4.0 Deposits related to felsic phanerocrystalline intrusive rocks

Deposits and occurrences related to felsic phanerocrystalline intrusive rocks in Afghanistan are a variety of tin and tungsten deposits and occurrences in the western and central parts of the country (section 4.1), several fluorite deposits and occurrences in southern Uruzgan Province and northern Kandahar Province (section 4.2), and numerous lithium-, beryllium-, rare-earth-, and gem-bearing pegmatite occurrences that occur in pegmatite fields in the northeast part of the country (section 4.3). Gemstones in pegmatites also are summarized in section 12.4.

4.1 Tin and tungsten deposits

Contributions by Stephen D. Ludington and Stephen G. Peters.

More than 100 mineral deposits and occurrences in Afghanistan are reported to contain tin and/or tungsten (Kabakov, 1973; Anonymous, 1976; Abdullah and Chmyriov, 1977). The most important occurrences are associated with Cretaceous to Oligocene magmatism and are located south and west of Kabul. The majority of these can be classified as tin and tungsten greisen, skarn, and vein deposits, although a few of the occurrences may indicate the presence of a tin porphyry deposit. A summary and references to the appropriate occurrence and grade and tonnage models are given in table 4.1-1.

Table 4.1-1. Median tonnage and grade for tin and tungsten occurrence models.

Deposit model	Median tonnage (Mt)	Median grade (percent)	Reference
W skarn (model 14a)	1.1	0.67 WO_3	Cox, 1986; Jones and Menzie, 1986a.
Sn skarn (model 14b)	9.4	0.31 Sn	Reed and Cox, 1986; Menzie and Reed, 1986c.
Replacement Sn (model 14c)	5.2	0.8 Sn	Reed, 1986b; Menzie and Reed, 1986a.
W veins (model 15a)	0.56	0.91 WO_3	Cox and Bagby, 1986; Jones and Menzie, 1986b.
Sn veins (model 15b)	0.24	1.3 Sn	Reed, 1986d; Menzie and Reed, 1986d.
Sn greisen (model 15c)	7.2	0.28 Sn	Reed, 1986c; Menzie and Reed, 1986b.
Porphyry Sn	---	---	Reed, 1986a; Sinclair, 1995.
Mo-W greisen	20–40	About 0.2 WO_3; about 0.1 Mo	Kotlyar and others, 1995.

Tin and tungsten skarn and replacement tin deposits are associated with epizonal and mesozonal highly fractionated granitoid rocks emplaced in carbonate terranes, either post-orogenic rocks in continental collision belts, late in the history of a continental arc, often in a back-arc setting, or in extensional environments like intracontinental rift zones. Deposits are typically formed close to the apical contacts of plutons, sometimes within batholiths, sometimes near isolated intrusions.

Vein and greisen deposits of tin and tungsten exhibit the same association with highly fractionated source granites, but do not require carbonate wall rocks. Tungsten vein deposits typically consist of several veins of quartz and wolframite (rarely scheelite).

There has been abundant speculation in the past about the possibility to exploit large, low-grade stockwork tin deposits (that is, “porphyry tin” deposits) (Sillitoe and others, 1975; Taylor, 1979), and there are deposit models as well (Reed, 1986a; Sinclair, 1995). Most such deposits are difficult to distinguish geologically from greisen deposits and are exceptional mostly for their large size. Traditional examples have been large mineralized rock bodies at Catavi, Chorolque, and Llallagua, Bolivia, and at Mount Pleasant, New Brunswick, and East Kemptville, Nova Scotia, Canada.

In addition to the deposit types listed in table 4.1-1, tin- and tungsten-bearing pegmatite bodies are scattered throughout the Pamir and Hindukush Mountains in eastern Afghanistan.

According to the U.S. Geological Survey (Shedd, 2006), tin is produced primarily in China (about 37 percent), Indonesia (about 31 percent), Peru (about 15 percent), and Bolivia (about 7 percent), whereas most tungsten production worldwide comes from China (about 85 percent) and Russia (about 6 percent).

4.1.1 Descriptive models for tin and tungsten deposits

Although there has been no modern production of tin or tungsten in Afghanistan, the variety of tin- and tungsten-bearing mineral occurrences and prospects indicates that a wide variety of deposit types is present. There may have been unrecorded production from ancient workings, and a few tin placer deposits are known in the western part of the country. Below, we summarize common descriptive models and list important recognition criteria, primarily using information from Cox and Singer (1986), Taylor (1979), and Taylor and Pollard (1986).

Tin and tungsten vein and stockwork deposits consist of quartz-cassiterite and quartz-wolframite veins that are located near epizonal highly evolved granitic intrusive rocks, most commonly in continental crust. Some prominent examples include Cornwall, England; Renison Bell, Tasmania; and Herberton, Australia (tin); and Panasqueira, Portugal; Pasto Bueno, Peru; and Xihuashan, China (tungsten). Mineralogy of tin veins is extremely varied and may include cassiterite, wolframite, arsenopyrite, molybdenite, hematite, scheelite, beryl, galena, chalcopyrite, sphalerite, stannite, and (or) bismuthinite. Many deposits show an inner zone of cassiterite ± wolframite veins, with distal veins that contain Pb-, Zn-, Cu-, and Ag-bearing sulfide minerals. Mineralogy of tungsten veins may include wolframite, molybdenite, bismuthinite, pyrite, pyrrhotite, arsenopyrite, bornite, chalcopyrite, scheelite, cassiterite, beryl, and (or) fluorite.

Alteration assemblages associated with tin veins include: sericitization (greisen) ± tourmalization adjacent to veins and granite contacts; silicification, chloritization, and hematization; an idealized zonal scheme might consist of quartz-tourmaline-topaz, quartz-tourmaline-sericite, quartz-sericite-chlorite, quartz-chlorite, and chlorite. Alteration assemblages associated with tungsten veins (innermost to outermost zones) include: 1) proximal pervasive albitization; 2) pervasive to vein-selvage pink K-feldspar replacement with minor disseminated rare-earth element (REE) minerals; 3) vein selvages of dark-gray muscovite or zinnwaldite (greisen); and 4) chloritization. Concentrations of tin- and tungsten-bearing minerals tend to occur within or above the apices of granitic cusps and ridges; localized controls include variations in vein structure, lithologic and structural changes, vein intersections, dikes, and cross-faults.

Both tin and tungsten veins are found associated with highly evolved granites, often with a type of granite termed rare-metal granites (Pollard, 1995; Štemprok, 1977). Rare metal granites have silica contents greater than 75 percent, elevated Rb/Sr (Rb often greater than 400 ppm), Y and Nb greater than 30 ppm, and are the products of extreme differentiation, and may be peraluminous, metaluminous, or peralkaline. They may be I-, S-, or A-type granites, but they are typified by uncommonly high concentrations of fluorine, lithium, and rubidium, as well as by high concentrations of some or all of the rare metals, tantalum, niobium, beryllium, zirconium, and REE.

Geochemical signatures of the deposits may include high abundances of Sn, Ag, W, Cu, Zn, As, Pb, Rb, Li, B, Mo, Bi, Be, and F. The base metals are seldom an important part of production ore. Tin- and (or) tungsten-bearing ore minerals, topaz, tourmaline, and columbite-tantalite may be found in heavy mineral concentrates. Weathering of deposits can produce placer deposits, particularly of tin.

Where carbonate wall rocks are present, skarn and replacement deposits of tin and tungsten may occur in place of vein, stockwork, or greisen deposits. Some examples are Lost River, Alaska; and Moina, Tasmania (tin), and Pine Creek, California, USA; MacTung, Yukon, Canada; and Sang Dong, Korea (tungsten). Skarns are high-temperature replacements of carbonate rocks at and closely adjacent to contacts with intrusive rock. Mineral assemblages in tin skarn may include idocrase, Mn-rich andradite-grossular garnet, malayaite, pyroxene, and fluorite. Tin is present as cassiterite or tin silicate minerals. Mineral assemblages in tungsten skarn may include diopside-hedenbergite, grossular-andradite, spessartine and (or) almandine garnet, and wollastonite. Tungsten is usually present as scheelite.

At greater distances from the source pluton, tin replacement deposits can form. Examples include Mt. Bischoff, Tasmania; and Dachang, China. Tungsten replacement deposits have not been recognized. Tin generally occurs as cassiterite or tin-bearing sulfide minerals, and is commonly accompanied by pyrrhotite, arsenopyrite, and chalcopyrite. Sideritic alteration of dolomite near the replacement bodies is common, and disseminated tourmaline may also occur.

