Chapter 24A. Summary for the Mineral Information Package for the Nuristan Rare-Metal Pegmatite Area of Interest

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Abstract

Numerous rare-metal pegmatites are found in the mountainous terrain of the Hindu Kush in northeastern Afghanistan. Earlier investigations by Soviet geologists suggested that this area contains the largest concentration of lithium-bearing pegmatites in the world. In addition to lithium, these pegmatites are enriched in other rare metals such as tantalum, niobium, beryllium, tin, and cesium. Gem-quality tourmaline, kunzite, beryl, and optical grade quartz have been mined from some of these pegmatites. The pegmatites discussed in this report occur within the Nuristan rare-metal pegmatite area of interest (AOI).

Rare-metal pegmatites in the Nuristan rare-metal pegmatite AOI are found within Early Proterozoic and Late Triassic metamorphic rocks. These pegmatites are spatially and genetically related to Oligocene-age two-mica granites which represent the youngest of three phases of the Laghman intrusive complex. The two-mica granites are regarded as fertile granites because the associated pegmatites are enriched in rare metals such as lithium, tantalum, niobium, beryllium, tin, and cesium. Two pegmatite belts—the Nuristan and Hindukush—flank the Alingar Pluton on the east and west sides, respectively. The central part of the Nuristan pegmatite belt lies within the Nuristan rare-metal pegmatite AOI, and identified rare-metal pegmatites are concentrated in four pegmatite fields: Pacigram, Paron, Kantiway, and Darrahe Pec. Geologic maps suggest that numerous unclassified pegmatites are present in much of the Nuristan pegmatite belt and suggest additional and unrecognized mineralization may be present.

Pegmatite districts in the Nuristan rare-metal pegmatite AOI exhibit vertical zonation from relatively barren pegmatites to those enriched in the rare metals. Many pegmatites are quite extensive with strike lengths on the order of 2 to 5 kilometers and widths ranging from 1 to 60 meters.

Exploration and assessment of these pegmatites for economic concentrations of rare metals may be facilitated by their size and probably excellent exposure in the mountainous terrain. However, access to this area is limited by the mountainous terrain and by a poor road and trail network.

24A.1 Introduction

This chapter summarizes and interprets results for the Nuristan rare-metal pegmatite area of interest (AOI) from geologic and compilation activities conducted during 2009 to 2011 by the U.S. Geological Survey (USGS), the U.S. Department of Defense Task Force for Business and Stability Operations (TFBSO), and the Afghanistan Geological Survey (AGS). Accompanying complementary chapters 24B and 24C address hyperspectral data and geohydrologic assessments, respectively, of the Nuristan rare-metal pegmatite AOI. Additional supporting data for this chapter are available from the Afghanistan Ministry of Mines in Kabul.

Pegmatites are one source for rare metals such as lithium, tantalum, niobium, beryllium, tin, and cesium, which are in demand for their individual properties or properties that they impart to other materials or metals (Kunaz, 1994; Harben and Kužvart, 1996). Although lithium-bearing brines have replaced lithium-bearing pegmatites as the principal source of lithium, current and future demand for lithium may result in a return to mining of lithium-bearing pegmatites. The pegmatites in northeastern Afghanistan are described as the largest concentration of lithium-bearing pegmatites in the world

(Rossovskiy and Chmyrev, 1977) and could be considered as the world's recognized future principal source of lithium. The world's supply of tantalum, niobium, and cesium comes from only a few large pegmatites, such as Tanco in Manitoba (Crouse and Černý, 1972; Stilling and Černý, 2006), Greenbushes in Western Australia (Partington, 1990; Partington and McNaughton, 1995; Harben and Kužvart, 1996), and Bikita in Zimbabwe (Harben and Kužvart, 1996). The Big Whopper Pegmatite in Ontario is a recently explored, large pegmatite of economic significance enriched in lithium, tantalum, cesium, and rubidium (Avalon, 2010). Although more than 90 percent of the world's beryllium resources are in pegmatites, only about 40 percent of the beryllium production is from pegmatites (Harben and Kužvart, 1996). About 60 percent of the world's beryllium production is from bertrandite replacement of altered rhyolite tuffs at Spor Mountain, Utah (Harben and Kužvart, 1996).

