Chapter 6C. Geohydrologic Summary of the Dusar-Shaida Copper and Tin Area of Interest

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6C.1 Introduction

This chapter describes the geohydrology of the Dusar-Shaida copper and tin area of interest (AOI) in Afghanistan identified by Peters and others (2007) (fig. 6C–1*a,b*). The AOI is located in the districts of Ghoryan, Guzara, Adraskan, Anar Dara, and Shindand in Hirat and Farah Provinces in western Afghanistan, and is centered about 85 km (kilometers) southwest of the city of Herat (fig. 6C–1*a,b*). The Kaftar volcanogenic massive sulfide (VMS), Shaida, and Dahana-Misgaran subareas occupy 2,717 km^2 (square kilometers), 334 km^2, and 171 km^2, respectively, of the 8,619-km^2 area of the AOI.

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, generalized geohydrology and topography, and well locations. Where these data are available, the depth to water and height of static water in wells are documented. 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 some 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, and U.S. Geological Survey (USGS) minerals teams conducted field reconnaissance work in the AOI in August 2010; 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.

6C.1.1 Climate and Vegetation

Climate information for the Dusar-Shaida copper and tin 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 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.

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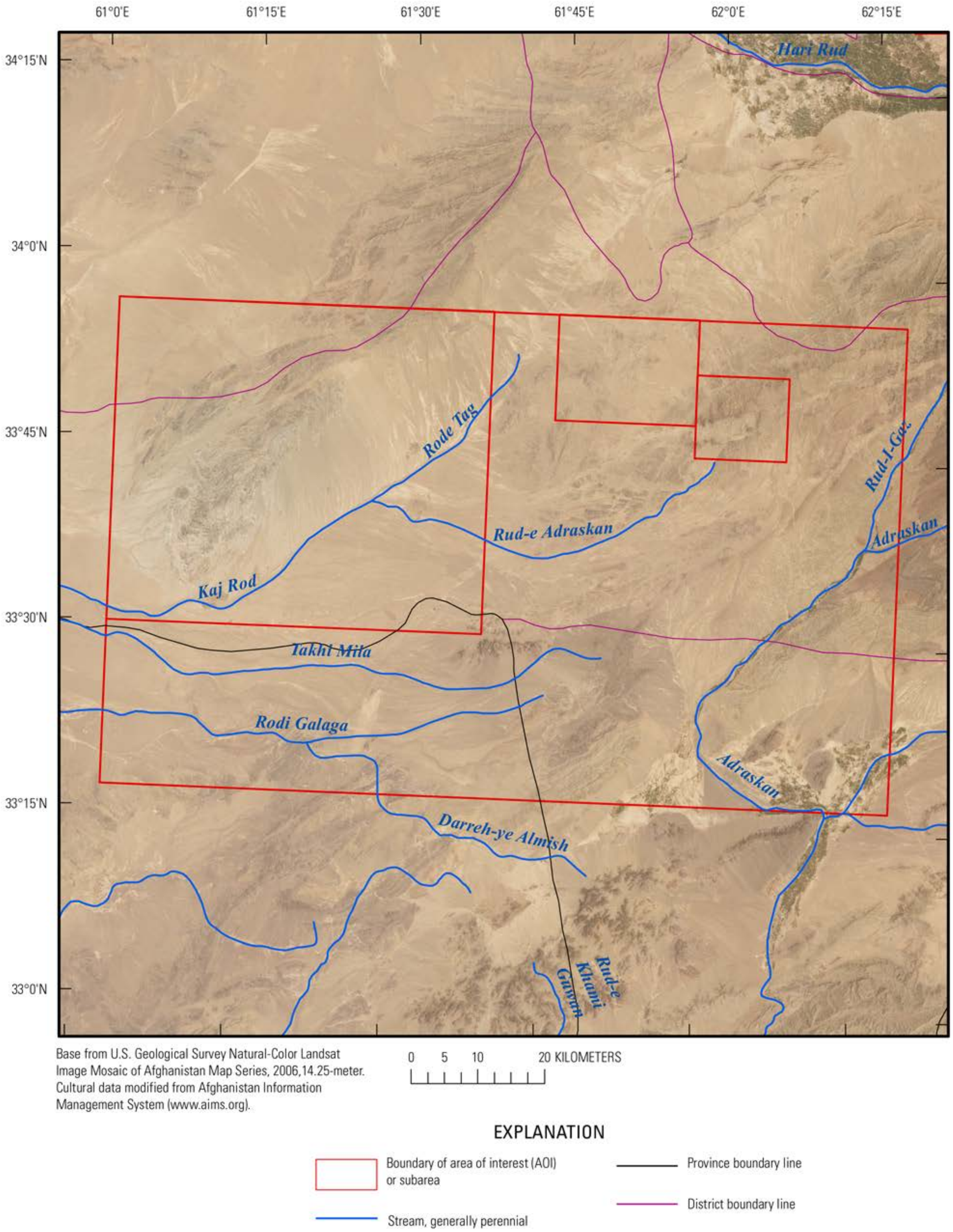

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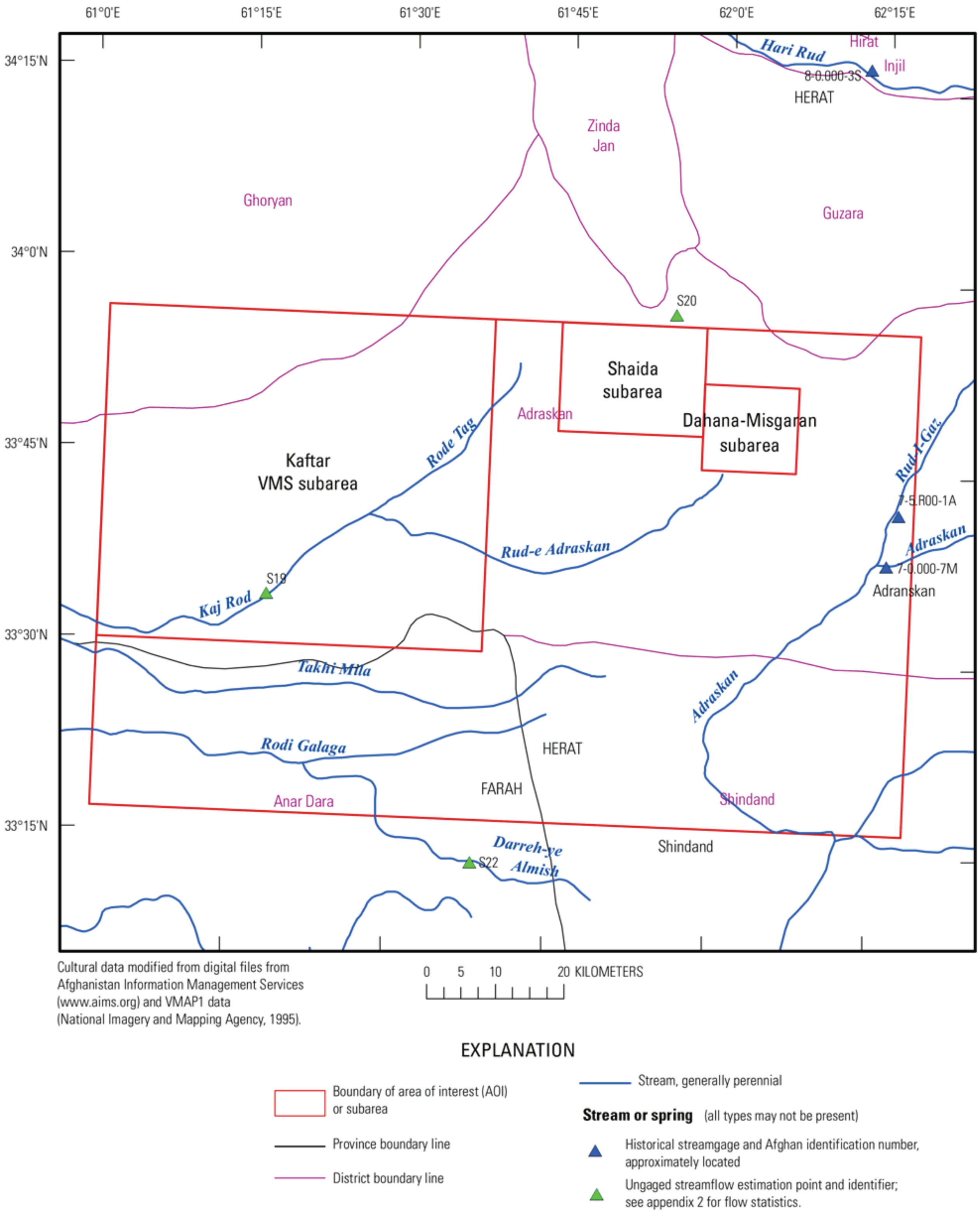

Figure 6C–1. *(a)* Landsat image showing the location of, and *(b)* place names, stream names, and streamgage station numbers in, the Dusar-Shaida copper and tin area of interest in western Afghanistan.