Tungsten skarn deposits generally form within a few tens to hundreds of meters from contacts with intrusive rock. The most common ore mineral is scheelite, often accompanied by molybdenite, pyrrhotite, and small amounts of base-metal sulfides. The skarn assemblage is usually diopside-hedenbergite and grossular-andradite, sometimes accompanied by wollastonite. Curiously, while tin skarns are usually associated with rare-metal granites, tungsten skarns are most commonly associated with distinctly less-evolved calc-alkaline granodiorite and quartz monzonite. This association remains enigmatic, as tungsten-rich greisens and veins are usually associated with specialized evolved granites.

Tin porphyry deposits are characterized by fine-grained cassiterite that occurs in veinlet and fracture stockwork zones, breccia zones, and disseminated in hydrothermally altered plutonic rocks and nearby country rocks. Most of the characteristics described above for vein, stockwork, and greisen deposits apply to tin porphyry deposits, the chief difference being their size; porphyry tin deposits may contain hundreds of millions of metric tons of ore.

In the northeast part of Afghanistan, where more deeply-eroded Cretaceous and Tertiary granites associated with the collision of India and Asia are exposed, a few pegmatite deposits contain cassiterite. Pegmatite deposits are not an important source of tin.

4.1.2 Tract Descriptions

The Anar Dara (snw01) tract has been delineated to be permissive for the occurrence of tin and (or) tungsten vein and stockwork deposits. This tract is located in the far west of Afghanistan, in Herat and Farah Provinces (figs. 4.1-1 and 4.1.2). In addition, five areas of interest that could contain tin and (or) tungsten deposits are described in Herat, Ghor, Daikondy, Farah, Uruzgan, Bamyan, Wardak, Logar, Ghazni, Zabul, and Helmand Provinces.

Anar Dara tract (snw01)—This tract is delineated to encompass a number of known tin- and tungsten-bearing prospects and occurrences that are associated with Upper Cretaceous to Paleocene felsic intrusive rocks (map unit P_3grg; granite and granodiorite). The tract is permissive for vein, stockwork, greisen, and porphyry deposits of tin. In areas where carbonate rocks crop out, it is also permissive for skarn and (or) replacement deposits. Most of the deposits and prospects occur in 3 clusters, identified as Shand, Tourmaline, and Bandi-Medira areas (fig. 4.1-2).

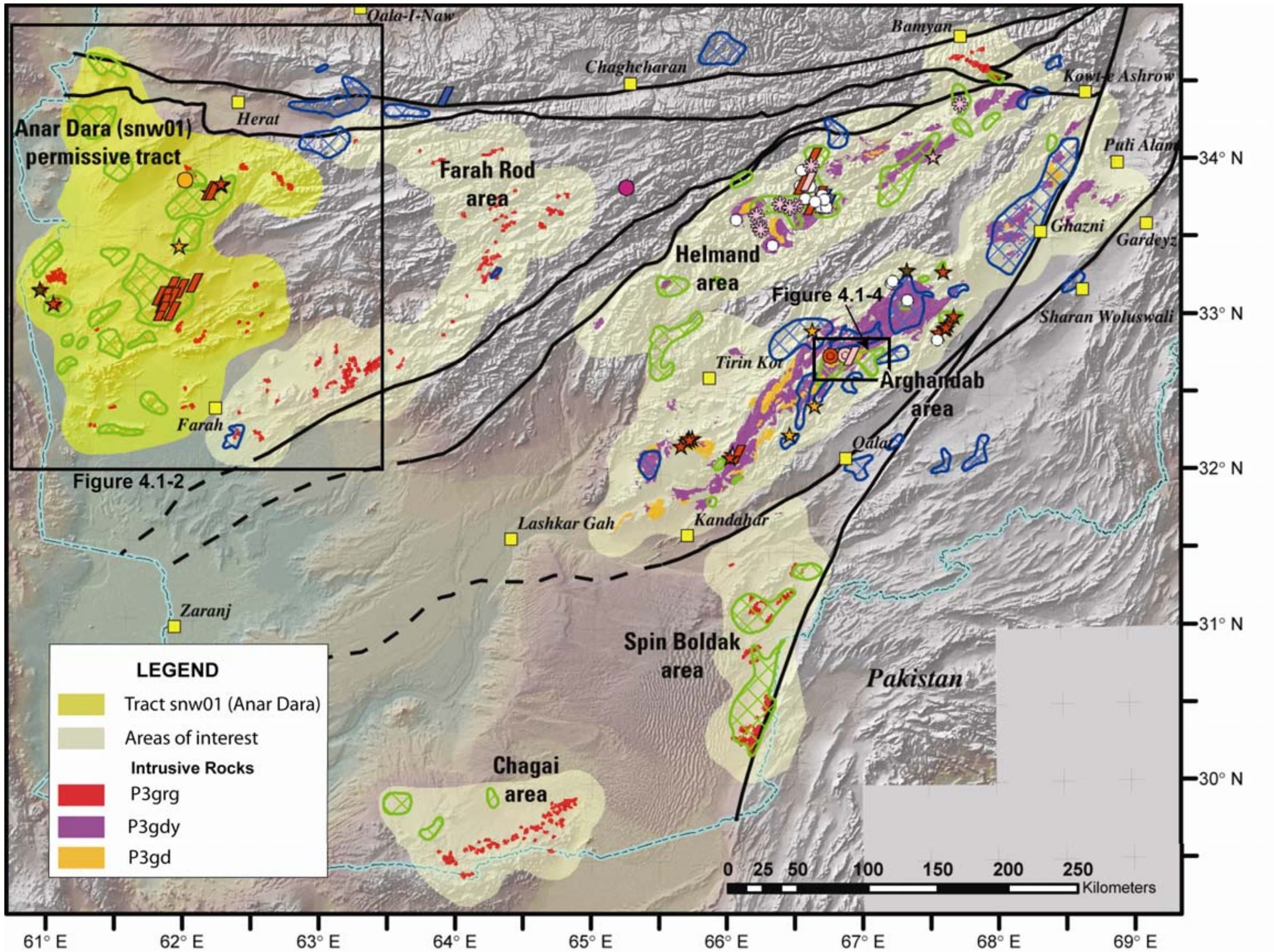

Figure 4.1-1. Map showing location of areas in Afghanistan that may contain deposits of tin and (or) tungsten. Permissive tract snw01 (Anar Dara) is delineated specifically for vein, stockwork, and porphyry deposits. Solid color polygons indicate intrusive rocks associated with tin and tungsten deposits: red – map unit P_3grg, pink-purple – map unit P_3gdy, orange – map unit P_3gd. Green crosshatch indicates tin geochemical halos; blue crosshatch indicates tungsten geochemical halos. The Farah Rod area of interest contains abundant outcrops of the same intrusive rocks that occur in the Anar Dara tract. The Helmand, Arghandab, Spin Boldak, and Chagai areas of interest contain some tin and tungsten deposits, but are delineated for porphyry copper deposits and are described in detail in that section. Symbols and map units from Doebrich and Wahl (2006).