The Nuristan rare-metal pegmatite AOI lies in the Hindu Kush Mountains in northeastern Afghanistan, approximately 135 kilometers (km) northeast of Kabul (fig. 24A–1). The Nuristan rare-metal pegmatite AOI lies mainly within Nuristan and Kunar Provinces, with small portions in Badakshan and Lagham Provinces (fig. 24A–1). The main districts are Matal, Kamdesh, Kuran Wa Munjan, Wama, Waygal, Pech, Chapa Dara, and Nuristan. The Nuristan rare-metal pegmatite AOI covers an area of about 3.5 square kilometers (km^2) and includes four important pegmatite fields: Pacigram, Paron, Kantiway, and Darrahe Pec.

The names of pegmatites and pegmatite fields have various spellings in the literature; the principal spellings used in this summary are based on those shown by Rossovskiy and Nuiskov (1974a,b). It was not always possible to determine if names of features by different or the same authors were supposed to be the same, such as Paran, Paron, Parun, Parum, or different features.

24A.2 Previous Work

Pegmatites within the Nuristan rare-metal pegmatite AOI were poorly known to the western world until Soviet geologists began mapping the geology and assessing the mineral resources of northern Afghanistan in the 1960s and 1970s. Soviet geologists contributed an immense body of work on the pegmatites through geologic mapping, sampling, and interpretation (Narodnyi, 1965; Chmyriov and Mizrad, 1972; Cmyriov and others, 1973; Filippov, 1974; Rossovskiy, 1974, 1977, 1980, 1981a, b, 1986, 1990; Rossovskiy and Nuiskov, 1974a, b; Rossovskiy and Chmyrev, 1976; 1977; Rossovskiy and Konovalenko, 1976, 1979, 1980; Rossovskiy and others, 1976a-e, 1977a, b, 1978 1979, 1987; Alemyar and others, 1977a, b; Bogatskiy and others, 1978; Rossovskiy and Shmakin, 1978; Shmakin and Rossovskiy, 1978; Geruvol' and others, 1980; Konovalenko and others, 1982; Vityaz and others, 1983; Fenogenov and Musazai, 1989). More recent studies have focused on those Afghanistan pegmatites that contain gem- or museum-quality mineral specimens (Bariand and Poullen, 1978; Bowersox and Chamberlain, 1995; Abdullah and Chmyriov, 2008).

The geology and mineral resources of Afghanistan have been summarized by Abdullah and others (1977), Orris and Bliss (2002), Doebrich and Wahl (2006), Peters and others (2007), and Abdullah and Chmyriov (2008). These publications contain more information regarding pegmatites in northeastern Afghanistan.

24A.3 Geology

The oldest rocks in the Nuristan rare-metal pegmatite AOI are Early Proterozoic metamorphic rocks that are divided into an Early Part, a Middle Part, and a Late Part (figs. 24A–2, 24A–3). Early Part rocks consist of mica, biotite, biotite-amphibole, garnet-biotite, garnet-sillimanite-biotite, and pyroxene-amphibole gneiss, as well as plagiogneiss, schist, migmatite, quartzite, marble, and amphibolite. Middle Part rocks consist of biotite and garnet-staurolite-biotite gneiss and schist, quartzite, marble, and amphibolite. Late Part rocks consist of biotite and garnet-biotite gneiss and schist, quartzite, marble, and amphibolite. Metamorphic grade of the Proterozoic rocks is either epidote-amphibolite or muscovite-staurolite-schist facies (Rossovskiy and Chmyrev, 1977). Younger lithologies include Carboniferous-Early Permian sandstone, siltstone, shale, and mafic-volcanic rocks and Late Triassic (Noria-Rhaetian) siltstone, sandstone, shale, and conglomerate (Doebrich and Wahl, 2006). Descriptions of the individual pegmatite fields and deposits indicate that the Carboniferous-Early Permian and Late Triassic rocks have been metamorphosed (Abdullah and Chmyriov, 2008).

