Chapter 18A. Summary of the Bakhud Fluorite Area of Interest

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Abstract

This chapter summarizes and interprets the results from the study of the Bakhud fluorite area of interest (AOI) and its subareas from joint geologic and compilation activities conducted from 2009 to 2011 by the U.S. Geological Survey, the U.S. Department of Defense Task Force for Business and Stability Operations, and the Afghanistan Geological Survey. Accompanying complementary chapters 18B and 18C address hyperspectral data and geohydrologic assessments respectively of the Bakhud fluorite AOI. Additionally, supporting data and other information for this chapter are available from the Ministry of Mines in Kabul.

The Bakhud fluorite AOI is located in south-central Afghanistan on the southeastern margin of the Helmand block where it is intersected by the southwest-to-northeast trending Tirin-Arghandab interfluve. Due to its location on the margin of an accretionary zone, the Bakhud fluorite AOI consists of diverse terranes and of highly imbricated rocks of mixed ages. A variety of mineral occurrences are identified in the AOI, which include chalcopyrite, barite, galena, sphalerite, tennantite, and fluorite. The fluorite deposits generally occur near continental rifts and fracture zones within major faults systems that facilitated circulation of mineralized fluids. Accordingly, the setting of the AOI is especially favorable for the deposition of fluorite, which is considered to be the most economically promising commodity in the AOI. The fluorite deposit models that are the most relevant to the Bakhud fluorite AOI are fluorite vein deposits and stratabound fluorite systems. In addition, several hybrid models or occurrence types may apply to the fluorite deposits in the region, making quantitative assessment of the fluorite deposits incomplete. Because of these complications, this assessment deals only with the main cluster of fluorite occurrences in Uruzgan and Kandahar Provinces.

18A.1 Introduction

The Bakhud fluorite area of interest (AOI) is a rectangular expanse of mountainous and semi-mountainous terrane covering 3,637 square kilometers (km^2). The AOI overlaps Uruzgan Province to the north and Kandahar Province to the south. Figure 18A–1 shows the perimeter of the AOI on a map of generalized lithological ages at a scale of 1:8,000,000; the insert map represents the AOI at a nominal scale of 1:1,500,000. The 1:2,000,000 scale map in figure 18A–2 expands the insert in figure 18A–1 and reveals the location of the AOI in the context of the major tectonic features of the region. An inspection of figure 18A–2 reveals that the Bakhud fluorite AOI is located on the southeast margin of the Helmand block and is bordered on the southeast by the southwest-to-northeast trending Tirin–Arghandab accretionary zone.

18A.2 Fluorite

18A.2.1 Age of Fluorite Mineralization

As discussed in chapter 16A of this report, the highly fractured mix of Precambrian, Paleozoic, Mesozoic, and Tertiary rocks was accreted on the trailing margin of the Helmand block during the later stages of the Cimmeride orogeny (Sengor, 1990). Subsequent to the emplacement of the Helmand block, tectonic activity resumed as India drifted north from Gondwanaland, colliding with the Afghan block at its southern margin during the Cretaceous to the early Tertiary. Geologic evidence or this event is the

Kandahar volcanic rocks and geothermal systems during the Cretaceous to early Tertiary (Debon and others, 1987).