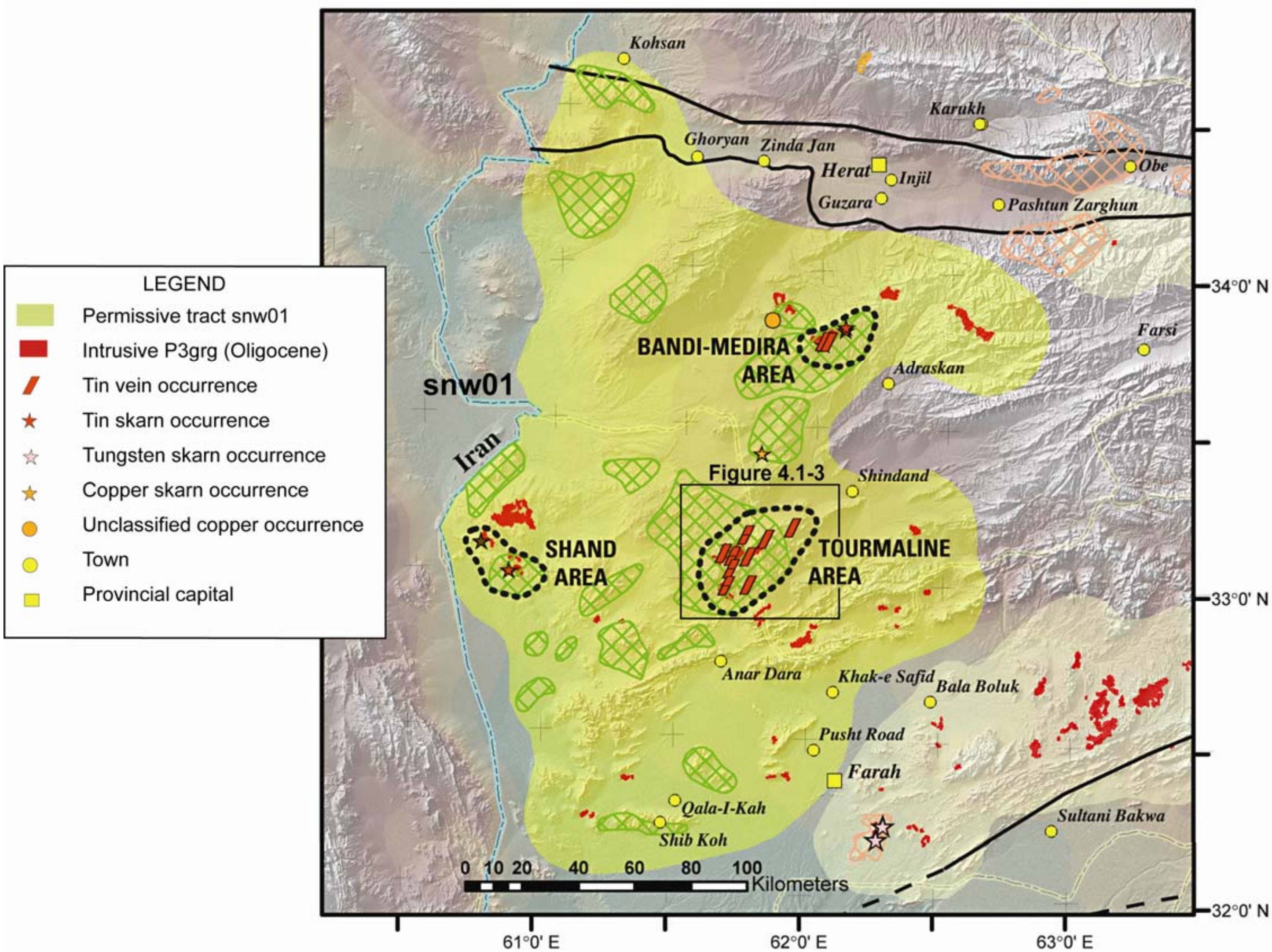

Figure 4.1-2. Map showing Anar Dara (snw01) permissive tract in west Afghanistan, showing mineral prospects and occurrences, geochemical halos, and outcrops of granitic rock. The area shaded in yellow is permissive for tin- and tungsten-bearing veins, stockworks, and porphyry deposits. Bright red polygons are outcrops of granite (map unit P_3grg). Green crosshatch indicates tin geochemical halos; salmon crosshatch indicates tungsten geochemical halos. Areas outlined in dotted line are discussed in detail in text.

Shand area (fig. 4.1-2) is a small Sn-Cu-Bi-bearing garnet-pyroxene skarn prospect on the west margin of a small (about 10 km^2) stock that intrudes Early Cretaceous limestones. There is a small Sn-bearing iron skarn prospect (Korezak) about 15 km to the northwest, in the same limestones.

In the Tourmaline area (fig. 4.1-2), tin-bearing vein and stockwork prospects surround a moderate-sized (about 60 km^2) stock that intrudes a sequence of presumably coeval volcanic rocks (fig. 4.1-3). Some of the altered and mineralized areas corresponding to these prospects are quite large, with reported dimensions of hundreds of meters. Several of the prospects yielded samples that contained from several tenths up to two percent tin (Efimenko and others, 1973). Alteration assemblages are reported to be primarily silicification and tourmalinization. A LANDSAT image of the area (fig. 4.1-3) suggests that the stock is pervasively altered to an advanced argillic assemblage. The widespread occurrence of the mineralized and altered rocks and the tin contents of samples indicate that this area could contain a large tin vein, stockwork, or porphyry deposit.

The Bandi-Medira area (fig. 4.1-2) is defined by three tin-bearing mineral prospects associated with a moderate-sized (about 50 km^2) Upper Cretaceous or Paleocene granitic stock that intrudes Early Cretaceous sandstones and siltstones that contain minor limestone beds (map unit ***K_1bevssl***) as well as presumably coeval volcanic rocks. Two vein and stockwork prospects are closely adjacent to the stock and are characterized by quartz-tourmaline alteration. An area about 3 km east of the stock is a large (about 12 km^2) area of tin-bearing polymetallic skarn alteration and mineralization with skarn beds as much as 46 m thick. Tin contents of as much as 0.11 percent, as well as copper, lead, and zinc contents of as much as 0.2, 1, and 1 percent, respectively, are reported (Abdullah and others, 1977). The thickness and widespread nature of this mineralized rock suggest that the area could contain a large skarn deposit.

The presence of three partially explored tin-bearing magmatic-hydrothermal systems and the widespread occurrence of tin geochemical halos indicate the possible presence of undiscovered tin deposits. Uncertainty about which deposit types (vein, stockwork, greisen, porphyry, skarn, and replacement) are more likely to be present prevents the making of a quantitative estimate of undiscovered deposits.

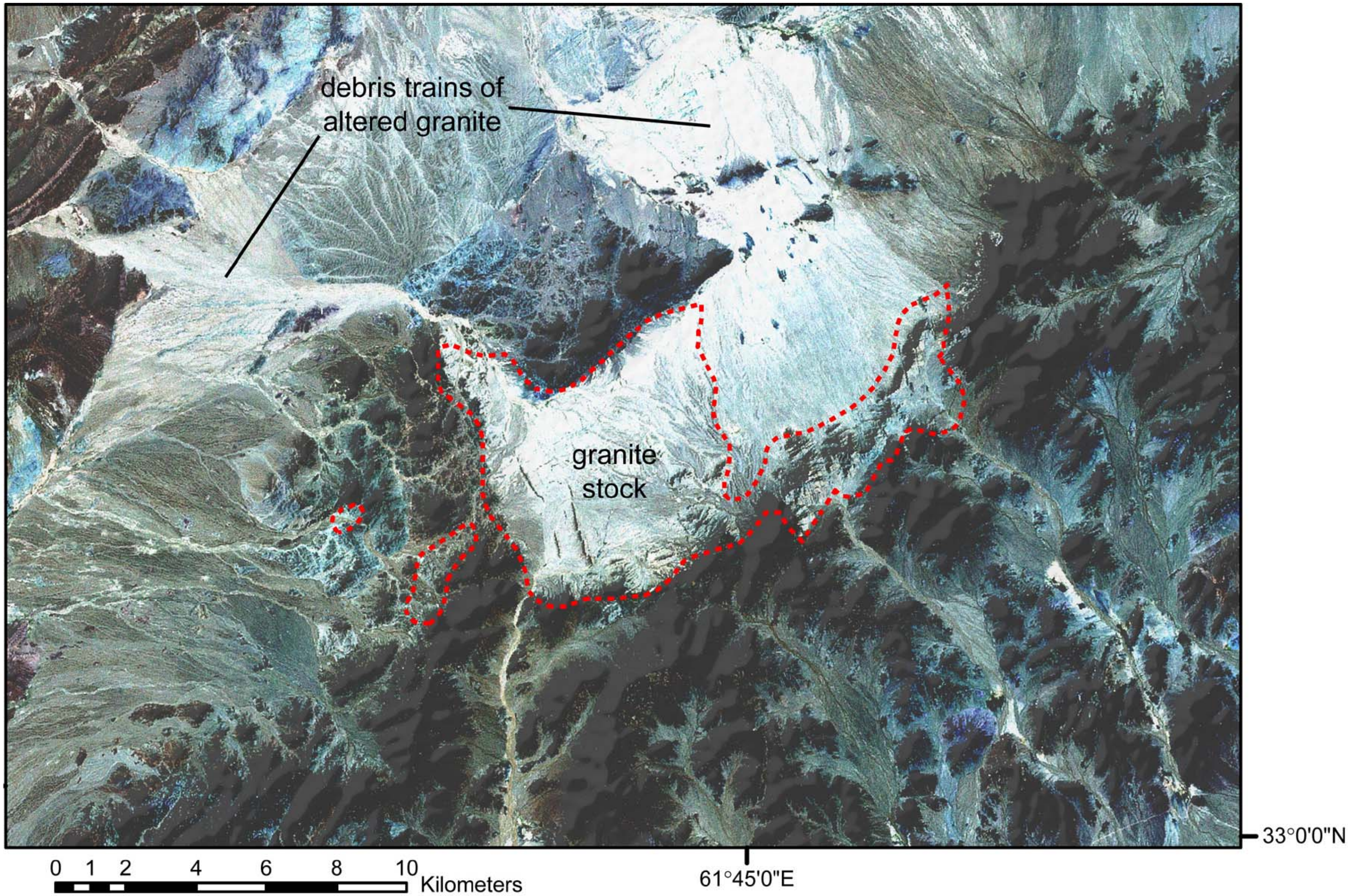

Figure 4.1-3. LANDSAT image (bands 1, 2, and 3) showing granite stock associated with Sn-bearing mineral prospects in the Tourmaline area, Afghanistan. Red dotted line outlines approximate contact of intrusive rocks.