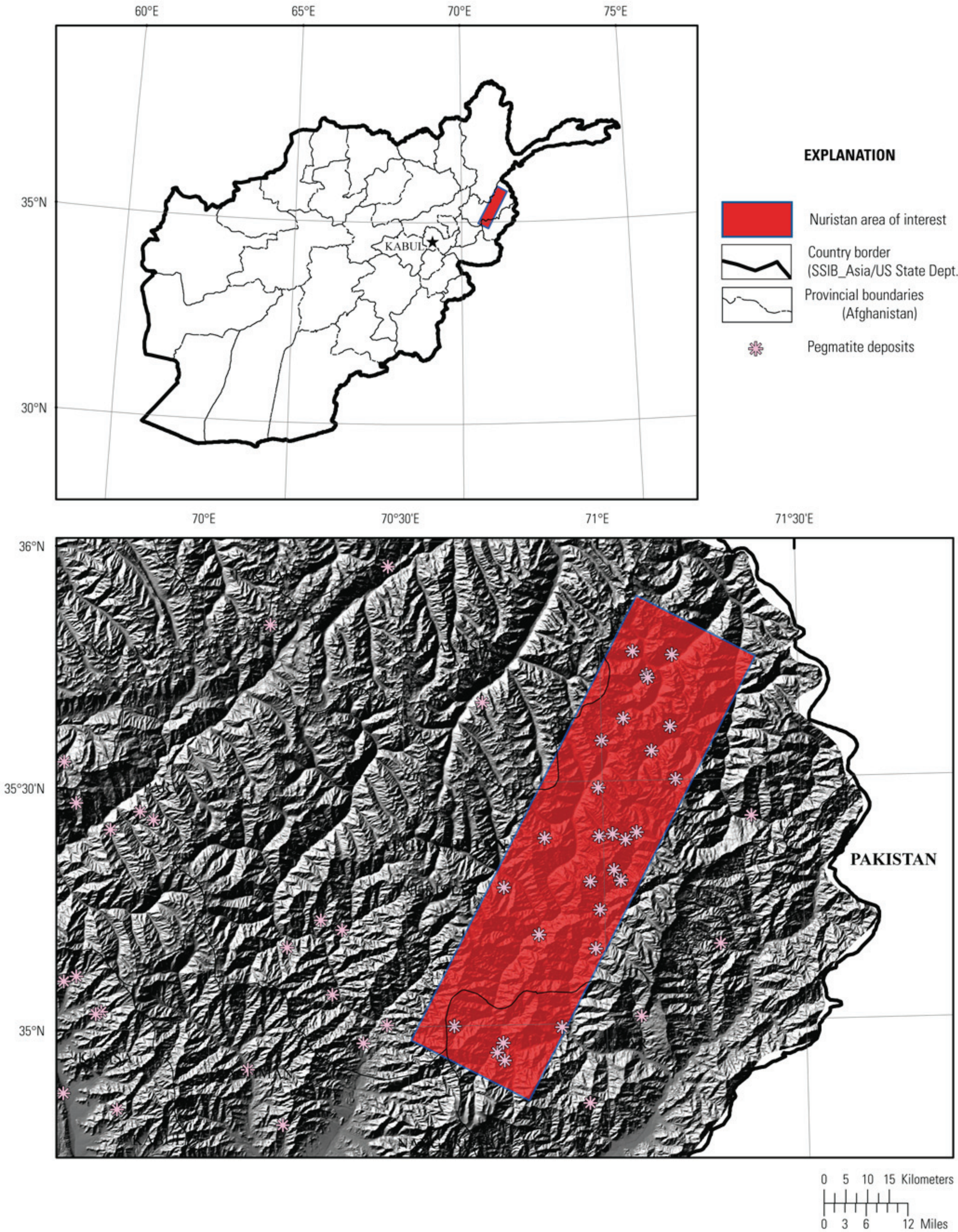

Figure 24A–1. Index map showing the location of the Nuristan rare-metal pegmatite area of interest. Stars indicate major pegmatite deposits.