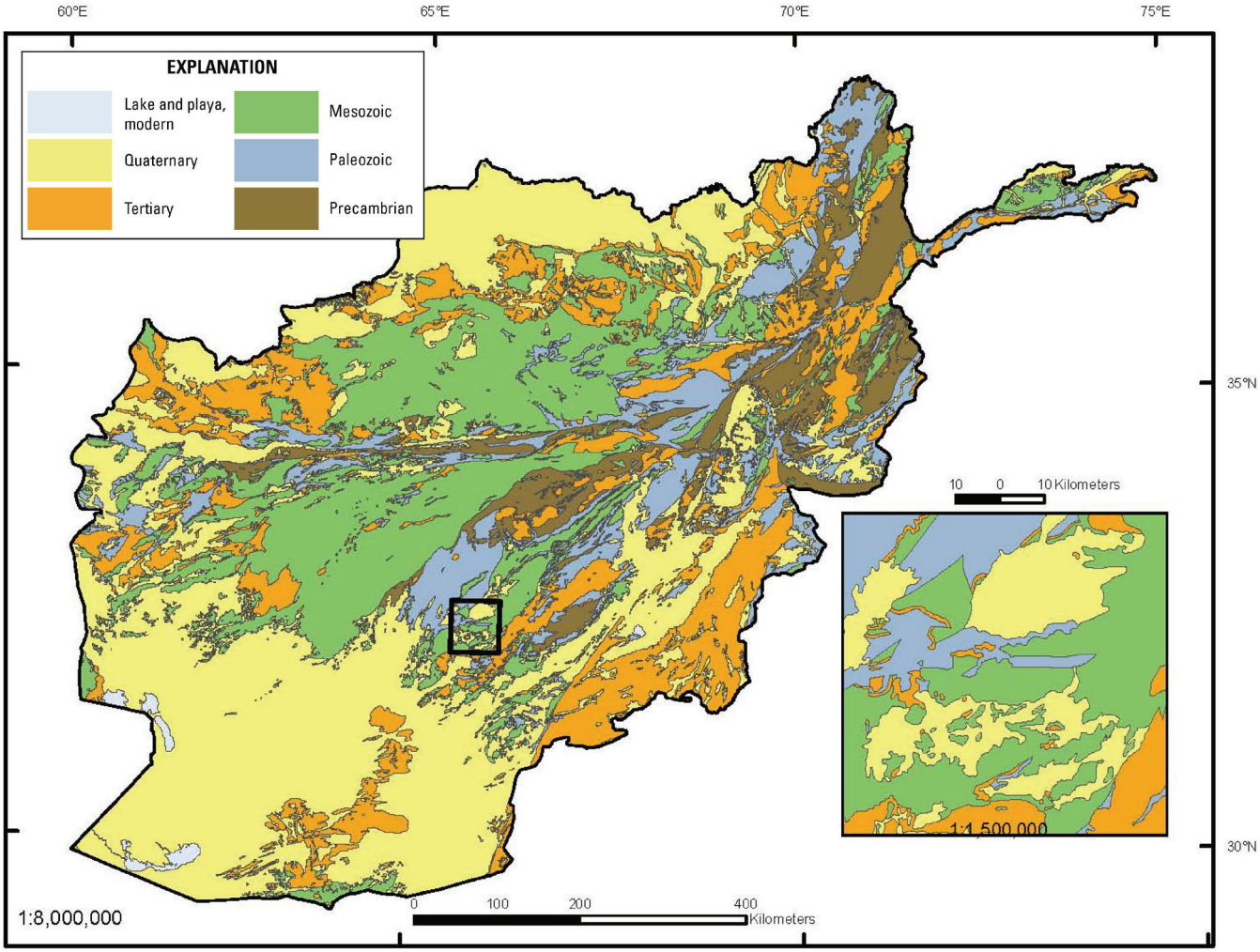

Figure 18A–1. Location of the Bakhud fluorite area of interest. Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Doebrich and Wahl (2006).

Eurasian continental margins were intruded by subduction-related, I-type granitoids along the southern and eastern margins of the Helmand block and in the Kabul block. Consequently, the Bakhud fluorite AOI on the margin of the Tirin–Arghandab Zone and the Helmand block is highly prospective for a number of different mineralization styles. A variety of mineral occurrences have been identified in the AOI, including chalcopyrite, barite, galena, sphalerite, tennantite, and fluorite (Orris and Bliss, 2002). Based on the currently available evidence, fluorite is considered to be the most economically promising commodity in the AOI. This assessment deals only with the main cluster of fluorite occurrences in Uruzgan and Kandahar Provinces (Debon and others, 1987).

18A.2.2 Fluorite Deposit Models

Fluorite forms in a number of geological environments, including fissure veins in igneous, metamorphic, and sedimentary rocks, as stratabound replacement deposits in carbonate rocks, as stockworks and fillings, and as deposits at the margins of carbonatite and alkalic rock complexes. Fluorite can be associated with galena, sphalerite, barite, quartz, and calcite. Fluorite is a common hydrothermal mineral deposit that could be a primary mineral in granites and other igneous rocks, and is

a common minor constituent of dolostone and limestone. The fluorite deposit models that are the most relevant to the Bakhud fluorite AOI are fluorite vein deposits and stratabound fluorite systems (Orris and Bliss, 1992). Because of the extensive paleotectonic history of south-central Afghanistan, however, several hybrid models may apply to the fluorite deposits in this region. In particular, fluorite vein deposits in the region are typically associated with faults where the deposits often form a part of the gangue and are associated with silica, calcite, other carbonate minerals, as well as metallic minerals, such as iron, lead, and zinc sulfide. The fluorite content of minable parts of the veins usually ranges between 25 and 80 percent.