Areas of interest

Five other areas (fig. 4.1-1) are classified as areas of interest rather than permissive tracts because the correspondence between tin- and tungsten-bearing prospects and the felsic intrusive rocks (map unit P_3grg) is not as clear as in the Anar Dara tract. In some cases, few prospects are present, but all contain outcrops of map unit P_3grg. Most of these areas also contain numerous copper- and gold-bearing prospects.

Farah Rod area*—**East of the Anar Dara tract, an area is designated that has no reported mineral prospects other than two small tungsten-bearing skarns near the southern tip, but does contain numerous stocks of the same intrusive map unit (P_3grg***) that was used to define the Anar Dara tract. These felsic subalkaline rocks were designated to be part of the same Farah Rod plutonic belt as those in the Anar Dara tract by Debon and others (1987). There are no tin geochemical halos, but three small parts of this area have tungsten geochemical halos. We have little reason to believe this area has been explored extensively and it could contain tin and (or) tungsten occurrences.

***Chagai area*—**In the southernmost part of Afghanistan, we designate an area surrounding the Chagai Hills to be of interest for tin and (or) tungsten deposits (fig. 4.1-1). We believe the area is more likely to contain porphyry copper deposits than tin deposits, but there are three tin geochemical halos on the northern flank of the hills, and it is possible that tin occurs here as well.

Spin Boldak area*—**East of the Chagai area, a northeast-trending group of intrusive rocks of map unit ***P_3grg defines the Spin Boldak area, which also contains several large tin geochemical halos (fig. 4.1-1). The rocks here are also felsic and subalkaline, probably of Paleocene age, and intrude the Kandahar complex, made up of volcanic and sedimentary rocks of Jurassic and Cretaceous age (Vachard and others, 1986). This area has also been designated as permissive for porphyry copper deposits, but, like in the Chagai area, it is possible that tin occurs here as well.

Arghandab area*—**In the central part of Afghanistan, more than 20 tin- and (or) tungsten-bearing prospects and occurrences surround or are found within rocks of the Arghandab batholith (fig. 4.1-1). The map units associated with tin and tungsten deposits in the batholith are ***P_3gd (granodiorite) and ***P_3gdy*** (granodiorite and granosyenite). These rocks are subalkaline to calc-alkaline in character, probably range in age from Upper Jurassic to as young as Oligocene (Debon and others, 1987), and form part of a large composite batholith.

Many of the prospects in this area are tungsten skarn occurrences, which are mostly small, with the exception of Kochak, where mineralized rock is found over a length of several kilometers. However, about equidistant between Gazni and Kandahar, a large (about 150 km^2) granitic pluton has five tin/tungsten mineral occurrences along its north contact (fig. 4.1-4). Most of these are reported to be vein, stockwork, or greisen deposits, and contain wolframite, scheelite, cassiterite, beryl, and columbite-tantalite (Nagaliov and others, 1971). The LANDSAT image shows a relatively large zone (about 15 km^2) along the north contact that appears to be hydrothermally altered and contains abundant weathered sulfide minerals. This area, which contains the Maydan-Ahu and Adamkhei prospects, could represent an exposed large low-grade deposit of tungsten, beryllium, and possibly other rare metals.

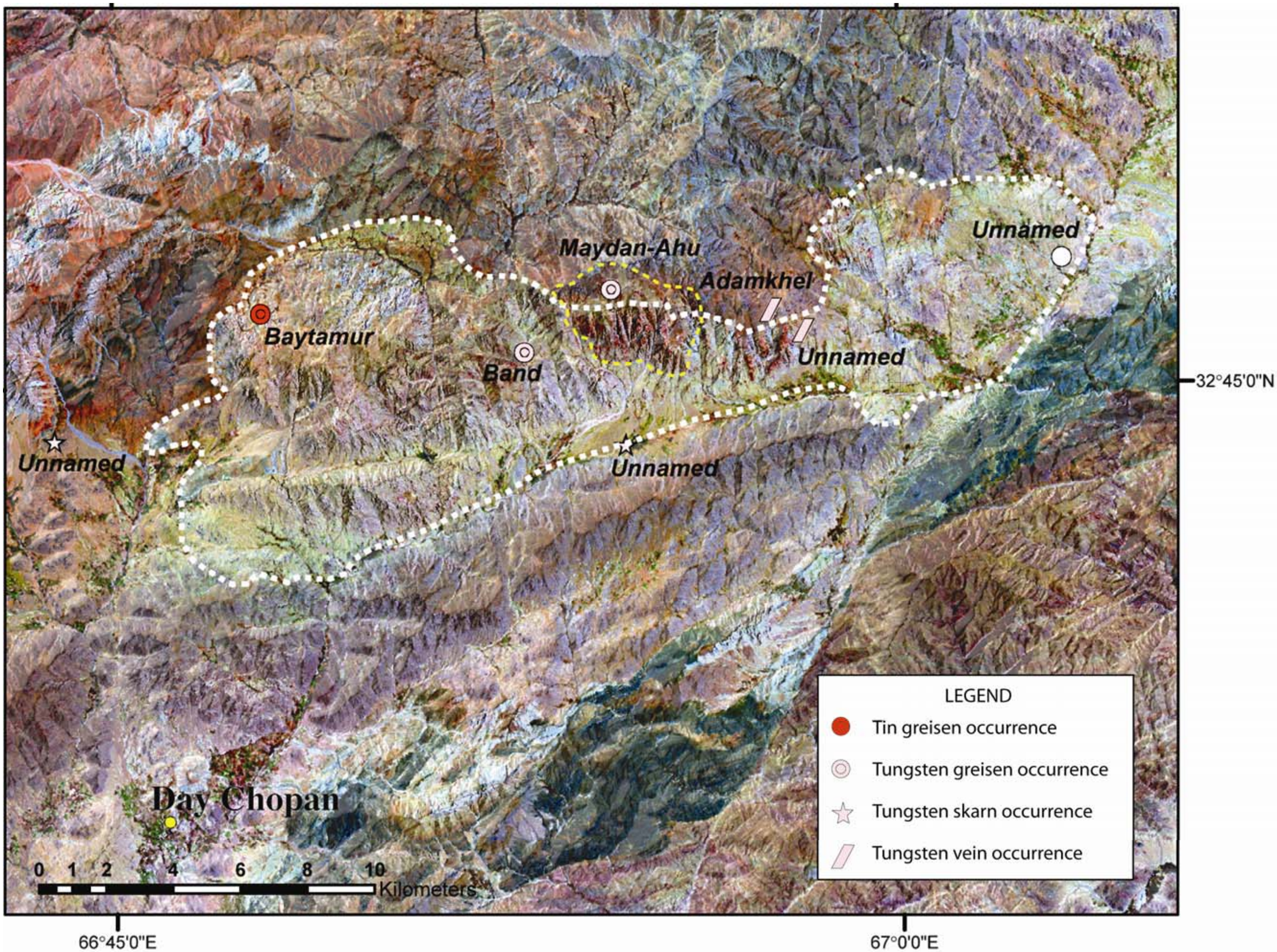

Figure 4.1-4. LANDSAT image (bands 7, 3, and 1), showing granitic pluton and the location of the Baytamur, Band, Maydan-Ahu, and Adamkhei prospects, Arghandab area of interest, Afghanistan. Heavy white dotted line outlines the pluton; lighter yellow dotted line outlines altered and mineralized area.

A group of six tin-bearing skarn deposits occurs near the Zarkashan copper skarn deposit about 100 km southwest of Ghazni (Kovalenko and others, 1971). This area (Meshcheriakov and Borozenets, 1970) is of primary interest for porphyry copper deposits, but the presence of so many stanniferous deposits suggests there may be another igneous/hydrothermal event that manifested in the same area.