The Shindand Agromet station is located at the southeastern border of the AOI in the settlement of Shindand (fig. 6C–1*a*,*b*). Precipitation at this station during the 2009–2010 water year was 198 mm (millimeters) (Ministry of Agriculture, Irrigation, and Livestock, 2010). The maximum monthly rainfall of 67 mm occurred in March 2010, whereas no precipitation was recorded at this station in September, October, and May through August. The annual long-term average (LTA) precipitation for the Shindand Agromet station is 195.5 mm. The monthly LTA precipitation is highest (50.8 mm) in March and lowest (0.0 mm) in September, June, July, and August (Ministry of Agriculture, Irrigation, and Livestock, 2010).

The Hirat (Herat) Agromet station (Ministry of Agriculture, Irrigation, and Livestock, 2010) is located about 85 km north of the AOI in the city of Herat (fig. 6C–1*a*,*b*). Precipitation and temperature data for the 2009–2010 water year as well as LTA data are available for this station and are summarized in table 6C–1. The total precipitation recorded at the Hirat Agromet station for the 2009–2010 water year was 198 mm. Monthly rainfall was highest (92 mm) in February 2010. The next highest monthly total was 51.8 mm in March 2010 (Ministry of Agriculture, Irrigation, and Livestock, 2010). No precipitation was recorded during September and October 2009 or June through August 2010. The annual LTA precipitation for this station is 224.7 mm, with 49.9 mm of precipitation occurring in March and 49.6 mm occurring in January. Monthly LTA precipitation at this station was 0.0 mm in September and June through August. No snowfall information was reported for the Hirat station. The historical average snow-cover map for the month of January depicts no snow cover in the AOI (Ministry of Agriculture, Irrigation, and Livestock, 2010). Both the 17 January, 2010, and the 30 September, 2010, Afghanistan snow-depth maps show less than 2 cm (centimeters) of snow cover in the AOI.

The maximum and minimum average monthly temperature for the Hirat Agromet station for the 2009–2010 water year was 29.88°C (degrees Celsius) for July 2010 and 8.09°C for December 2009, respectively. The exact elevation of the Hirat Agromet station is unknown, but the city of Herat is about 920 m (meters) above mean sea level (asl). Elevation in the AOI ranges from slightly less than 1,000 m to nearly 2,000 m asl. The temperatures recorded at the Hirat Agromet station are probably representative of those at the low elevations in the AOI; average temperatures at the high elevations probably are lower.

The vegetation in the AOI is sparse except in some irrigated areas near rivers, such as the Adraskan River, in the southeastern part of the AOI (fig. 6C–2) near Adraskan. The Map of Potential Natural Vegetation in Breckle (2007) depicts three vegetation zones in the AOI. Elevations greater than 1,500 m asl are classified as *Pistacia atlantica* woodlands; elevations from 900 to 1,500 m asl are in the Dwarf *Amygdalus*-semidesert vegetation type. The extreme western edge of the AOI is classified as “Other Deserts,” rich in Chenopod. Little or no growing vegetation was present in much of the AOI during the field reconnaissance in August 2010, except in some dry streambeds where groundwater may be near the land surface (fig. 6C–3).

Table 6C–1. Annual, long-term annual average, and long-term average monthly minimum and maximum precipitation and temperature at the Herat Agrometeorological (Agromet) station.

[Station is 100 km north of the Dusar-Shaida copper and tin area of interest, in western Afghanistan. AOI, area of interest; km, kilometers; m, meters; mm, millimeters; °C, degrees Celsius]

Agromet station	Distance from AOI center (km)	Elevation (m)	Precipitation: 2009–10 annual (mm)	Precipitation: Long-term average[1] Annual (mm)	Precipitation: Long-term average[1] Monthly minimum and month (mm)	Precipitation: Long-term average[1] Monthly maximum and month (mm)	Temperature: Long-term average[1] Minimum and month (°C)	Temperature: Long-term average[1] Monthly mean (°C)	Temperature: Long-term average[1] Maximum and month (°C)
Hirat	100	920	198	224.7	0 multiple months[2]	49.9 March	3.1 January	13.8	29.6 July

[1]Long-term averages are based on data from 1942 to 1993 and 2005 to 2010 as reported in the Afghanistan Agrometeorological Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010).

[2]Long-term average precipitation in September, June, July, and August was 0 mm.

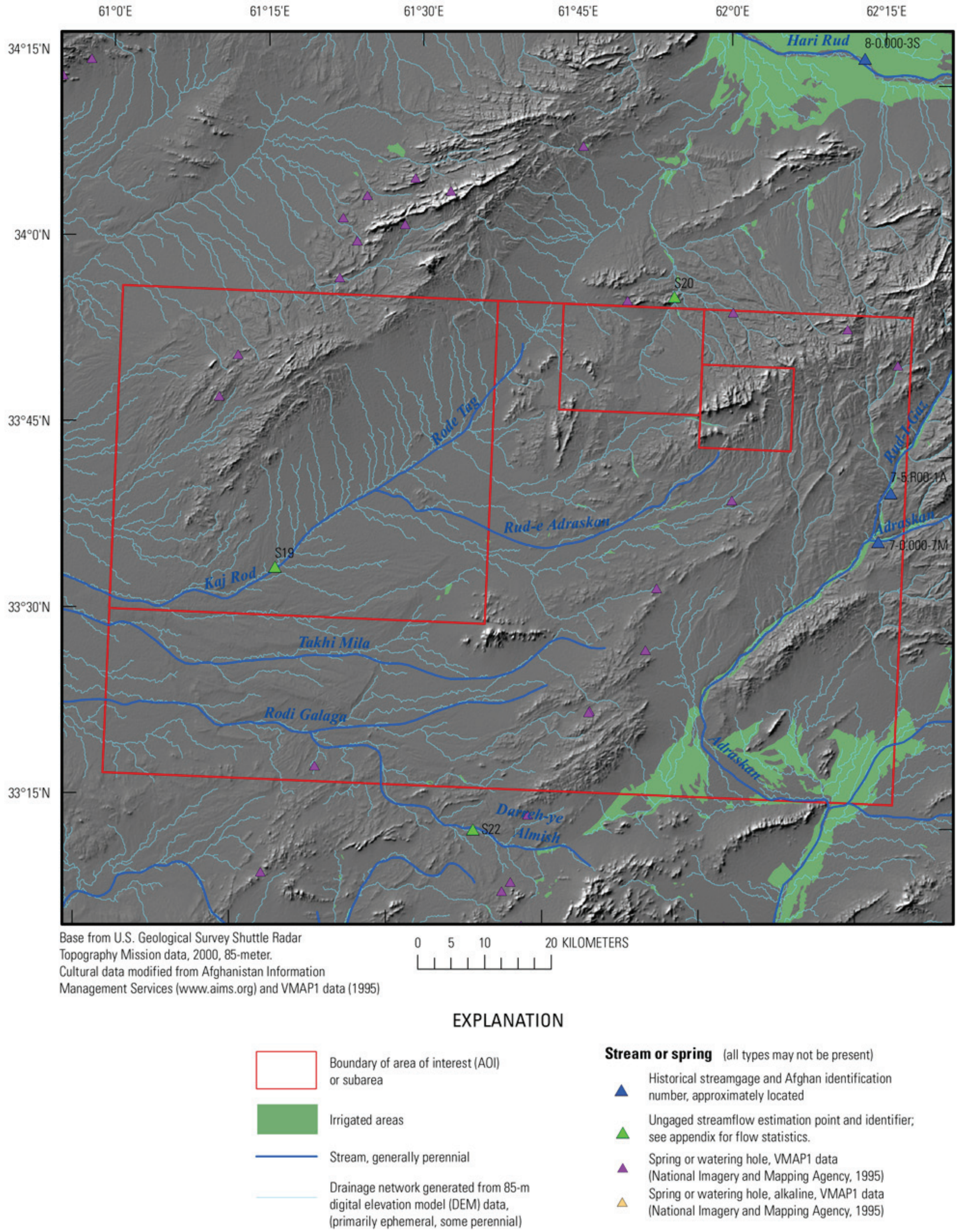

Figure 6C–2. Historical streamgage locations, digitally generated drainage network, and irrigated areas in the Dusar-Shaida copper and tin area of interest in western Afghanistan.