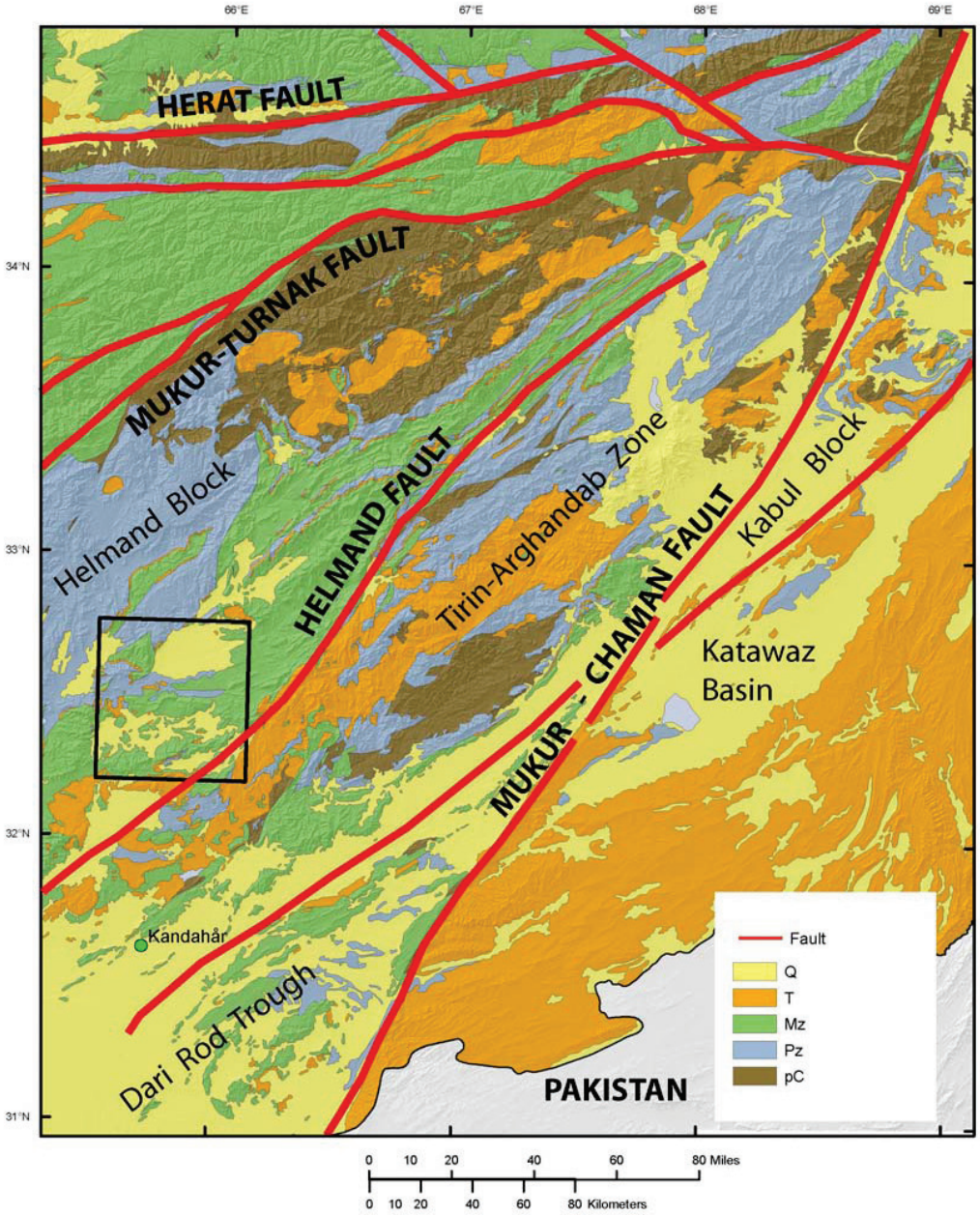

Figure 18A–2. Location of the Bakhud fluorite area of interest with significant tectonic features of the region. Map by U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis; geotectonic data from United Nations Economic and Social Commission for Asia and the Pacific (1995, p.13); base maps from Doebrich and Wahl (2006).