With the exception of the region near Day Chopan described above, the Arghandab batholith appears generally to be too deeply eroded to host vein, stockwork, and porphyry deposits of tin and (or tungsten), although many small tungsten skarn deposits are likely to exist. With dimensions of about 400 x 40 km, it appears to be a composite batholith that has been eroded to mesozonal depths, a level below that where most porphyry and stockwork deposits are found. The area has been delineated and described in more detail in the section on porphyry copper deposits.

Helmand area—North of the Arghandab area (fig. 4.1-1), a parallel band of calc-alkaline and subalkaline plutonic rocks that was termed the Helmand plutonic belt by Debon and others (1987). These rocks form a small composite batholith that is probably also mostly Cretaceous in age (Debon and others, 1987). The map units associated with tin and tungsten deposits are $\boldsymbol{P_3gd}$ (granodiorite) and P_3gdy (granodiorite and granosyenite). In the eastern part of the region, some of the intrusive rocks are apparently Cambro-Ordovician in age (Debon and others, 1987); these rocks are not associated with tin and tungsten deposits.

One deposit stands out as worthy of some attention in this area. In the west part of the area, Nili is described as a scheelite- and wolframite-bearing greisen complex that covers as much as 18 km^2 (Starshinen and others, 1975). Other tin- and tungsten-bearing deposits in the area are small vein deposits and occurrences. Skarns are rare as the plutons intrude primarily Paleozoic and Mesozoic siliciclastic sedimentary rocks. It is noteworthy that several tin-bearing rare-metal pegmatites are found in the western part of the area, suggesting that much of the batholith has been eroded to mesozonal depths, which is deeper than most porphyry and stockwork deposits.

Pegmatite deposits—In the east part of Afghanistan, a few of the numerous rare-metal pegmatites in the Safed Khers, Wakhan, and West Nuristan plutonic belts contain cassiterite (Debon and others, 1987). There are also a few poorly known tin and (or) tungsten-bearing polymetallic occurrences in the Safed Khers belt. Tin is unlikely to be produced from pegmatite deposits, except as a byproduct. The entire area appears to be been eroded to mesozonal (or greater) depths, which is deeper than most porphyry and stockwork deposits.

Elsewhere in Afghanistan, two occurrences merit further mention. In the Western Badakhsan plutonic belt, about 150 km northwest of Kabul, the Tundara prospect is described as a molybdenite- and cassiterite-bearing greisen deposit associated with strongly altered Triassic granite. In the West Hindu Kush plutonic belt, about 120 km northwest of Kabul, a small cluster of copper skarn deposits that contain cassiterite is associated with Triassic granites.

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4.2 Sedimentary rock-hosted fluorite (fluorspar)

Contributions by Stephen D. Peters and Greta J. Orris.

There are local occurrences of fluorite in sedimentary rocks in Central Afghanistan that indicate the potential for economic deposits.

Fluorspar is the commercial name for the mineral fluorite (CaF_2). Fluorspar is used to make hydrofluoric acid (HF), an intermediate for fluorocarbons, aluminum fluoride, and synthetic cryolite. It also is used as a flux in the steel and ceramic industries, in iron foundry and ferroalloy practice, and has many other uses (Fulton and Montgomery, 1994). A few fluorite vein and carbonate-hosted fluorite occurrences are present in Afghanistan. The main cluster of deposits lies in southern Uruzgan Province and northern Kandahar Province hosted in unconformities in Triassic and Jurassic limestone sequences. Additional occurrences are present in Badakhshan Province associated with Lower Carboniferous volcanic rocks and in Baghlan Province associated with silver mineralized zones in Upper Triassic volcanic rocks. This assessment deals only with the main cluster of fluorite occurrences in Uruzgan Province.

4.2.1 Fluorite vein deposit model

The fluorite vein model (model 26b, Orris and Bliss, 1992) may be considered for some of the fluorite deposits in central Afghanistan, although a number of additional models or occurrence types are likely for fluorspar. Fluorite is present 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 deposits at the margins of carbonatite and alkalic rock complexes. Fluorite vein deposits are typically associated with faults and contain silica, calcite and other carbonate minerals including iron, lead, and zinc sulfide minerals. Replacement of the wall rock by fluorite also is common adjacent to some veins. The CaF_2 content of minable parts of the veins usually ranges between 25 and 80 percent, although grades above 90 percent are not uncommon.

Stratabound, manto, or bedded fluorite deposits are also common in carbonate rocks. Host beds are replaced along or adjacent to faults and veins of fluorite. Commonly, there is a sandstone, shale, or clay capping or an unconformity. Bedded deposits commonly have typical banded features; massive crystalline ore types also are present. Minerals typically associated with bedded fluorite deposits are quartz, galena, sphalerite, pyrite, marcasite, barite, and celestite. CaF_2 content of minable bedded deposits range from 15 percent upward.

4.2.2 Fluorite Tract Description

Permissive tract fluor01—Bakhud

Deposit types—Sedimentary rock-hosted fluorite and fluorite vein

Age of mineralization—Post Middle Jurassic

Examples of deposit type—The Bakhud carbonate-hosted fluorite deposit, Chura, Anaghey, Saraw, Ganighay, and prospects in southern Uruzgan Province and the Surkhbed prospect in northern Kandahar Province.

The Bakhud fluorite deposit consists of a number of tabular zones dipping 5° to 20° located at the base of an angular unconformity between Upper Triassic dolomitic limestone of the Arghasu Formation and Upper Triassic to Lower Jurassic clay-marly sediments of the Arghasu Formation. There are four discontinuous mineralized zones in the north, south, east, and west, which are 80 to 860 m long, 10 to 200 m wide, and 1.1 to 2.8 m thick. Alteration consists of recrystallized dolomite with silicification that is restricted to limestone in the basal Alamghar Formation. Fluorite mineralization consists of abundant calcareous fluorite associated with lead and zinc sulfide minerals and less abundant siliceous fluorite.

The calcareous fluorite occurrences constitute 60 to 70 vol. percent of the ore and typically grade 33.8 to 64.38 percent fluorite, 0.66 to 0.99 wt. percent zinc, and 0.17 to 0.34 wt. percent lead (Abdullah and others, 1977). Galena contains 100 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. The less abundant irregular siliceous fluorite occurrences are restricted to the flat contacts with the underlying Alamghar Formation. Four mineral occurrences that are 150 to 420 m long are restricted mainly to the southern zone. The siliceous fluorite occurrences grade about 31.33 percent fluorite. Resources at the Bakhud fluorite deposit are 8,791,900 t averaging 46.69 vol. percent fluorite (Avtonomov and Palvanov, 1976; Avtonomov and others, 1976).

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

The Anaghey fluorite occurrence is hosted in Triassic marble and is composed of numerous parallel fissures with calcite and semi-transparent 10– to 15–cm-size fluorite nodules.

The Saraw I, II, and III occurrences are contained in faulted Upper Triassic to Lower Jurassic limestone and in Middle to Upper Jurassic sandy limestone. The mineralized zones are nest-like, column n-like bodies in Area No. I, which is about 100 m^2 and are restricted to fault intersections in brecciated limestone containing fluorite, barite, minor copper oxide minerals, and limestone. The strongly jointed, white, greenish gray, and violet fluorite is commonly non-transparent or semi transparent and grades 35.13 percent fluorite, 0.17 wt. percent copper, and 7.76 wt. percent lead and 5.02 wt. percent zinc. The No. II area is made up of conformable zones restricted to a stratigraphic contact between Upper Triassic to Lower Jurassic limestone and Middle to Upper Jurassic sandy limestone and consists of a 270 m long 3 m wide calcite zone containing fluorite lenses that are 2 by 3 m in size. 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. percent copper, 21.75 to 5.69 wt. percent lead, and 5.49 to 7.28 percent zinc. (Dovgal and others, 1971).

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

The Surkhbed 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 limestone.

Exploration history—Exploration has taken place around the Bakhud fluorite deposit and surrounding area that has consisted of geologic mapping and sampling. At the Bakhud deposit extensive trenching, sampling, and drilling were most likely used by Dovgal and others (1971) for the estimation of resources there. Geochemical sampling has taken place, and the central parts of the tract contain lead geochemical halo anomalies.

Tract boundary criteria—Permissive tract fluor01 was constructed in the Bakhud area near the settlements of Tirin Kot and Nesh in Uruzgan Province and also in parts of northern Kandahar Province. The outline of the tract was drawn to include known fluorite-bearing occurrences in the area and also to include host geologic units proximal to the occurrences (fig. 4.2-3a) (mainly map units **TJ_1sls, $J_{23}ls$,** and

T_3cnld; Doebrich and Wahl, 2006). In addition, tract fluor01 was also drawn using aeromagnetics (fig. 4.2-2b) (Sweeney and others, 2006).