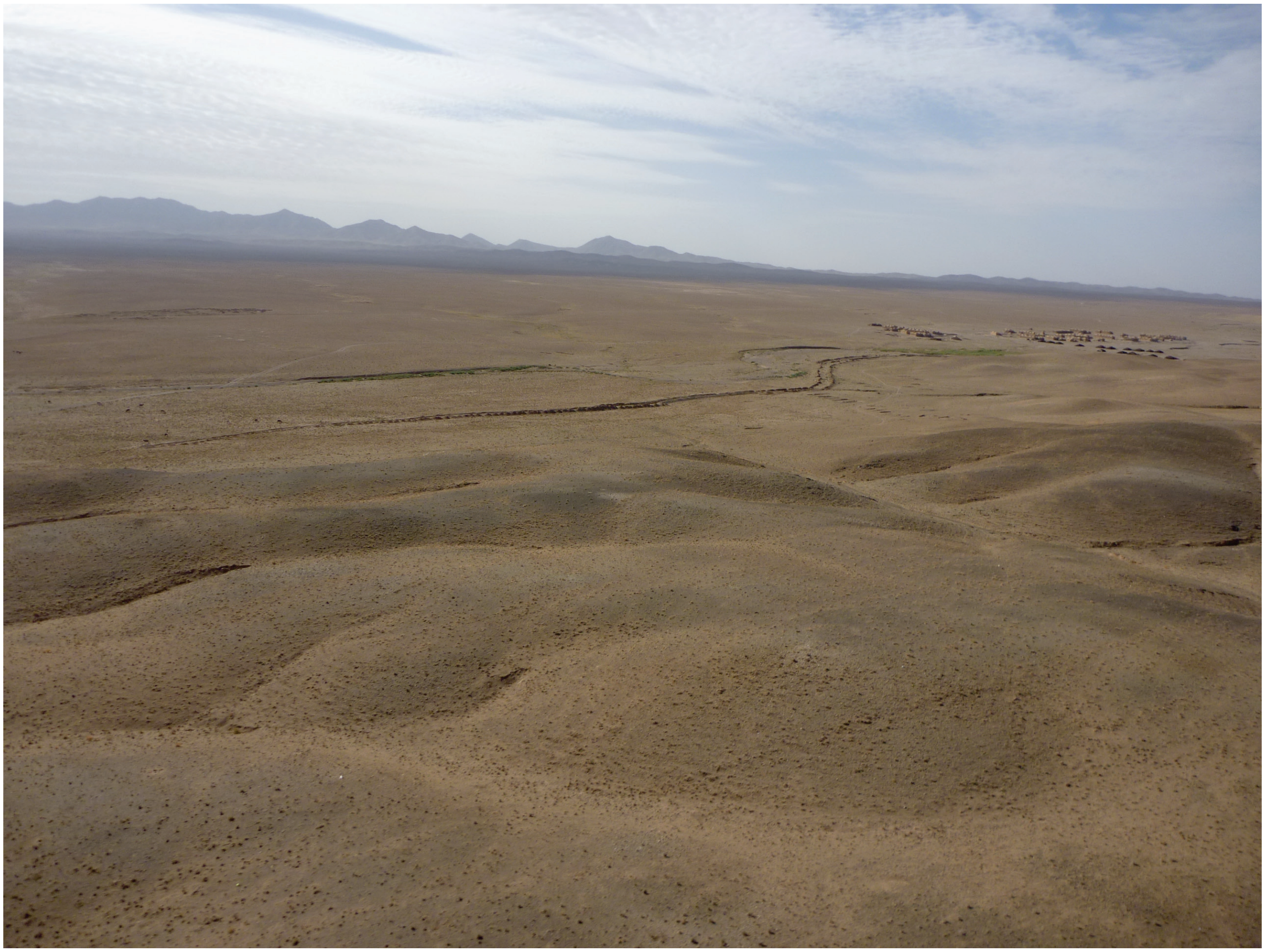

Figure 6C–3. Photograph showing vegetation in the Dusar-Shaida copper and tin area of interest, near the Shaida subarea, in western Afghanistan (August 2010).

6C.1.2 Demographics

There are few settlements in most of the Dusar-Shaida copper and tin AOI, particularly in the subareas; an exception is along the Adranskan River in the southeastern part of the AOI (fig. 6C–1*a*,*b*). Many villages in the AOI consist of tent structures and may be transient. In a photograph taken in the Shaida subarea (fig. 6C–4), some of the dwellings in the distant village (upper right corner of the photograph) are tent structures. As mapped by LandScan (Oak Ridge National Laboratory, 2010), the AOI is sparsely settled and the population is highly dispersed (fig. 6C–4). The population density in most of the AOI is fewer than 50 per km^2 and the subareas, particularly the Kaftar VMS subarea, are the least populated. The population density shown in figure 6C–4 has a pixel resolution of about 1 km^2 (Oak Ridge National Laboratory, 2010).

The largest settlement in the AOI is Shindand, the district center at the southeast border of the AOI. Adraskan, the district center of Adraskan District, is the second largest population center in the AOI. Although the population of these settlements is unknown, the population of Herat Province is 1,676,000, including 1,218,200 in rural areas and 457,800 in urban areas (Islamic Republic of Afghanistan, 2010). Herat is the largest population center near the AOI, with a population of slightly more than 400,000 (fig. 6C–1*a*,*b*).

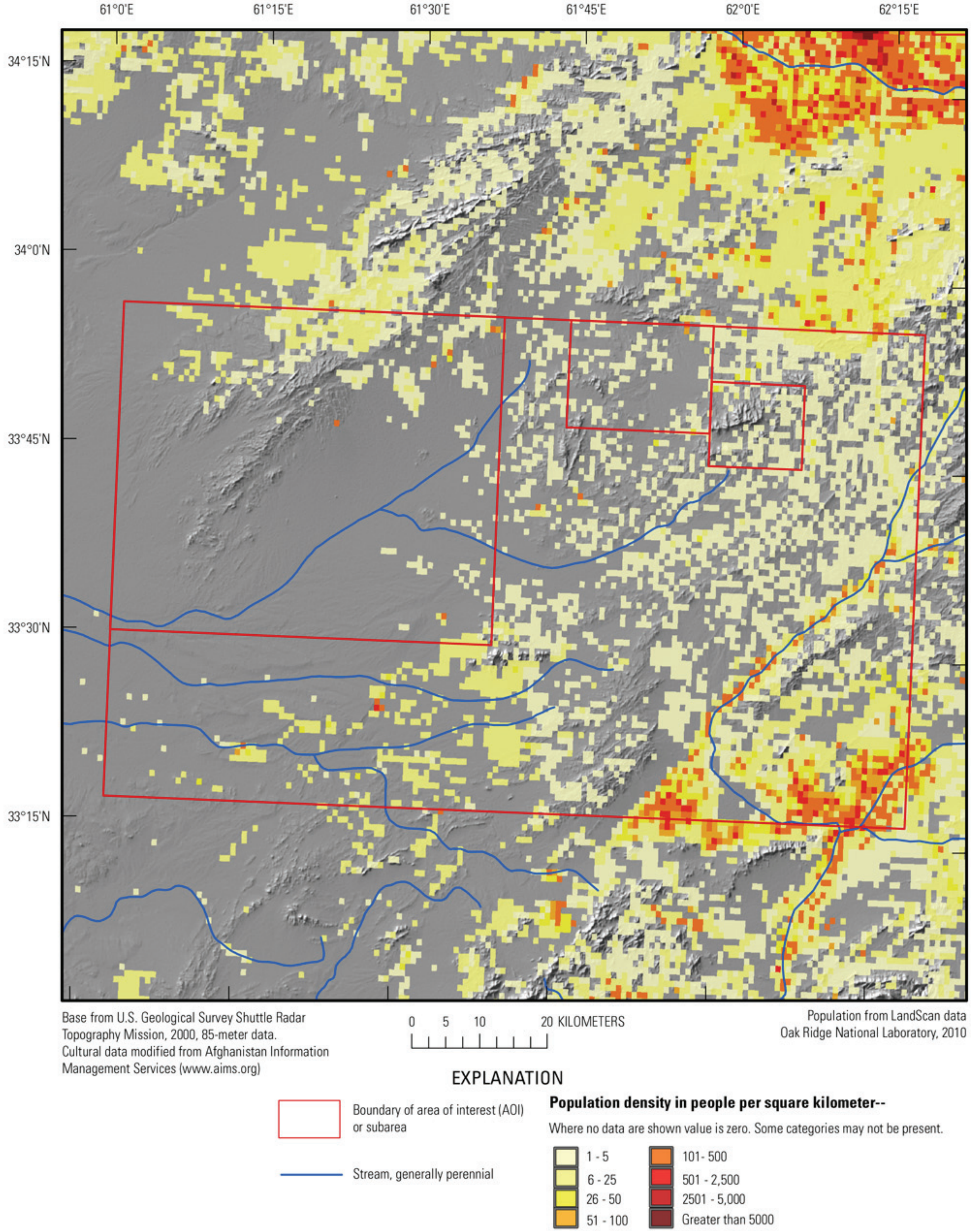

Figure 6C–4. Population density of the Dusar-Shaida copper and tin area of interest and surrounding areas in western Afghanistan.