Stratabound, manto, or bedded fluorite deposits are also common in carbonate rocks. Host beds are replaced along or adjacent to faults and fluorite veins. Sandstone, shale, or clay commonly cap an unconformity. Bedded deposits commonly exhibit banded features, and massive crystalline ore may occur. Minerals typically associated with bedded fluorite deposits are quartz, galena, sphalerite, pyrite, marcasite, barite, and celestite. Fluorite content of minable bedded deposits ranges from 15 percent upward.

18A.2.3 Exploration History

At the Bakhud deposit, extensive trenching, sampling, and drilling were most likely used by Dovgal and others (1971) for the estimation of resources. Geochemical sampling and analysis showed that the central parts of the tract contain lead geochemical halo anomalies.

18A.2.4 Quantitative Assessment

No quantitative assessment was attempted by the assessment team due to lack of an applicable deposit model and insufficient data on the regional and local geologic settings. Data on the host rocks and subsurface rocks need to be improved by geologic mapping and geophysical surveys.

18A.2.5 Geology and Permissive Tract Delineation

Fluorite is precipitated from fluids by cooling low-pH solutions. Because fluorite deposits generally occur near structures that facilitated circulation of mineralized fluids, a significant part of the Bakhud fluorite AOI is highly permissive for fluorite deposits by virtue of the geologic setting of the AOI. The permissive tract for fluorite vein deposits[1] and stratabound deposits (Peters and others, 2007) is shown in figures 18A–3**Error! Reference source not found.**[2] and 18A–4. The outline of the tract was drawn to include known fluorite-bearing occurrences, geologic units proximal to the occurrences shown in figure 18A–4 as map units TJ1sls, J23ls, T21d, and T3cnld (Doebrich and Wahl, 2006; Sweeney and others, 2006; Peters and others, 2007), and the aeromagnetic pattern across the AOI (Sweeney and others, 2006). The permissive tract extends from the settlement of Chura, north of Tirin Kowt (the seat of government in Uruzgan Province) to a zone south of the Bakhud and Nesh districts in northern Kandahar Province.

18A.2.6 Deposits and Prospects

The Bakhud fluorite deposit consists of a number of tabular zones dipping 5 to 20 ^{degrees} and located at the base of an angular unconformity between Upper Triassic dolomitic limestone of the Arghasu Formation and Upper Triassic to Lower Jurassic clay-marl strata of the Arghasu Formation. Four discontinuous mineralized zones occur in the north, south, east, and west, which are 80 to 860 meters (m) long, 10 to 200 m wide, and 1.1 to 2.8 m thick. Alteration consists of recrystallized dolomite with silicification in limestone in the basal Alamghar Formation. The deposit consists of abundant calcareous fluorite associated with lead and zinc sulfide minerals and less abundant siliceous fluorite.

The calcareous fluorite occurrences make up 60 to 70 volume percent (vol. %) of the ore and typically grade 30 to 65 percent fluorite, 0.5 to 1.0 zinc, and 0.2 to 0.4 lead (Abdullah and others, 1977). Galena contains 100 grams per metric ton (g/t) silver and 2,000 g/t antimony with associated tennantite. Fluorite is colorless, pale to dark violet, or almost black. Accessory minerals are sphalerite, galena, chalcopyrite, tennantite, and molybdenite. Gangue minerals are pyrite, barite, ankerite, dolomite, and silica. Supergene accessory minerals are common and include the less abundant irregular siliceous fluorite occurrences that are restricted to the flat contacts with the underlying Alamghar Formation. Four mineral occurrences, which are 150 to 420-m long, are restricted mainly to the southern zone. The siliceous fluorite occurrences grade about 30 percent fluorite. Resources at the Bakhud fluorite deposit are 8,791,900 metric tons, averaging about 47 vol. % fluorite (Avtonomov and Palvanov, 1976;

[1]This tract is identified as tract fluor01 (Peters and others, 2007).
[2]Note that the pre-2009, the border dividing Uruzgan and Kandahar in figure.