Important data sources—Geologic map and mineral occurrence data base (Abdullah and others, 1977; Doebrich and Wahl, 2006), aeromagnetic data base and contour map (Sweeney and others, 2006).

Needs to improve assessment—The distribution of the host rocks needs to be better identified, especially regionally and also under cover rocks.

Optimistic factors—The Bakhud fluorite deposit contains substantial resources and the additional occurrences indicate that there may be a district-size system with additional deposits within the fluor01—Bakhud tract.

Pessimistic factors—Much of the mineralized zone both at Bakhud and in the peripheral occurrences is irregular or "spotty". The age and genesis of the fluorite is not well understood and the occurrences are not wide spread but confined to a small area in southern Uruzgan Province.

Quantitative assessment—No quantitative assessment was attempted by the assessment team due to lack of an applicable deposit model.

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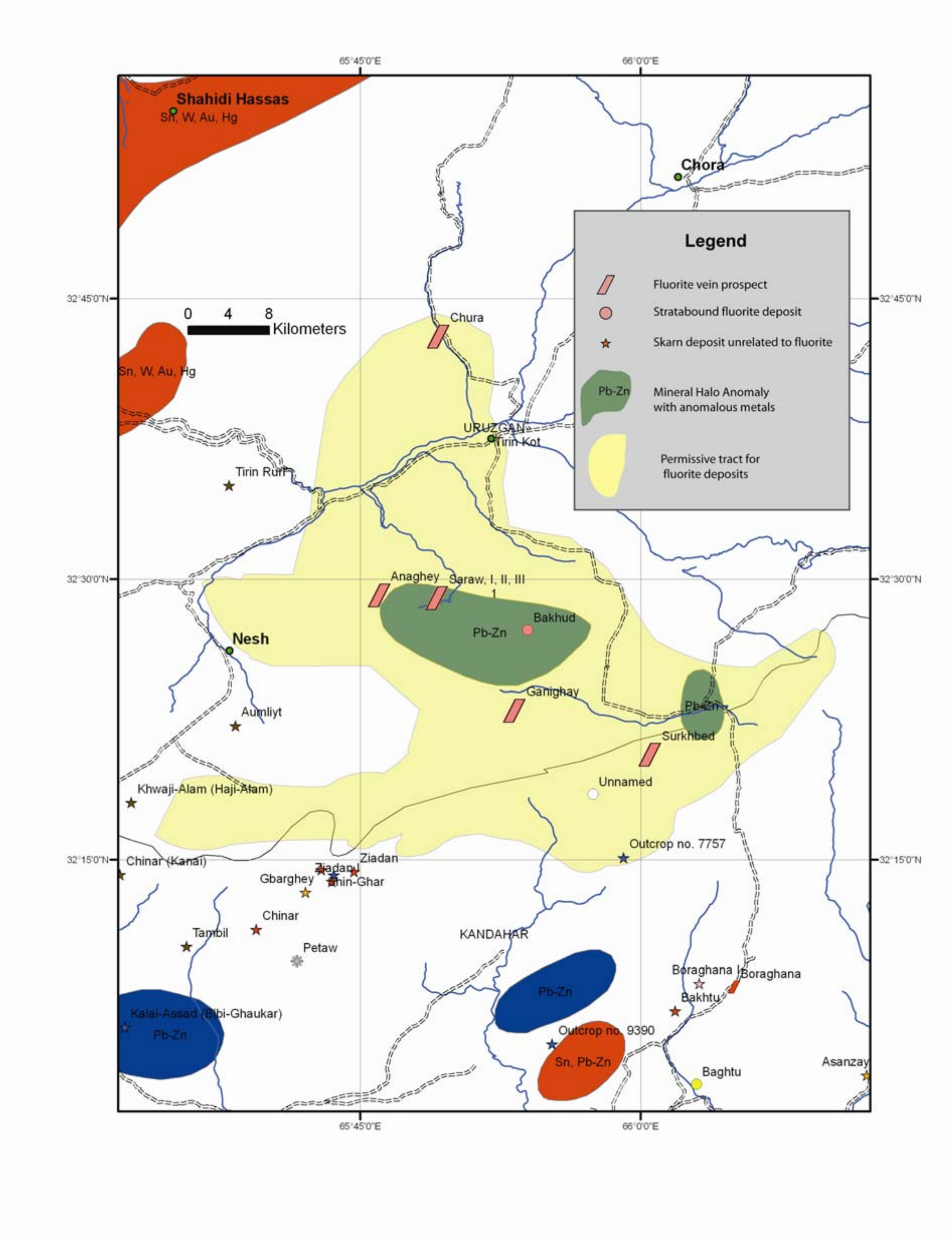

Figure 4.2-1. Location of permissive tract fluor01—Bakhud for undiscovered fluorite deposits, showing location of geochemical halo anomalies. Polygons outside of the permissive tract mainly are polymetallic skarn deposits.

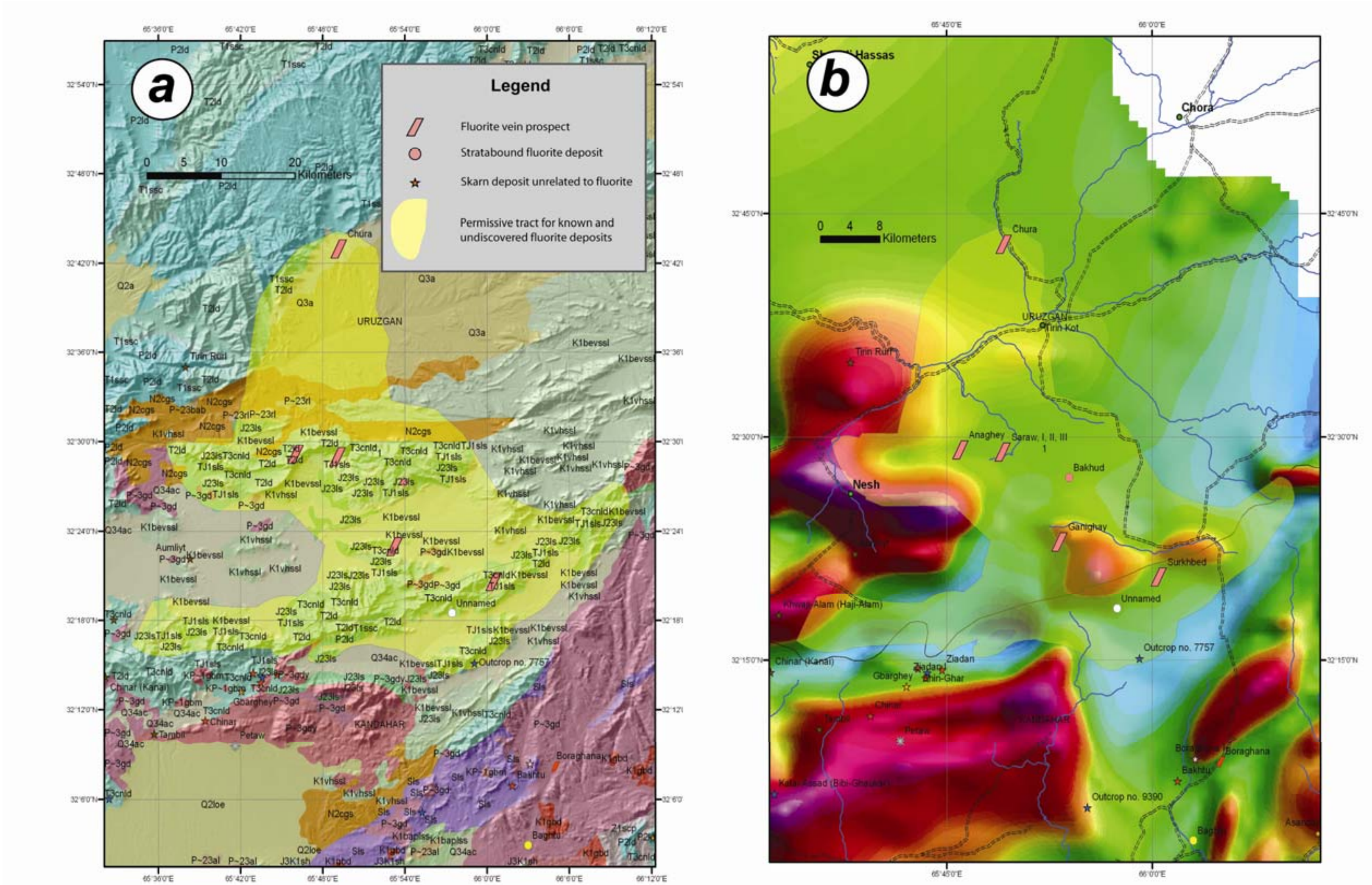

Figure 4.2-2. Map showing features of fluorite occurrences in south central Afghanistan. (a) Geology (from Doebrich and Wahl, 2006) of permissive tract fluor01 for known and undiscovered fluorite deposits in northern Kandahar and southern Uruzgan Provinces. Permissive host lithologies for undiscovered fluorite deposits include: T_2ld = Middle Triassic limestone and dolomite, TJ_1sls = Late Triassic to Early Jurassic siltstone, sandstone, shale and limestone, T_3cnkd = Late Triassic limestone and dolomite, and J_{23}ls = Middle to Late Jurassic limestone and marl. These are locally covered by Late Pliocene to Recent colluvium and alluvium. (b) Location of permissive tract fluor01—Bakhud overlying the aeromagnetic map showing aeromagnetic anomalies in relation to the tract from Sweeney and others (2006a).