The Nuristan rare-metal pegmatite AOI and surrounding areas are characterized by northeast-trending structures and similar trending belts of rocks. The belts are composed of Early Proterozoic, Carboniferous to Early Permian, and Late Triassic rocks, which are bounded by northeast-trending faults (figs. 24A–2, 24A–3). Oligocene-age granite intrusions are also elongate along the same structural trends. Neither rock type nor the faults appear to have a great effect on the topography.

A narrow, northeast-trending, elongate structural block of Carboniferous to Early Permian sandstone, siltstone, shale, and mafic volcanic rocks is fault bounded on the east and west, and bordered by Early Proterozoic (Early Part) metamorphic rocks (figs. 24A–2, 24A–3). A number of northeast-trending, elongate, Oligocene-age granites are located along and on either side of these boundary faults (fig. 24A–4).

A much larger block of Late Triassic rocks extends nearly the entire length of the Nuristan rare-metal pegmatite AOI and is fault bounded with Early Proterozoic (Early Part) metamorphic rocks on the west and by Early Proterozoic (Early Part and Late Part) metamorphic rocks on the east (figs. 24A–2, 24A–3) . As with the Carboniferous-Early Permian block, Oligocene-age granite intrusions are elongate within and outside of the Triassic fault block with some of the intrusions appearing to cross the faults. Strike symbols depicted on the map of Doebrich and Wahl (2006) are oriented approximately along the same structural trends.

24A.3.1 Oligocene and Older Intrusions

The Early Cretaceous age Nilau igneous complex (K1gbm) at the southern end of the Nuristan rare-metal pegmatite AOI (figs. 24A–2, 24A–3) is composed of gabbro, monzonite, diorite and granodiorite. It intrudes rocks of Early Proterozoic age and Triassic age. Major northeast-trending faults cut and offset portions of this complex. The Darrahe Pec pegmatite field is located mainly within this complex.

The rare-metal pegmatites are genetically and spatially related to the Oligocene-age granitic intrusions, and these granites are described below. Granitoid intrusive rocks in northeastern Afghanistan are widespread (figs. 24A–2, 24A–3) and form large, northeast-oriented massifs. These massifs are localized within a sequence of Proterozoic and Carboniferous gneisses and schists and Triassic clastic sedimentary rocks. The largest granitoid massif is the Oligocene-age Laghman intrusive complex, which is located in the Nuristan Fault Block (Abdullah and Chmyriov, 2008). The Nuristan Fault Block and the Laghman intrusive complex are not depicted on any map inspected for northeastern Afghanistan. This fault block may lie between the Mississippian rocks (fig. 24A–2) located to the northwest and southeast.

The Laghman intrusive complex is separated into three main phases. Phase I rocks of the Laghman intrusive complex include diorite, quartz diorite, granodiorite, tonalite, granosyenite, and plagiogranite (Abdullah and Chmyriov, 2008). Phase II rocks include medium- and coarse-grained, commonly porphyritic biotite and amphibole-biotite granite and granodiorite (Rossovskiy and Chmyrev, 1977; Abdullah and Chmyriov, 2008). Phase III rocks include biotite and two-mica granite, granite porphyry, and aplitic and pegmatoid granite (Rossovskiy and Chmyrev, 1977; Abdullah and Chmyriov, 2008). Rare-metal pegmatites are spatially and probably genetically related to Phase III granites and intrude the earlier Laghman intrusive complex phases.