6C.1.3 Topography and Geomorphology

The Dusar-Shaida copper and tin AOI is characterized by low, hilly topography, with land-surface elevations generally less than 1,000 m asl in the Kaj Rod River basin (fig. 6C–5). The Kaj Rod River is a tributary to the Farah Rod River, whose basin is in the southwest corner of the AOI (fig. 6C–

2). Northeast of the Kaj Rod River basin, elevations approach 2,000 m asl along ridges in the Dahana-Misgaran subarea. The longer ridges and valleys are oriented northeast-southwest (Bohannon, 2005*a* and 2005*b*; Davis, 2006).

Figure 6C–5. Photograph of the headwaters area of the Kaj Rod drainage system in the Dusar-Shaida copper and tin area of interest in western Afghanistan (August 2010).

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 Dusar-Shaida copper and tin AOI is in the Lower Helmand and Regestan artesian basins of the Southern Afghanistan Artesian Region. 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 6C–6 with the underlying topography to allow examination of the geohydrology in the context of relief. Figures 6C–7*a* and *b* shows the generalized geohydrology without topography for a clearer depiction of the geohydrologic units. Wells present in the map area (discussed in the Groundwater section) are shown in figures 6C–7*a* and *b*. 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 “river-channel sediments; sands, undifferentiated; conglomerate sediments and rocks; limestones and dolostones; sedimentary rocks; and intrusive rocks and lavas” (figs. 6C–6 and 6C–7*a*). The limestones and dolostones, sedimentary rocks, and intrusive rocks and lavas geohydrologic groups form the topographic highs (Bohannon and Lindsay, 2005). These outcrops may be aquifers of limited extent, especially where the permeability of these rocks is enhanced by fractures. 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 Bohannon and Lindsay (2005) and Williams (2005).

6C.2 Geohydrology

The primary water resource of the AOI generally is groundwater in areas where sands and gravels and semiconsolidated conglomerates that are more than 100 m thick form aquifers. Such aquifers are likely to be present in low-lying areas of the large drainage basins in the AOI; in the smaller basins, these aquifers may be limited in extent and thickness. Villagers in the Kaftar VMS subarea who were interviewed during the field assessment in August 2010 indicated that saline groundwater was present near the land surface. The presence of saline groundwater was also noted in the AGS prospecting report (Tarasenko and others, 1972), and saline groundwater is likely to be present in other areas of the AOI. Where shallow wells (less than 20 m deep) were installed 5 km north of the AOI, about one third of the wells were found to be dry or inoperative (Danish Committee for Aid to Afghan Refugees (DACAAR), 2011). Lineament analysis appeared to be useful for identifying upland areas where limited amounts of groundwater may be stored or transmitted in bedrock aquifers. Particularly in topographically high areas of the watersheds, however, bedrock aquifers may have only limited potential for use as a water supply for relatively small villages. In general, available groundwater is likely to be limited to the large basins. Close management of the use of this resource likely will be needed in order to continue to meet existing water needs.

6C.2.1 Surface Water

A network of major streams, mostly perennial streams, modified from AIMS (Afghanistan Information Management Services, 1997) and VMAP1 (National Imagery and Mapping Agency, 1995), in the Dusar-Shaida copper and tin AOI is shown in figure 6C–2. A network representing likely ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 6C–2. Names of major streams and identification numbers for any streamgages and ungaged streamflow estimation sites in the AOI are shown in figure 6C–1*b*. Surface water in nearly all of the AOI flows west. These drainage basins are part of the Farah Rod basin, which is located adjacent to, or south of, the Hari Rod drainage basin (figs. 6C–1*a*,*b* and 6C–2). The Shaida and Dahana-Misgaran subareas are located on a drainage divide; consequently, the northern areas drain northward to the Hari Rod River basin. With the exception of the southwestern areas of the AOI, little or no streamflow is likely to be available for other than subsistence needs except during the spring months (April and May). Available streamflow in the northern areas of the AOI, which are located on a drainage divide, is also likely to be extremely limited, and groundwater resources may be equally limited.

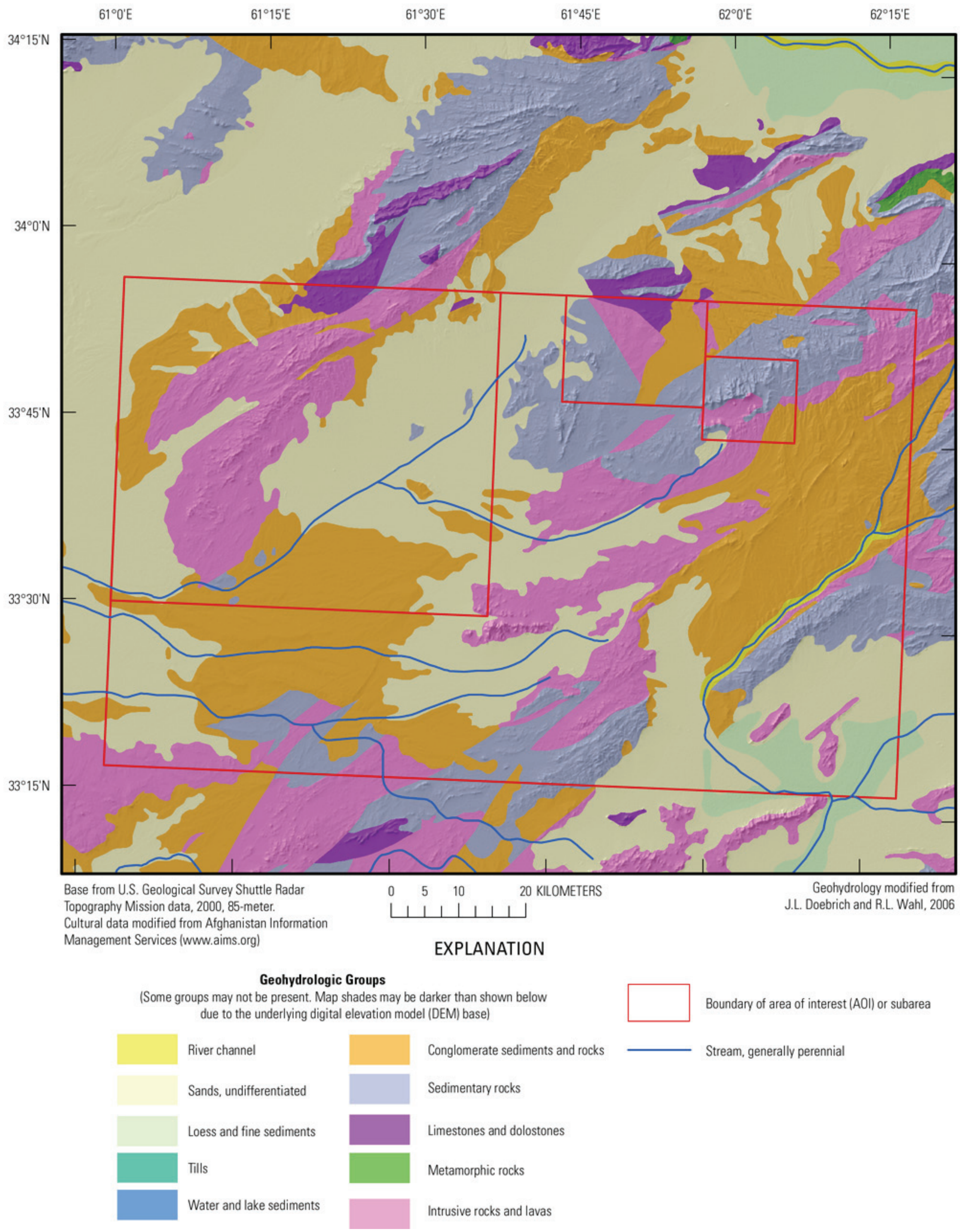

Figure 6C–6. Topography and generalized geohydrology in the Dusar-Shaida copper and tin area of interest in western Afghanistan.