4.3 Pegmatites

Contributions by Greta J. Orris, Karen S. Bolm, and Stephen G. Peters

Abundant pegmatite fields, principally in northeast Afghanistan, offer a variety of commodities, such as lithium, beryllium, quartz, feldspars, micas, gemstones, tantalum, niobium, and cesium, which could be used for local glass, chemical, or artisanal industries. Pegmatites have been a source of lithium in the past; however, because lower cost sources have been developed in the world, pegmatites are no longer an important source of lithium.

Pegmatites are commonly coarse-grained igneous rocks with interlocking crystals. They usually are of granitic composition and may be enriched in normally incompatible trace elements and a large variety of uncommon minerals. A more encompassing definition would define them as coarse-grained rocks of diverse mineralogy, variable texture and structure, and with locally complex geochemistry. A wide variety of commodities have been produced from pegmatites. The more common commodities include feldspar, quartz, and mica which are found in most pegmatites. However, pegmatites are probably best known for their gems and mineral specimens (section 12.4) and for rare or rare elements, including sources of beryllium, cesium, gallium, lithium, niobium, rubidium, tantalum, and tin. Although pegmatites have traditionally been an important deposit type, the importance has waned in the last few decades as cheaper and more easily mined sources of some of the commodities have come to the fore. For example, through the mid-20th Century, pegmatites were the main source of lithium. However, in the late part of the century, Li-rich brines have proven to be a productive, relative low-cost source of Li and production from pegmatites has notably decreased.

4.3.1 Description of pegmatite deposit models

Pegmatites are commonly coarse-grained, unevenly textured rocks composed dominantly of quartz and feldspars that are Precambrian to Tertiary in age (*http://www.pegmatology.com/*). They form from post-magmatic residual fluids concentrated in exotic elements that are not usually constituents of the normal rock-forming minerals. They are composed of structural, mineralogical, textural, and lithological units that may make them simple or complex in appearance. Mineralogical and textural zones may include a border zone, wall zone, intermediate zones, and a core that is commonly composed of predominant quartz and feldspar (Page, 1998; Anderson and others, 1998). The more rare minerals tend to occur in more complex, zoned pegmatites than those with simple mineralogy.

Pegmatites commonly are hosted by schist, gneiss, marble, quartzite, and igneous rocks in areas of regional metamorphism and where granitic plutons intrude country rock. Although most pegmatites have a granitic composition, this is not an absolute. However, pegmatites of other compositions are far smaller in number.

Commodities from pegmatites

Lithium tends to concentrate in silicic residual magmas along with beryllium and cesium (Harben and Kuzvart, 1996). In addition to forming from magmatic fluids, pegmatites may also form as a result of metasomatism fluids in deep metamorphic environments (Kunasz, 1994). In lithium’s case, it can form minerals across the paragenetic range from early to late stages, so that some lithium-bearing pegmatites may have zones of particular lithium minerals, such as spodumene and lepidolite. However, homogenous, unzoned pegmatites have been more important commercially (Harben and Kuzvart, 1996).

Beryllium is found as beryl in pegmatites and also may be present as a late-stage product. Beryl mineralization is commonly contains within biotite and muscovite granites but rarely with other granitic rocks (Harben and Kuzvart, 1996). Beryl within these deposits can form crystals many meters in length and weighing several tons. In terms of age, most beryl-bearing pegmatites are Precambrian and Paleozoic in age. Most commercial deposits are found in zoned pegmatites.

Quartz, feldspar, and mica (muscovite, phlogopite, and (or) biotite) are found in most pegmatites. Pegmatites are the oldest source of feldspar, and most commercial pegmatites are zoned pegmatites in metamorphic host rocks.

Exploration guides—There are a variety of techniques that can aide exploration for pegmatites. Most pegmatites are close to the most fractionated parts of granitic batholiths and many are slightly radioactive. Geochemical signatures include Li, P, Ta, Nb, Ti, F, W, REE, Zr, U, Th, B, Be, and Sn. In some areas, pegmatites are strongly weathered to kaolinite and other clays. Pegmatites tend to occur in clusters (Landes, 1933; Cameron and others, 1949; Page, 1998). Within pegmatites, the number and complexity of zones may be a guide to mineral content.

Examples of deposit type—Deposits that belong to this deposit type include Kings Mountain, North Carolina, United States; Greenbushes, Western Australia; and Bikita, Zimbabwe.

Known occurrences—There are over one dozen known pegmatite fields in Afghanistan (fig. 4.3-1); most occur in the northwestern part of the country associated with Oligocene plutons (Abdullah and others, 1977). Pegmatite occurrences in Afghanistan have been divided into a number of pegmatite fields, mostly contained within an area of Late Cimmerian folding in the northeastern part of the country (table 4.3-1; see also fig. 12.4-1 a and b in section 12.4)