Avtonomov and others, 1976). Examples of the Bakhud style of carbonate-hosted fluorite vein deposit include the Chura, Anaghey, Saraw, and Ganighay occurrences, as well as prospects in southern Uruzgan Province and the Surkhbed prospect in northern Kandahar Province.

18A.2.6.1 Chura Fluorite

The deposit is hosted in Triassic limestone inliers in Quaternary rocks in a strongly jointed zone and contains calcite and fluorite veins with pink to gray and violet fluorite (Plotnikov and Slozhenikin, 1968).

18A.2.6.2 Anaghey Fluorite

The occurrence is hosted in Triassic marble and is composed of numerous parallel fissures with calcite and translucent 10- to 15-centimeter- (cm) size fluorite nodules.

18A.2.6.3 Saraw I, II, and III

The Saraw I, II, and III deposits are hosted in faulted Upper Triassic to Lower Jurassic limestone and in Middle to Upper Jurassic sandy limestone. The mineralized zones in Saraw I are about 100 square meters (m^2) and occur along fault intersections in brecciated limestone. In addition to limestone, the occurrences contain fluorite, barite, and minor copper oxide minerals. The strongly jointed, white, greenish gray, and violet fluorite grades 35 weight percent (wt. %) fluorite, 0.2 percent copper, 8 percent lead, and 5 percent zinc. The Saraw II deposit consists of conformable zones restricted to a stratigraphic contact between Upper Triassic to Lower Jurassic limestone and Middle to Upper Jurassic sandy limestone. The deposit consists of a 270-m-long, 3-m-wide calcite zone containing fluorite lenses that are 2 by 3 m in size. The Saraw III deposit is hosted in Upper Triassic to Lower Jurassic dolomitized limestone and consists of a brecciated, mylonite zone that is 40 to 50 m long and 3 to 5 m wide. In the southwestern part, there is fracture-filled fluorite-bearing material grading 6.3 to 82.37 percent fluorite, or 0.19 to 0.29 wt. % fluorite. The southwestern part consists of fracture-filled fluorite-bearing material grading 6 to 80 percent fluorite, 0.2 to 0.3 wt. % copper, 7 to 22 wt. % lead, and 5 to 7 percent zinc (Dovgal and others, 1971).

18A.2.6.4 Ganighay Fluorite

The Ganighay fluorite occurrence follows a stratigraphic contact between Upper Triassic limestone and Middle to Upper Jurassic sandy limestone. The occurrence is a foliated vein-type that is more than 1-kilometer (km) long and 5- to 8-m wide, and consists of chalcedony and fluorite with lenses of pure fluorite that are 3- by 50-m thick in size (Dovgal and others, 1971).

The No. III area is hosted in Upper Triassic to Lower Jurassic dolomitized limestone and consists of a brecciated, mylonitized zone that is 40- to 50-m long and 3- to 5-m wide. In the southwestern part, there is fractured-filled fluorite-bearing material grading 6.3 to 82.37 percent fluorite, 0.19 to 0.29 wt. % copper, 21.75 to 5.69 wt. % lead, and 5.49 to 7.28 percent zinc (Dovgal and others, 1971).

18A.2.6.5 Surkhbed Occurrence

This occurrence is a silver-lead vein with minor amounts of fluorite, zinc, and copper that is located along the contact of Upper Triassic and Upper Triassic to Jurassic limestones.

18A.2.7 Important Data Sources

Data sources include geologic maps and mineral-occurrence databases (Abdullah and others, 1977; Doebrich and Wahl, 2006) and aeromagnetic databases and contour maps (Sweeney and others, 2006).

18A.2.8 Optimistic Factors

The Bakhud fluorite deposit contains substantial resources; additional occurrences indicate the possibility of a district-size system with additional deposits within the fluor01—Bakhud tract.