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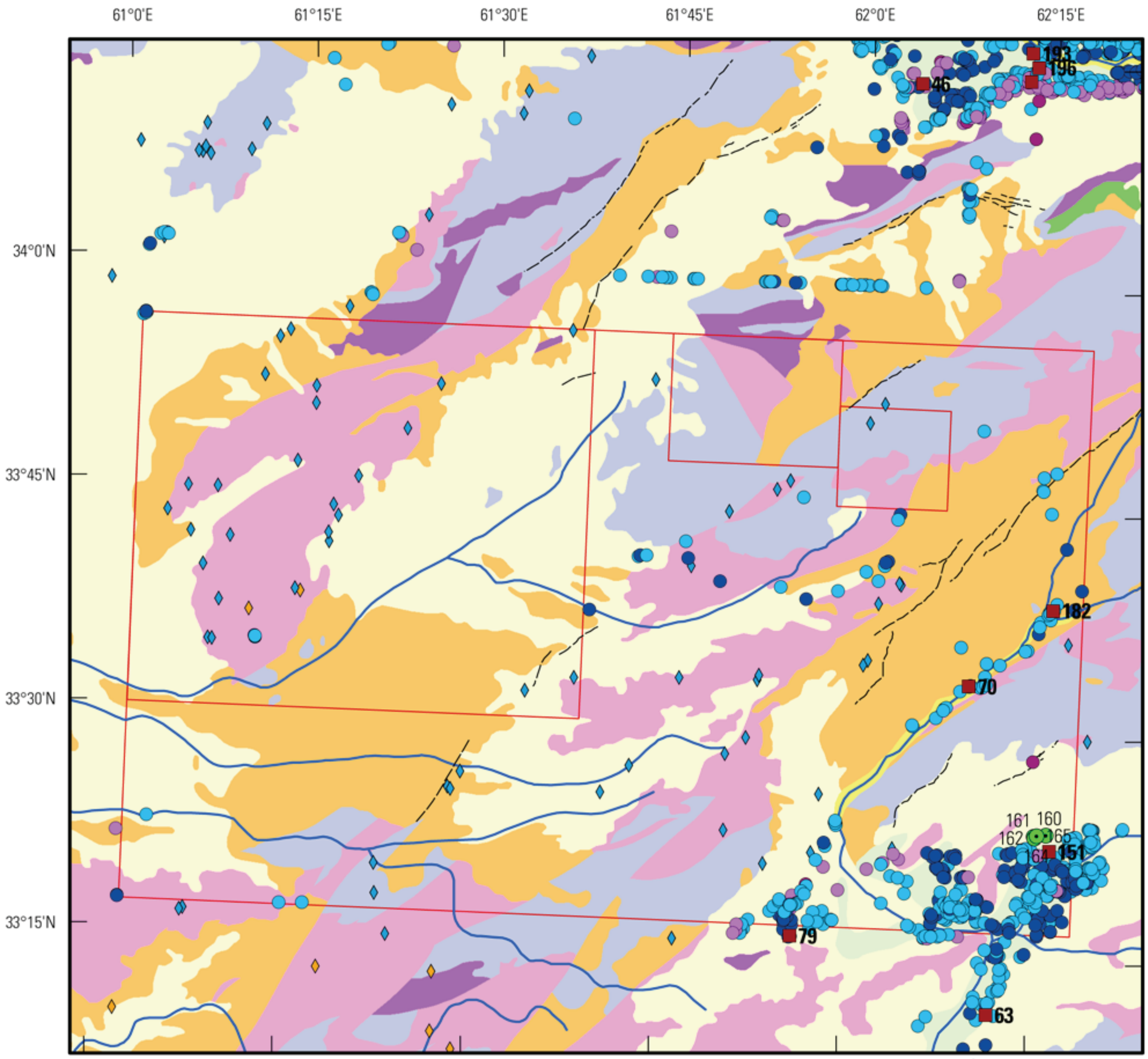


Cultural data modified from Afghanistan Information Management Services (www.aims.org)

0 5 10 20 KILOMETERS

Geohydrology modified from J.L. Doebrich and R.L. Wahl, 2006

EXPLANATION

Boundary of area of interest (AOI) or subarea

Stream, generally perennial

Fault (Ruleman and others, 2007)

Geohydrologic Groups

(Some groups may not be present)

- River channel
- Sands, undifferentiated
- Loess and fine sediments
- Tills
- Water and lake sediments
- Conglomerate sediments and rocks
- Sedimentary rocks
- Limestones and dolostones
- Metamorphic rocks
- Intrusive rocks and lavas

Well (Wells or some types of wells may not be present)

- Supply well and identifier
- Monitoring well and identifier -- From Danish Committee for Aid to Afghan Refugees (DACAAR), 2011

Community-supply well -- From DACAAR, 2011. Static depth to water below ground surface in meters

- Less than 5
- 5 to less than 15
- 15 to less than 30
- 30 or greater

Well and water quality -- From VMAP1 (National Imagery and Mapping Agency,1995)

- Freshwater or potable
- Alkaline

b

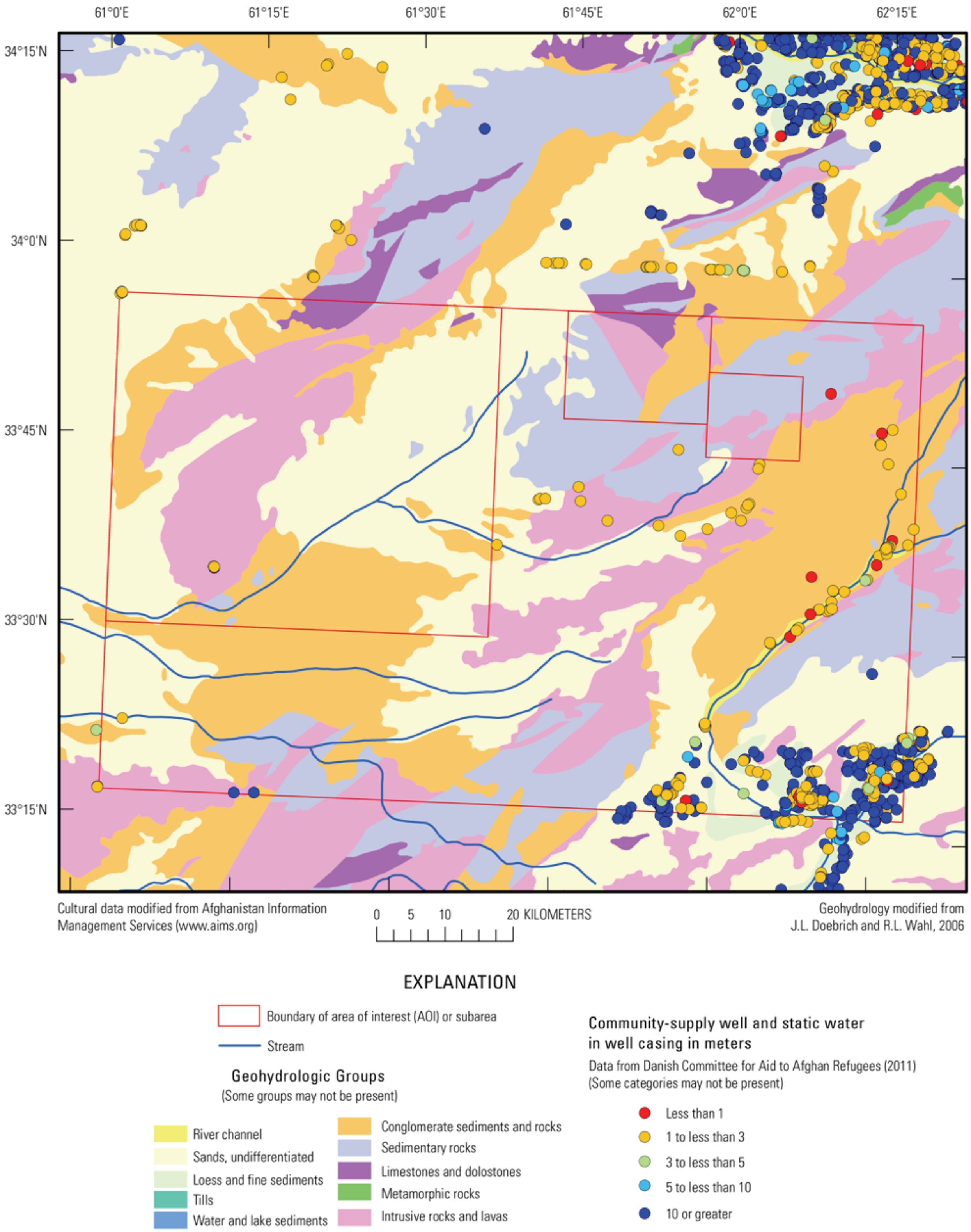


Figure 6C–7. (*a*) Generalized geohydrology, mapped faults, well locations, and depth to water, and (*b*) geohydrology and height of static water in well casings in community-supply wells in the Dusar-Shaida copper and tin area of interest in western Afghanistan.