The Alingar Pluton is described as a massif of the Laghman intrusive complex, but the literature is unclear about the spatial distributions of the Laghman intrusive complex and the Alingar Pluton (Rossovskiy and Chmyrev, 1977), and no map showing the outlines or any location of these units was found. Based on the references to these igneous units, most of the Alingar Pluton lies between the Hindukush and Nuristan pegmatite belts (fig. 24A–2), and the Laghman intrusive complex includes both the Alingar Pluton in figure 24A–2 and the rest of the Oligocene intrusive rocks in the western part of figure 24A–2. Given that Alingar Pluton is part of the Laghman intrusive complex, it likely have the same phases as the larger unit. Most of the exposed portion of this pluton lies west of the Nuristan rare-metal pegmatite AOI (fig. 24A–2).

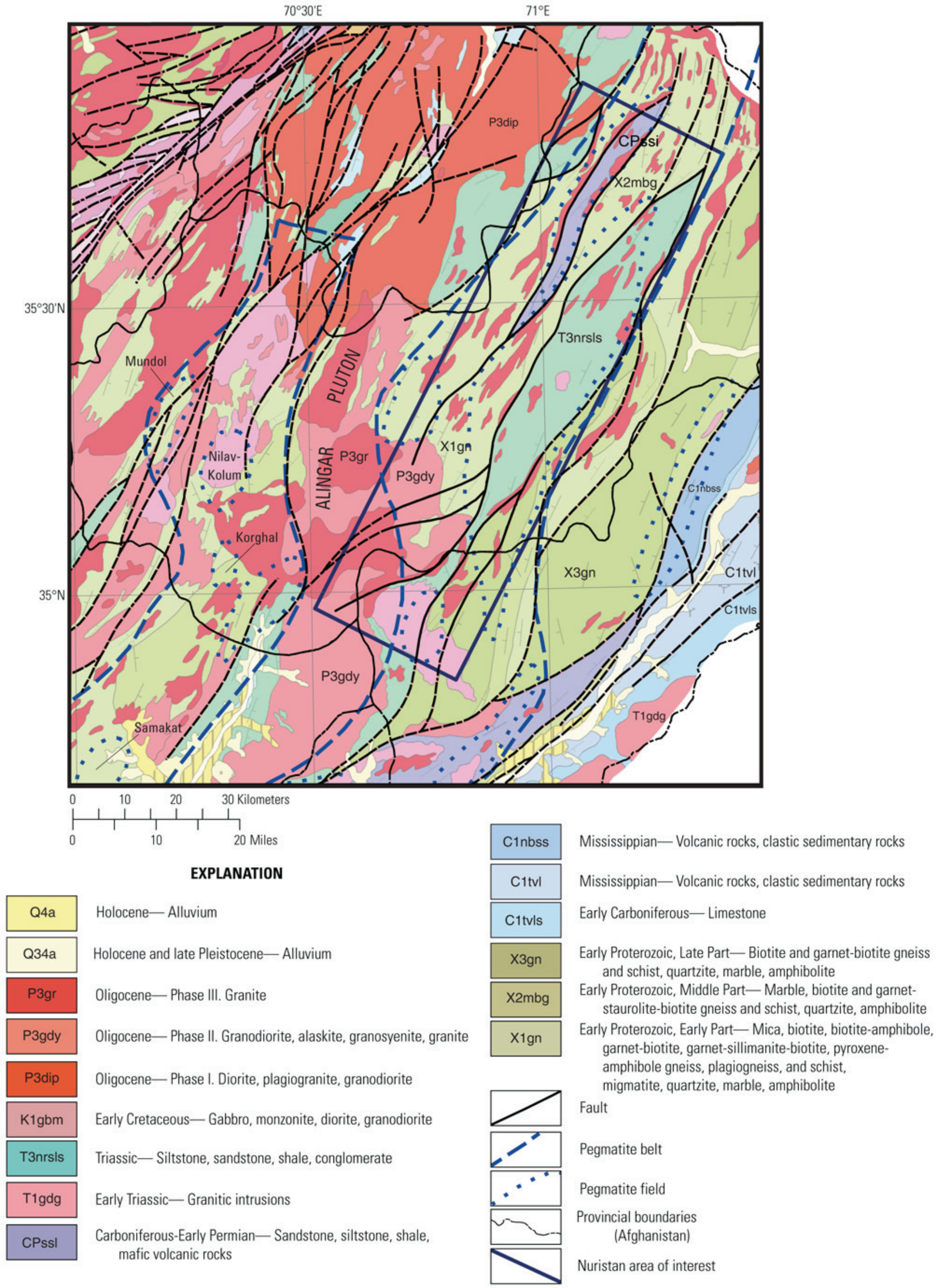

Figure 24A–2. Regional geologic map showing the major granitic bodies of the Pagram intrusive complex, faults, and pegmatite belts, fields, and the Nuristan rare-metal pegmatite area of interest. Units from Doebrich and Wahl (2006).