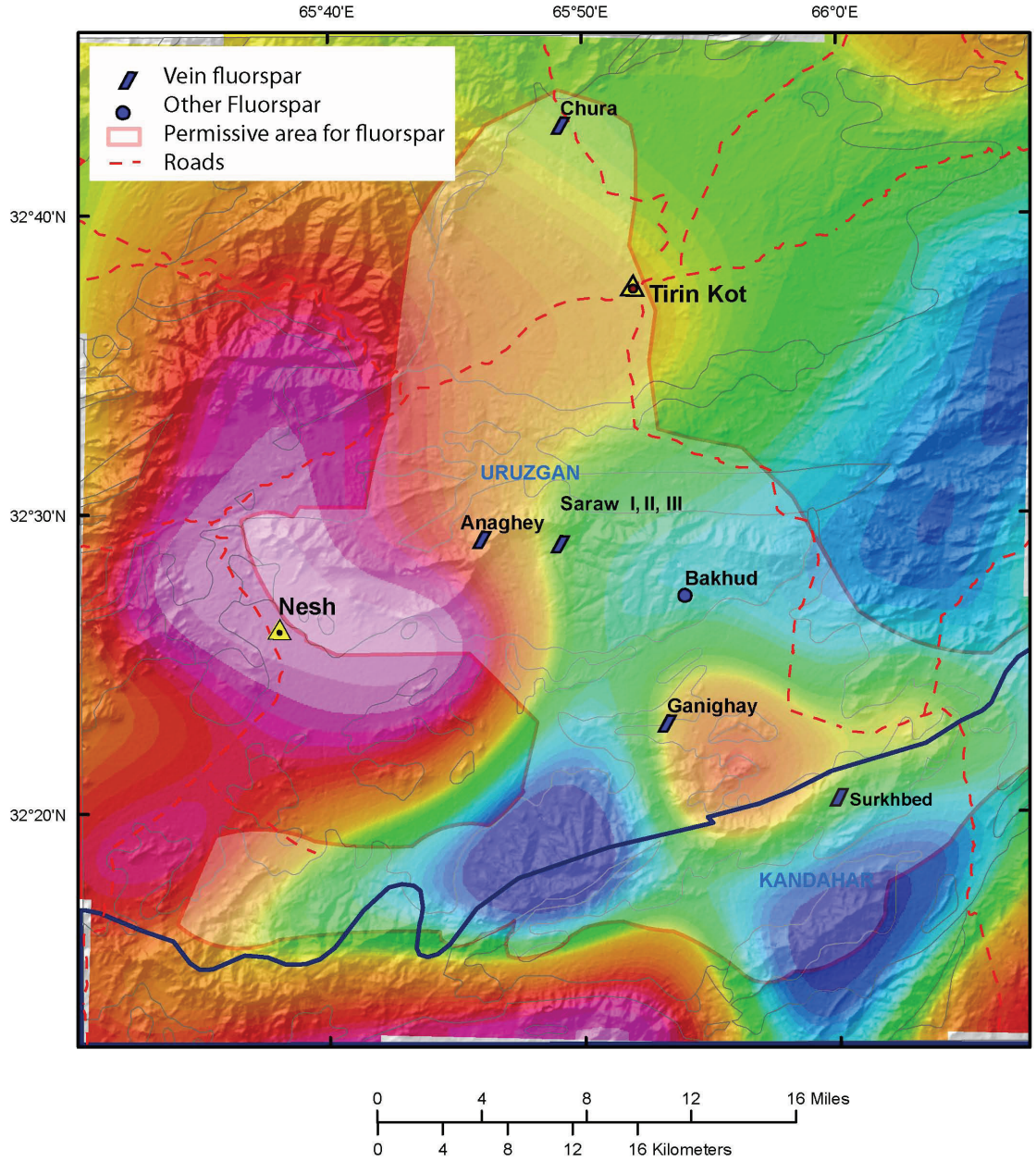

Figure 18A–3. Locations of fluorite vein deposits and other fluorite deposits (stratabound and groundmass); yellow: permissive tract for fluorite, with superimposed red, green and blue fields representing high, medium, and low aeromagnetic anomalies, respectively); dark blue line: pre-2009 Kandahar border. Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Peters and others (2007).

18A.2.9 Pessimistic Factors

Much of the mineralized zone at Bakhud and in the peripheral occurrences is irregular or spotty. The age and genesis of the fluorite is not well understood. The occurrences are not widespread and are confined to a small area in southern Uruzgan Province.