The two rivers in the eastern area of the AOI, the Rud-i-Gaz River near Adraskan (Afghan identification number 7–5.R00–1–A) and the Adraskan River at Adraskan (Afghan identification number 7–0.000–7M), are the largest rivers in the AOI (fig. 6C–2). The Rud-i-Gaz River is a tributary to the Adraskan River, and both are part of the larger Farah Rod drainage system. The Adraskan and Rud-i-Gaz Rivers drain 1,970 and 2,180 km^2, respectively; flow southwest; and, as determined from historical streamgage data, have historical mean streamflows of 6.5 and 5.5 m^3/s (cubic meters per second), respectively. The mean annual streamflow per unit area for these stations is 0.003 and 0.002 $m^3/s/km^2$, respectively. A statistical summary of monthly and annual mean streamflows for the Adraskan River at Adraskan streamgage station (Williams-Sether, 2008) is presented in table 6C–2. A statistical summary of monthly and annual mean streamflows for the Rud-i-Gaz River near Adraskan streamgage station (Williams-Sether, 2008) is shown in table 6C–3. Statistical summaries of streamflow data for all available historical gages in Afghanistan can be accessed at *http://afghanistan.cr.usgs.gov/water.php*.

As a result of its location at a regional topographic divide, the Shaida subarea has essentially no potential for surface-water flow. The photograph in figure 6C–5 includes the topographic divide, about 6 to 7 km distant (south) in this view, between the northward-draining drainage system in the foreground and the headwaters area of the Kaj Rod drainage system to the south.

Streamflow statistics were estimated for selected ungaged streams that may be prominent in the AOI or subareas to provide some probable estimates of flow for these locations. Streamflow statistics, presented in appendix 2, were calculated for points S19 and S20 (figs. 6C-1*b* and 6C-2) using a drainage-area-ratio method (Olson and Mack, 2011) based on historical streamflows at the Adraskan and Rud-i-Gaz Rivers streamgage stations (Afghan identification numbers 7–0.000–7M and 7–5.R00–1–A, respectively) (Williams-Sether, 2008). These streamgage stations were selected as the most representative historical gages, based on drainage-basin size and location in Afghanistan, for use with this method at this location. Streamflows were estimated for point S20 (app. 2) at the northward-draining channel just north of the Shaida subarea. This small, ephemeral drainage (218 km^2 at point S20) flows north from the Shaida subarea. The point S20 was selected immediately outside (north of) the Shaida subarea to include a larger drainage area than would be possible from within the subarea. With a drainage area of 218 km^2, however, the stream has a marginal estimated mean annual flow (0.5–0.6 m^3/s), and flow estimates for S20 should be used with caution.

The Kaj Rod River, on the western side of the AOI, flows southwest and drains the Dusar Kaftar VMS subarea. Streamflows were estimated for point S19 (fig. 6C–2; app. 2), with a drainage area of 2,900 km^2, using a drainage-area-ratio method (Olson and Mack, 2011). As determined from historical streamgage data for the Adraskan and Rud-i-Gaz Rivers, mean annual streamflows were estimated to be about 9.9 and 7.5 m^3/s, respectively. The Dahana-Misgaran subarea is at the headwaters of the Kaj Rod River (figs. 6C–1*b* and 6C–2), or at the divide between the Kaj Rod River drainage area in the Farah Rod basin and the drainages to the Hari Rud basin (which includes the Herat area).

VMAP1 data (National Imagery and Mapping Agency, 1995) indicate that several springs are present in the AOI (fig. 6C–2); however, it is not known whether these springs are still active. Alkaline water has been reported in some wells in the AOI, but there is no indication of alkaline springs (National Imagery and Mapping Agency, 1995). Evidence of karezes (hand-dug water tunnels) was observed during the August 2010 reconnaissance flights near communities in the AOI. Unmapped springs and karezes probably are present in the AOI; protection of these features will help ensure that local communities can continue to depend on them as water sources.

Table 6C–2. Statistical summary of monthly and annual mean streamflows for the Adraskan River at Adraskan streamgage station.
[m^3/s, cubic meters per second]

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	1.77	1970	0.149	1964	0.79	0.50	0.64	1.02
November	4.50	1978	0.703	1972	1.69	1.00	0.59	2.19
December	19.3	1969	0.415	1964	2.79	4.62	1.66	3.61
January	10.7	1969	1.02	1971	3.03	2.65	0.87	3.93
February	19.5	1972	1.57	1971	7.66	5.24	0.68	9.93
March	40.8	1972	2.46	1971	17.9	10.4	0.58	23.2
April	57.1	1976	3.85	1963	23.4	17.6	0.75	30.4
May	34.4	1967	2.80	1970	13.4	9.40	0.70	17.4
June	10.9	1976	0.715	1970	3.98	3.00	0.75	5.17
July	3.52	1972	0.306	1970	1.35	0.93	0.69	1.75
August	2.04	1976	0.010	1971	0.58	0.53	0.92	0.75
September	1.37	1976	0.010	1971	0.56	0.42	0.75	0.72
Annual	**13.0**	**1972**	**1.89**	**1971**	**6.53**	**3.60**	**0.55**	**100**

Table 6C–3. Statistical summary of monthly and annual mean streamflows for the Rud-i-Gaz River near Adraskan streamgage station.
[m^3/s, cubic meters per second]

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	1.10	1977	0.062	1972	0.51	0.33	0.66	0.77
November	2.48	1978	0.209	1971	0.96	0.62	0.65	1.46
December	11.9	1969	0.410	1965	1.74	2.84	1.63	2.65
January	6.68	1969	0.602	1964	2.07	1.51	0.73	3.15
February	8.14	1969	1.04	1971	4.51	2.42	0.54	6.86
March	39.9	1972	1.75	1967	19.3	13.4	0.70	29.3
April	76.7	1976	6.45	1971	24.2	18.7	0.77	36.9
May	25.6	1976	1.29	1971	9.10	8.14	0.89	13.8
June	4.80	1967	0.232	1971	1.78	1.53	0.86	2.70
July	1.93	1976	0.075	1971	0.75	0.58	0.77	1.14
August	1.16	1976	0	1970, 1971	0.39	0.35	0.90	0.59
September	1.05	1976	0	1971	0.40	0.34	0.85	0.61
Annual	**13.2**	**1976**	**1.05**	**1971**	**5.47**	**3.31**	**0.61**	**100**

6C.2.2 Groundwater

Few data are available from which quantify the extent of the groundwater resource in the Dusar-Shaida copper and tin AOI. Groundwater is present in thick, unconsolidated to semi-consolidated sediments that include conglomerate sediments and rock, sand, silt, and gravel (figs. 6C–6 and 6C–7). The water may be near the land surface adjacent to ephemeral streams. In other areas and at higher elevations in the AOI, the depth to water may be tens of meters. Information provided by DACAAR (Danish Committee for Aid to Afghan Refugees, 2011) indicates that the depth to water in supply wells drilled by NGOs in the AOI is typically less than 15 m. Most wells in the AOI are dug or driven wells that are open only to several meters below the water table. Few deep wells (greater than 30 m) are known to have been drilled in the AOI and surrounding area. Several 80-m-deep supply wells were installed in one area of Shindand (fig. 6C–7*a*, numbers 160–165). Little information about the wells is available, but the static water levels were about 20 m below ground surface and the specific conductance of the water was about 70 µS/cm (microsiemens per centimeter at 25°C).