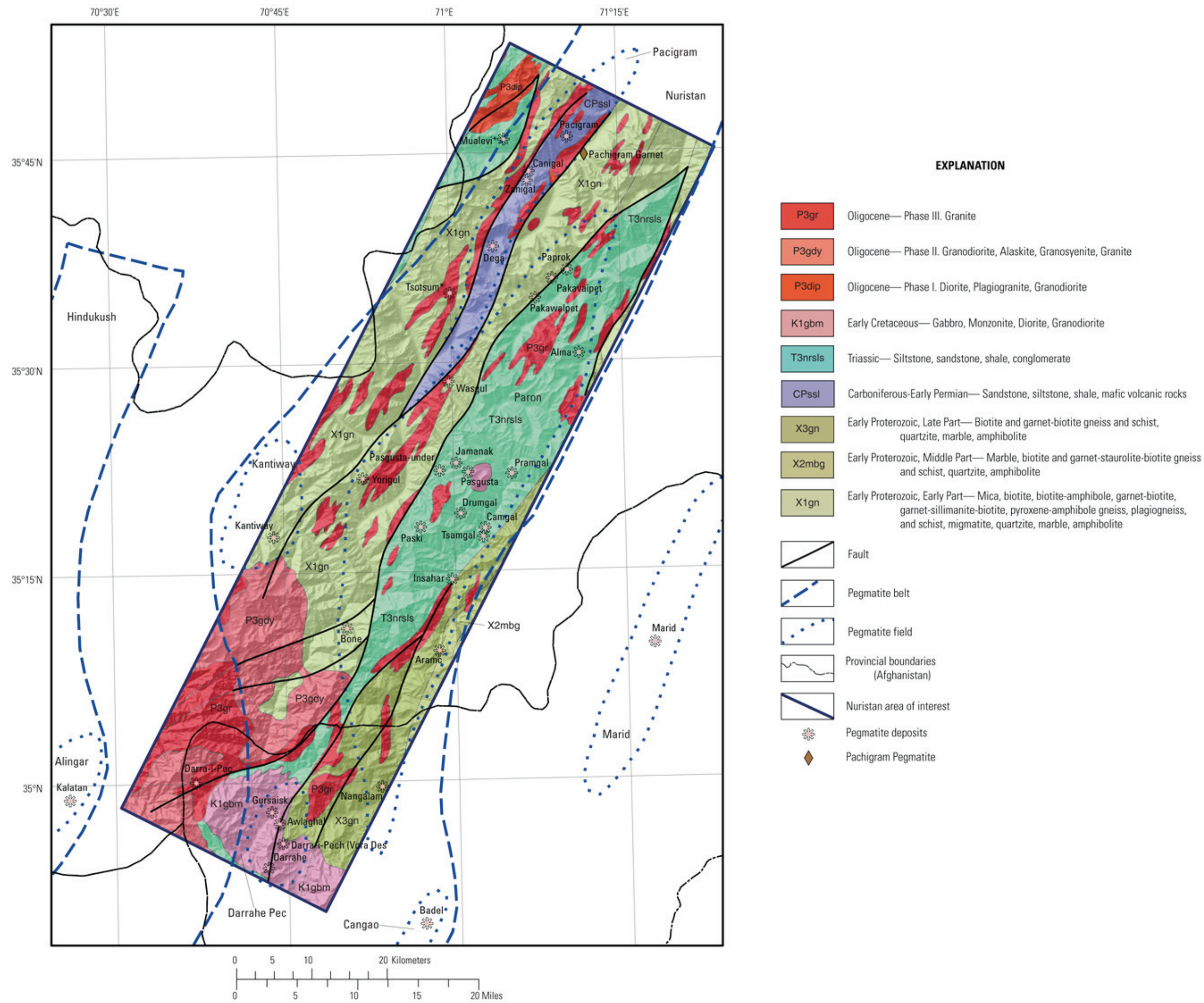

Figure 24A–3. Geologic map of the Nuristan rare-metal pegmatite area of interest with pegmatite belts, fields, and deposits. Units from Doebrich and Wahl (2006).

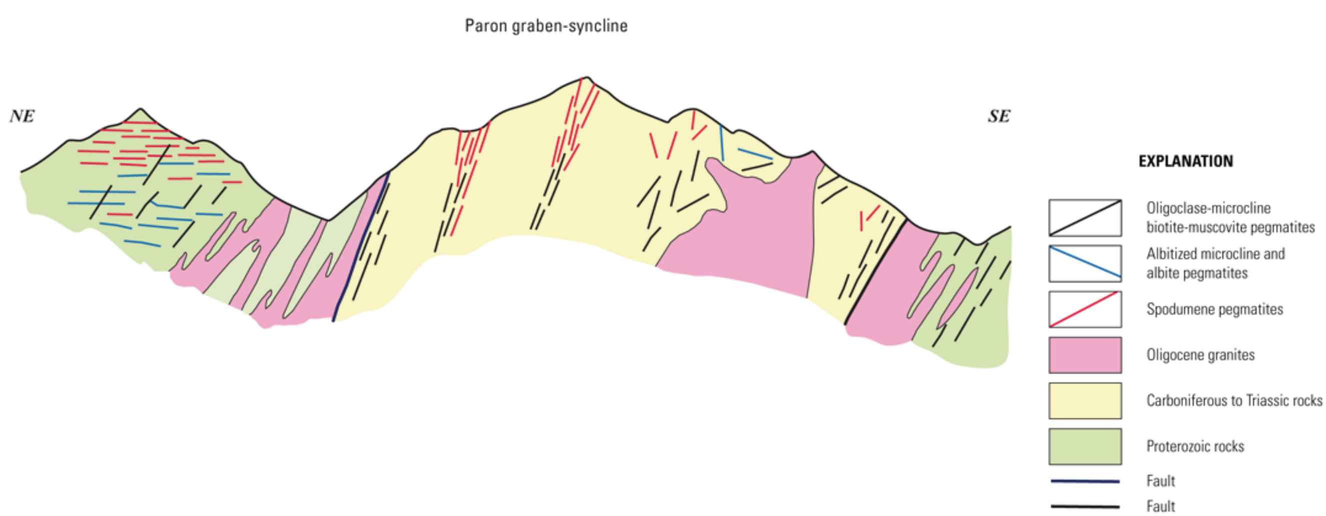

Figure 24A–4. Diagrammatic geologic cross section of the Paron graben-syncline (modified from Rossovskiy and Konovalenko, 1979). (Many maps and diagrams in the Russian literature lack vertical and horizontal scales.)