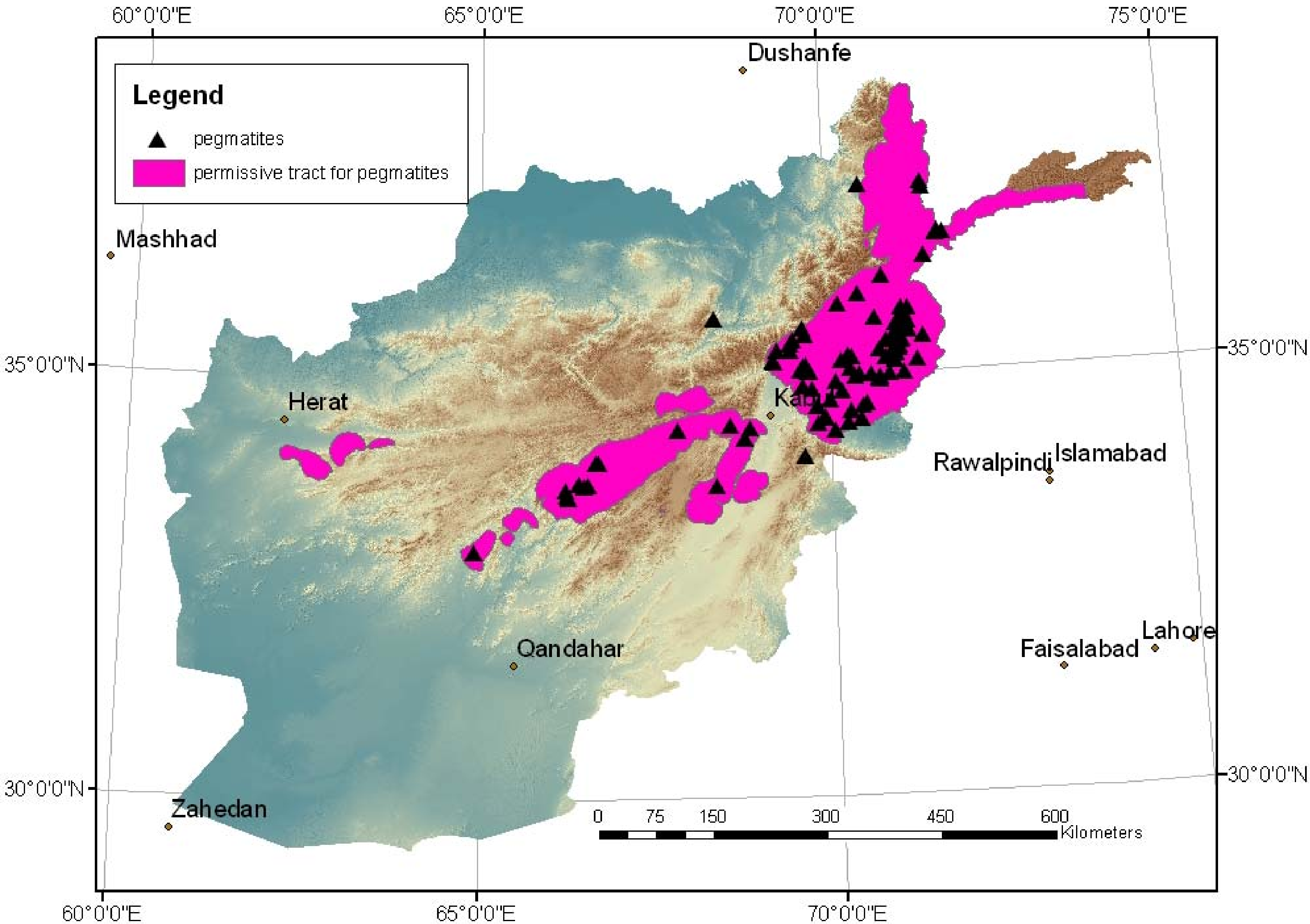

Figure 4.3-1. Area permissive for pegmatites affiliated with Oligocene plutons in Afghanistan.

Table 4.3-1. Pegmatite fields in Afghanistan.

Locality/Deposit Name	Province	Commodity(s)	Significant Minerals or Materials (other quartz, mica, feldspar)	Selected References
Alinghar Pegmatite Field	Laghman	Li, Cs, Rb	Spodumene, lepidolite, petalite, amblygonite, pollucite	Chmyriov and others, 1973; Bogatskiy and others, 1978; Abdullah and others, 1977.
Besud Field	Vardak	Ta, Nb, Sn	---	Abdullah and others, 1977; Bowersox and Chamberlin, 1995.
Chawki Pegmatite Field	Nangarhar	Be, Nb, Ta	Beryl, schorl, columbite-tantalite, cassiterite	ESCAP, 1995; Abdullah and others, 1977; Bowersox and Chamberlin, 1995.
Dara-i-Daram Pegmatite Field	Kapisa	Nb, Ta, Sn	Columbite-tantalite, cassiterite	ESCAP, 1995; Abdullah and others, 1977; Bowersox and Chamberlin, 1995.
Darra-i-Pech Field	Nangarhar	Be, Nb, Ta, Li, mica	Spodumene, beryl, columbite-tantalite, pollucite	ESCAP, 1995; Rossovskiy, 1977; Abdullah and others, 1977.
Darrahe-Nur Pegmatite Field	Laghman	Be, Li, Nb, Ta, Sn	Beryl, spodumene, schorl	ESCAP, 1995; Abdullah and others, 1977.
Eshkashim Pegmatite Field	Badakhshan	Li, Ta, Sn, Be, Nb	Spodumene, microcline, cleavelandite, beryl	ESCAP, 1995; Abdullah and others, 1977.
Kantiway Pegmatite Field	Nangarhar	Gemstones, Li, quartz	Kunzite, spodumene, tourmaline, cassiterite, cleavelandite,	ESCAP, 1995; Abdullah and others, 1977.
Kokcha Field	Badakhshan	Li, Ta, Nb, Sn, Cs, Rb	Cleavelandite, columbite-tantalite	ESCAP, 1995; Abdullah and others, 1977; Bowersox and Chamberlin, 1995.
Kurghal Pegmatite Field	Laghman	Cs, Rb, Li, Ta, Nb, gemstones	Pollucite, tantalite, lepidolite, tourmaline, schorl, beryl	ESCAP, 1995; Abdullah and others, 1977.
Marid Pegmatite Field	Nangarhar	Li, Be	Spodumene, beryl	ESCAP, 1995; Abdullah and others, 1977; Bowersox and Chamberlin, 1995.
Mundel Pegmatite Field	Laghman	Be	Beryl	ESCAP, 1995; Abdullah and others, 1977.
Nilaw-Kolum Field	Laghman	Gemstones, Be, Ta, Nb, Li, Cs, Rb	Beryl, kunzite, spodumene, schorl, lepidolite, tourmaline, kunzite, pollucite	ESCAP, 1995; Rossovskiy, 1977; Abdullah and others, 1977.
Pachaghan Pegmatite Field	Kapisa	Be, mica	Beryl	ESCAP, 1995; Abdullah and others, 1977.
Pachighram Pegmatite Field	Nangarhar	Li, Be, Sn, Nb	Spodumene, schorl	ESCAP, 1995; Abdullah and others, 1977.
Panjsher Pegmatite Field	Parvan	Ta, Nb, Sn	Emerald, tantalite-columbite, cassiterite, spodumene, schorl, garnet, tourmaline	ESCAP, 1995; Abdullah and others, 1977; Bowersox, 1985; Bowersox and others, 1991.
Parun Field	Nangarhar	Li, Ta, Nb, Sn, Cs, Rb	Spodumene, tantalite, columbite, cassiterite, schorl, garnet, beryl	ESCAP, 1995; Abdullah and others, 1977.
Shahidan Pegmatite Field	Laghman	Li, Be	Spodumene, beryl,	ESCAP, 1995; Abdullah and others, 1977.
Shamakat Pegmatite Field	Laghman	Li, Sn, Ta, Be, Cs	Spodumene, petalite, pollucite, tourmaline	ESCAP, 1995; Rossovskiy, 1977; Abdullah and others, 1977; Rossovskiy and others, 1976.
Shewa Pegmatite Field	Badakhshan	Ta, Sn	Cassiterite, microcline	ESCAP, 1995; Abdullah and others, 1977.
Surkh-Rod Pegmatite Field	Nangarhar	Cs, Rb, Li	Pollucite, lepidolite, spodumene, tourmaline, cleavelandite, rubellite, cassiterite, schorl, garnet	Chmyriov and others, 1973, 1995; ESCAP, 1995; Abdullah and others, 1977.

Locality/Deposit Name	Province	Commodity(s)	Significant Minerals or Materials (other quartz, mica, feldspar)	Selected References
Taghawlor Field	Oruzgan	Li, Sn, Ta, Be	Spodumene, columbite, tantalite, cassiterite, beryl, schorl	Abdullah and others, 1977, p. 219; ESCAP, 1995.
Talbuzanak Field	Badakhshan	Li, Be, Ta, Nb	Spodumene, beryl, columbite-tantalite	Bowersox, 1985; Bowersox and others, 1991.

4.3.2 Pegmatite Mineral-Resource Tract

Permissive tract afpegs

The permissive tract for undiscovered pegmatite deposits in Afghanistan covers a wide area of Oligocene pluton outcrop and adjacent areas.

Examples of deposit type—More than one dozen pegmatite fields are known to occur within the tract. Commodities include: quartz, feldspar, mica, lithium, gems, beryl, rubidium, cesium, and many others (table 4.3-1).

Probable age(s) of mineralization—The expected age of pegmatite mineralization within the designated tract is Oligocene.

Exploration history—Tract afpegs has been fairly well-explored for surficial pegmatites because of interest in gems.

Tract boundary criteria—The tract was determined by the extent of the Oligocene granitic plutons (map units P_3gr, P_3gdy, P_3gd, P_3dlp, P_3grg). After the Oligocene plutons were delineated, they were buffered for 20 km. Proterozoic rocks were selected and buffered to 5 km. Overlapping areas were selected and buffered an additional 3 km to capture more of the known occurrences and small outcrops that do not show on the geologic map. The tract was then expanded to the eastern-most Afghan border and up the panhandle to include all Oligocene granitic rocks exposed at sufficient depth for pegmatite occurrence.

The southwestern-most Oligocene plutonic rocks in Afghanistan shown by Doebrich and Wahl (2006) are too shallow for pegmatites. The rocks are sub-volcanic; that is, there are associated skarns and veins indicating that they are too high level to permit formation of pegmatites. An area of late Cimmerian folding (see figure 12.2-1) may also act proxy as a proxy for depth sufficient to form pegmatites.

Needs to improve assessment—The assessment team recognized more detailed geology and occurrence descriptions may have been useful.

Optimistic factors—Extensive known deposits.

Pessimistic factors—There is a lack of detailed information on pegmatite zoning. Such information could possibly help with commodity determination.

Quantitative assessment—No quantitative assessment of this deposit type was made. There is no pegmatites grade and tonnage deposit model.

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