Three groundwater-monitoring wells (GWMs) are operated by DACAAR within the AOI. GWMs 70 and 162 are near the Adraskan River, and GWM 151 is near Shindand (fig. 6C–7). DACAAR water-level and specific-conductance hydrographs are provided in appendix 3 (Danish Committee for Aid to Afghan Refugees, 2011). GWMs 63 and 79 are located just south of the AOI. The hydrograph for GWM 70 indicates a declining trend in which water levels have decreased several meters (from about 9 to 11 m below ground surface) over the past 5 years (2005–10). Specific conductance for GWM 70 appears to have been stable at about 650 µS/cm over the past 4 years (2005–2009). The record for GWM 162 is unclear and therefore was not analyzed. The hydrograph for DACAAR GWM 151 indicates a depth to water of about 10 m and an apparent decline in water levels of 1 to 2 m in the past 4 years. The specific conductance of the water in this well increased slightly, from 550 to about 600 µS/cm, during this period. GWMs 63 and 79, just outside the AOI, show similar trends—that is, water-level declines of several meters and increases in specific conductance. The specific conductance of the water in GWMs 63 and 79 was about 7,000 and more than 2,000 µS/cm, respectively, indicating that the concentration of dissolved ions in the groundwater is elevated, which is a concern if the groundwater is used as a source of drinking water.

VMAP1 data (National Imagery and Mapping Agency, 1995) indicate that water wells in most areas of the AOI contain potable (fresh) water (fig. 6C–7); however, groundwater is alkaline in western areas of the AOI and in areas just south of the AOI. The source of VMAP1 groundwater-quality data is unknown, but the data were collected sometime from the 1970s to 1995.

No flow was observed in any of the stream channels during field reconnaissance of the subareas (fig. 6C–1*a*,*b*) in August 2010; however, the presence of green vegetation in some streambeds (fig. 6C–3) indicates that groundwater may be near the land surface. The basins in the AOI (fig. 6C–6) are filled with conglomerates which, when sufficiently thick, may store considerable groundwater supplies. Village elders interviewed in the Shaida subarea on 7 August, 2010, indicated that they had recently had a well drilled for their village (background in figure 6C–3) and that the water was saline at the water table and fresh 30 m beneath the land surface. The AGS prospecting report (Tarasenko and others, 1972) also indicated the presence of saline groundwater (Russian text translation provided by Alex Chaihorsky, U.S. Task Force for Business and Stability Operations). Yields of wells in coarse-grained lenses of conglomerate rocks and sediments in the basins of the AOI may be high. However, the aquifer system probably receives little recharge, even during the winter and spring months, and the presence of saline groundwater indicates that close management of withdrawals would be needed in order to prevent the creation of adverse conditions.

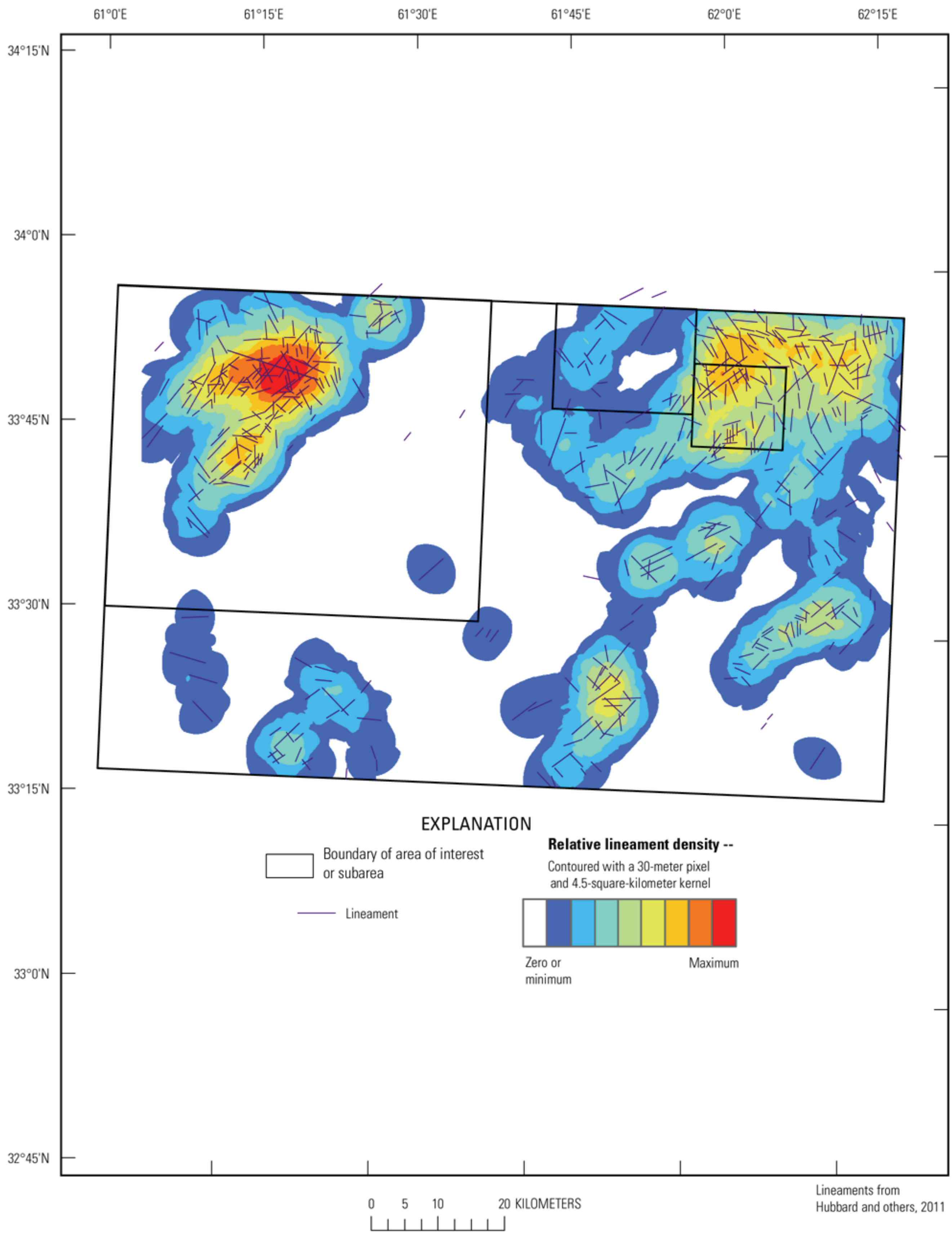


Figure 6C–8. Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the Dusar-Shaida copper and tin area of interest in western Afghanistan.

6C.2.3 Lineament Analyses

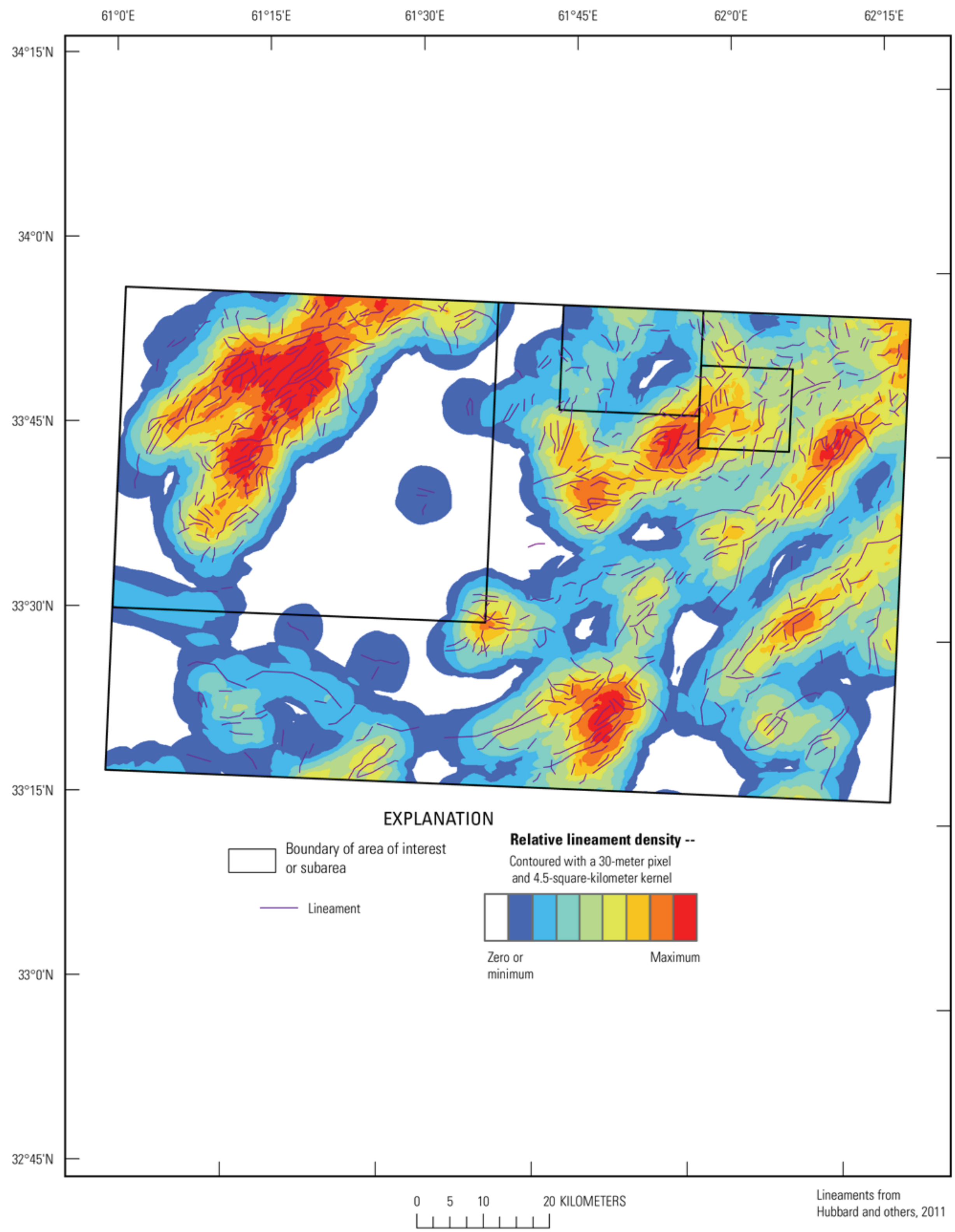
Lineaments are photolinear features that could be the result of underlying zones of high-angle bedrock fractures, fracture zones, faults, or bedding-plane weaknesses. Lineament analyses of the Dusar-Shaida copper and tin AOI were conducted using DEM and natural-color satellite imagery (fig. 6C–8) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 6C–9*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 6C–8 were delineated visually, whereas those in figure 6C–9 were delineated on the basis of multispectral characteristics of the land surface by using an automated process (B.E. Hubbard, T.J. Mack, and A.L. Thompson, U.S. Geological Survey August 24, 2011, written commun.). Because the bedrock outcrops trend northeast-southwest, with basin fill between the ridges, the lineament-density pattern follows a similar trend. Water wells in bedrock aquifers generally are most productive where boreholes are located in areas of highly fractured bedrock. Areas where lineament density is high (figs. 6C–8, 6C-9*a*, and 6C–9*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.