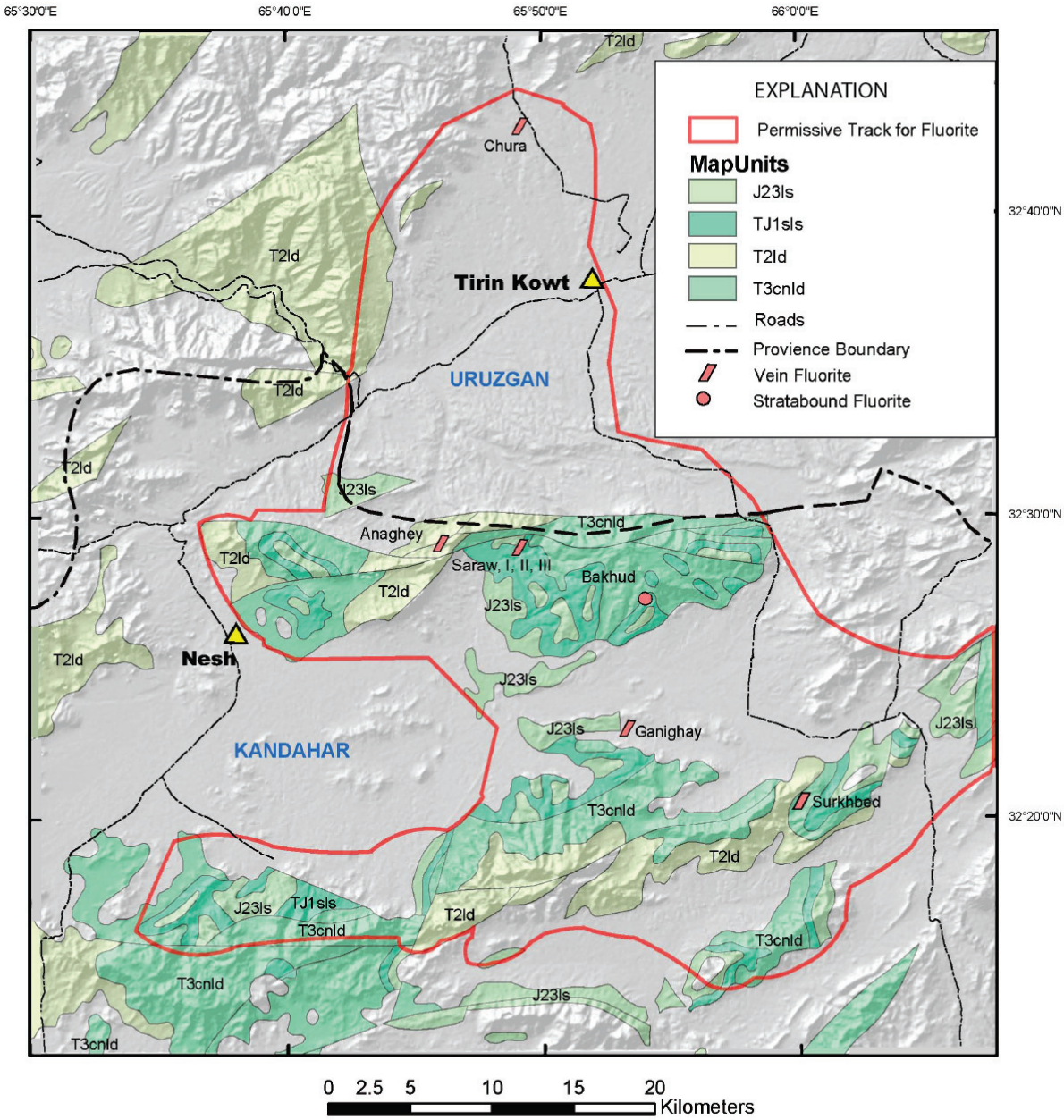

Figure 18A–4. Permissive tract for fluorite (fluor01) with locations of fluorite vein deposits and stratabound deposits, and with lithological units; the Kandahar border is drawn post-2009 (scale 1:350,000). Map from U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Digital Information and Analysis Project; base maps from Peters and others (2007).

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