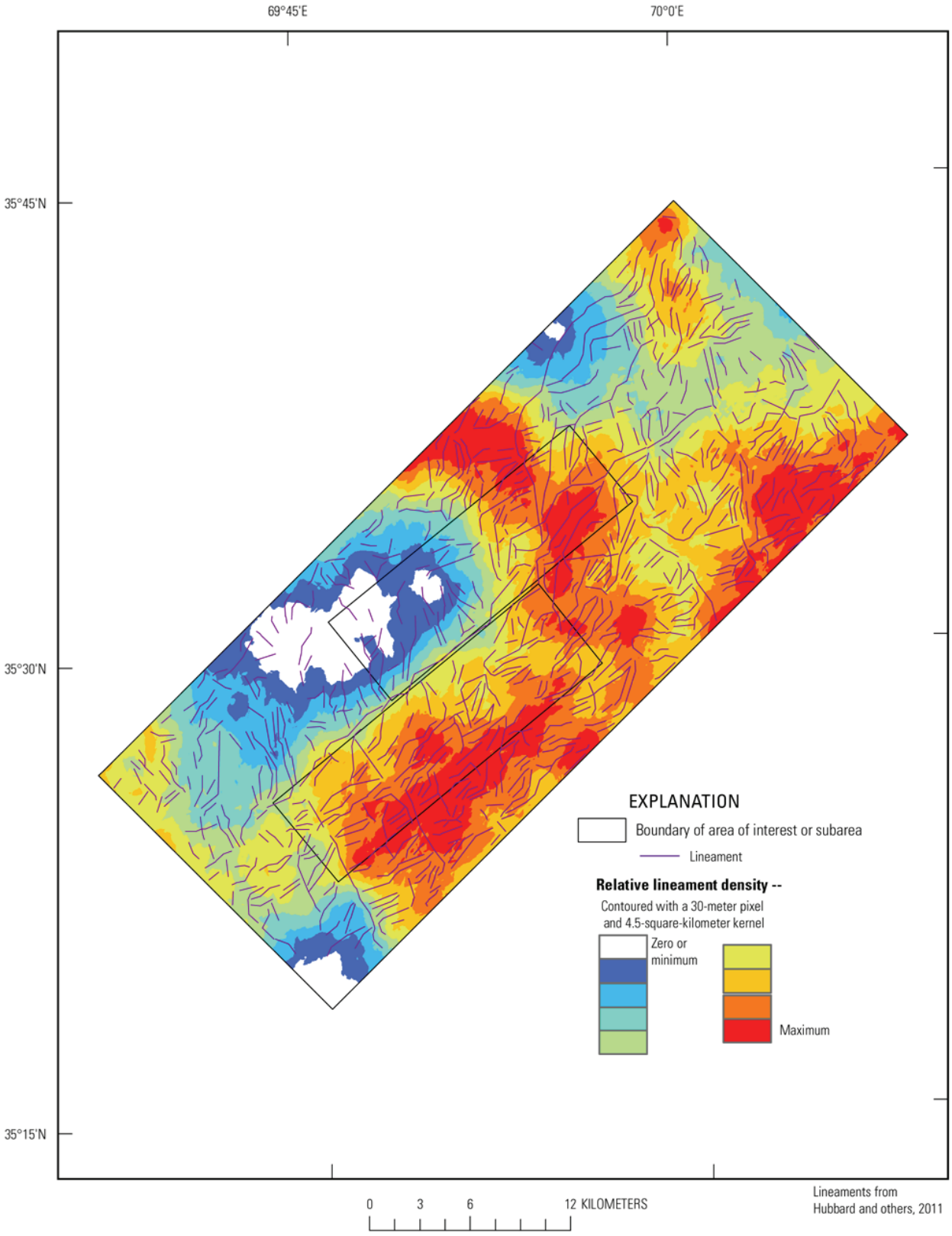

Figure 13C–7. (on previous pages) (*a*) Lineaments and lineament density based on 30-meter multispectral Landsat imagery and (*b*) lineaments and lineament density based on 15-meter multispectral Landsat imagery in the Panjsher-Valley emerald-iron-silver area of interest in Afghanistan.

13C.3 Summary and Conclusions

Water resources in the Panjsher-Valley emerald-iron-silver area of interest (AOI) are likely to be more available than in other areas of Afghanistan as determined from the high annual precipitation and streamflow in the area. The known water resources in the AOI and surrounding area consist mainly of surface water. Shallow alluvial aquifers in the valley bottoms of the AOI are a likely to be a highly utilized groundwater resource. Most streams are also likely to be highly utilized by the local population for irrigation. Any diversion of water from the rivers to support mining activities would need to be closely monitored, particularly during low-flow periods. The quantity and quality of the water resource need to be assessed so that surface-water flow remains sufficient to supply water for irrigation and to provide recharge to the aquifers that supply groundwater to the shallow wells for domestic consumption.

No information about deep groundwater in the AOI or adjacent areas is available. Some areas of the AOI, as indicated by generalized geohydrologic maps and lineament analyses, are potential areas for further exploration for groundwater resources. The quality and sustainability of water resources in the AOI remain to be determined, however. Close monitoring and careful management of potential new surface-water or groundwater withdrawals would help to protect the quantity and quality of the existing supply for current local water uses. Field investigations including geologic mapping, geophysical surveys, and hydraulic well testing are needed to adequately characterize the extent and availability of groundwater resources in the AOI.

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