Many of the lineaments shown in figures 6C–8 and 6C–9 were observed during low-altitude field reconnaissance flights over the region. These features are important in that they may indicate zones of relatively greater well yields and greater storage in the bedrock aquifer that may provide water for limited use, such as local drinking water. A lineament observed from the ground during field reconnaissance (fig. 6C–10) was identified in ASTER lineament analysis (fig. 6C–9*a*,*b*), but its scale was too small for the DEM analysis (fig. 6C–8). The predominant fracture pattern in the bedrock underlying this lineament strikes north-south, roughly parallel to the lineament, which supports the premise that this feature is fracture-controlled. It is possible that this lineament represents a potential bedrock fracture zone that may transmit groundwater to the area of the village that can be seen in the distance in figure 6C–3.

6C.3 Summary and Conclusions

Little surface water is present in the Dusar-Shaida copper and tin area of interest (AOI) in western Afghanistan, with the exception of the Adraskan River in the eastern area of the AOI. Groundwater is present either in limited quantities in shallow alluvial aquifers or in larger quantities in deeper alluvial or conglomerate sediments and rock aquifers in the larger basins. Limited seasonal recharge to the shallow aquifers probably occurs during winter and spring months, and the capacity of the shallow aquifers to supply large quantities of water likely is low. Much of the AOI, particularly the northern and western areas, is in headwaters drainage areas. It is likely that withdrawals from deep aquifers would be relatively old water with a long residence time and may contain high concentrations of dissolved solids. The quality of the water in both shallow and deep aquifers is of concern as a result of reports of saline conditions in and just south of the AOI.

a


61°0'E
61°15'E
61°30'E
61°45'E
62°0'E
62°15'E
34°15'N
34°0'N
33°45'N
33°30'N
33°15'N
33°0'N
32°45'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 5 10 20 KILOMETERS
Lineaments from Hubbard and others, 2011

b

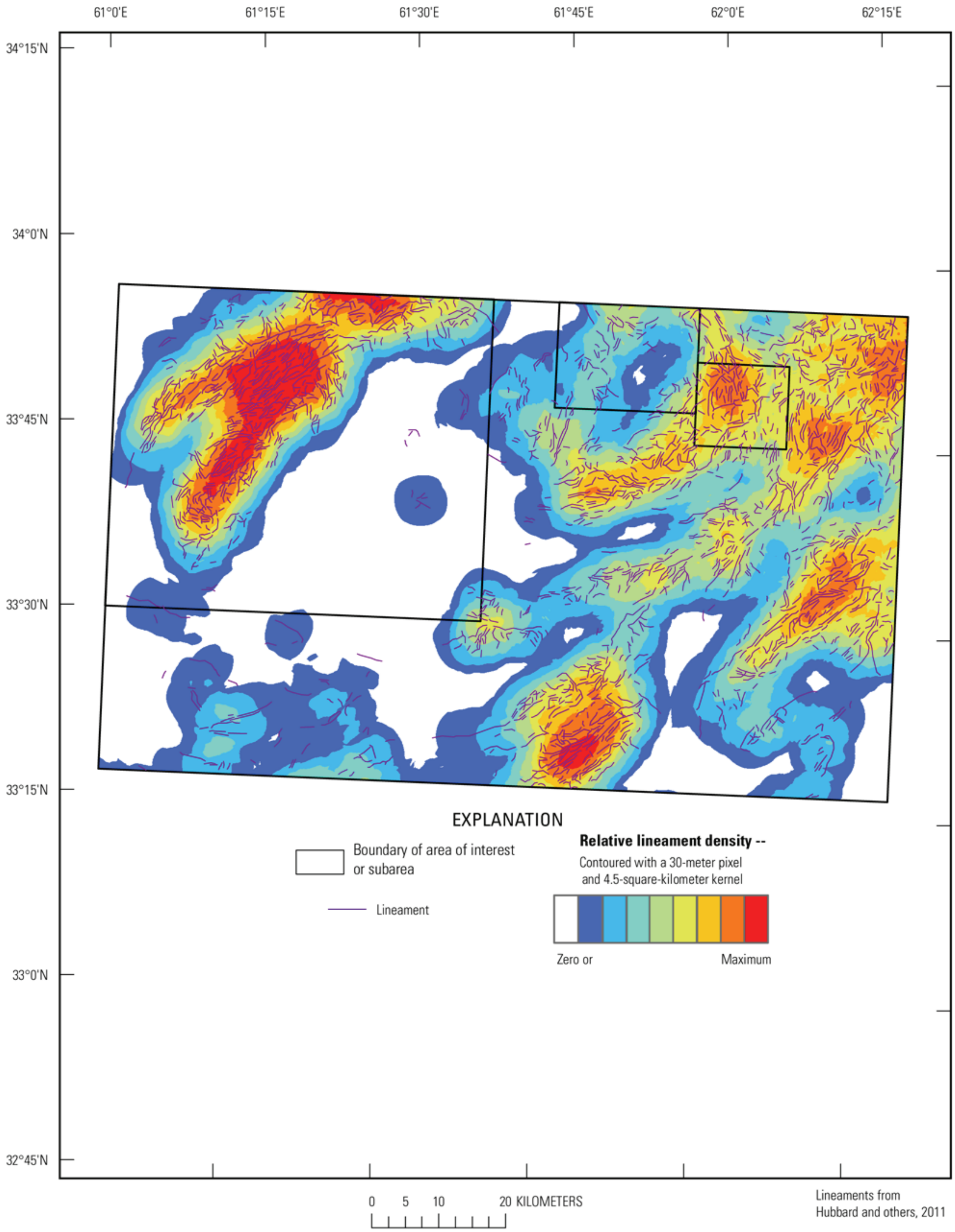


Figure 6C–9. (*a*) Lineaments and lineament density based on 30-meter multispectral Landsat imagery in the Dusar-Shaida copper and tin area of interest and (*b*) lineaments and lineament density based on 15-meter multispectral Landsat imagery in the Dusar-Shaida copper and tin area of interest in western Afghanistan.

Figure 6C–10. Photograph showing a north-south-trending lineament observed from the ground in the Dusar-Shaida copper and tin area of interest, Shaida subarea, in western Afghanistan (August 2010).

Some areas of the AOI, as indicated by generalized geohydrologic maps and lineament analyses, are likely areas for further exploration for groundwater resources. The quality and sustainability of water resources in the AOI remain to be determined, however. Careful evaluation and 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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