The biotite and two-mica granites are light-gray or gray and fine- and medium-grained. The composition of the granites is 30 to 50 volume percent potassium feldspar, 25 to 30 volume percent quartz, 20 volume percent albite-oligoclase, and 5 to 10 percent biotite and muscovite (Rossovskiy and Chmyrev, 1977). The average composition of 12 samples of two-mica granites from Phase III of the Laghman complex is 71.97 weight percent SiO_2, 0.40 weight percent TiO_2, 14.33 weight percent Al_2O_3, 0.14 weight percent FeO, 2.01 weight percent MnO, 0.06 weight percent MgO, 0.87 weight percent CaO, 3.37 weight percent Na_2O, 4.09 weight percent K_2O, 0.17 weight percent P_2O_5, and 0.47 weight percent calculated loss (based on data from Rossovskiy and Chmyrev, 1977).

Phase III granites are generally small, with dimensions on the order of 1 to 5 km up to5 to 30 km. These intrusions are commonly elongated layer-like bodies that are conformable with the strike of the surrounding rocks and are commonly located along major northeasterly striking faults. They also commonly occur in the contact zones between the gneiss sequences of the Nuristan series and Upper Triassic rocks (Rossovskiy and Chmyrev, 1977).

The two-mica granite and pegmatite intrusions are guided mainly by the structural characteristics of the host rocks rather than by the host rock composition (Rossovskiy and Chmyrev, 1977). Most of the rare-metal pegmatites are intruded into quartz-muscovite-biotite schists with garnet and staurolite. These pegmatites are also found in gabbro-diorites, diorites, gneisses, limestones, and amphibolites, but to a much lesser extent.

Phase II granites of the Oligocene-age Alingar Pluton are bounded by the fault on the western side of the Triassic fault block. Phase I granites of the same intrusive complex are, in some cases cut by the faults, and in others, they apparently are guided by the faults and some may cross the faults. This suggests that some fault movement occurred subsequent to formation of the Phase II granites, and perhaps during and after the Phase I granites.

24A.3.2 Metallogeny

The Nuristan and Hindukush pegmatite belts belong to a Himalayan pegmatite megabelt that extends from northeastern Afghanistan through Pakistan and into India, Nepal, and Bhutan (Baratov and Rossovskiy, 1987). Throughout this megabelt, rare-metal pegmatites are associated with two-mica, peraluminous granite batholiths. In addition to rare-metal pegmatites, gem-quality kunzite (a pink to violet, clear spodumene), tourmaline, aquamarine, morganite, emeralds, and sapphires are found in association with some of these pegmatites. These pegmatites are also sources for museum-quality mineral specimens (Baratov and Rossovskiy, 1986; Bariand and Poullen, 1978; Bowersox and Chamberlain, 1995).

The metallogenic specificity of rare-metal pegmatite belts may be dependent on (1) the overall geochemistry of the province, (2) the composition of the fertile granites within different tectonic zones, (3) the tectonic regime during emplacement of the pegmatites, and (4) the structure and morphology of the pegmatite veins (Rossovskiy, 1990, 1991). Overall, the pegmatites of the Pamir-Hindu Kush pegmatite province (Rossovskiy and Mogarovskiy, 1988), which includes the Hindukush and Nurestan pegmatite belts (fig. 24A–2), are anomalous in lithium, beryllium, tantalum, and tin ,with a general enrichment of cesium in the Hindukush region (Rossovskiy, 1990, 1991). As the granites are S-type granites, this suggests that the sediments from which these granites were derived were anomalous in these elements (Rossovskiy and Mogarovskiy, 1988). The enrichment of lithium, rubidium, and cesium in pegmatitic fluids may result from conversion of biotite to muscovite in the two-mica granites at the end of granite crystallization (Rossovskiy and Mogarovskiy, 1988).

Pegmatites can be classified using petrogenetic criteria based on how pegmatites develop by igneous differentiation from various plutonic source magmas (Černý and Ercit, 2005). For example, the NYF family of pegmatites exhibits a progressive accumulation of niobium, yttrium, and fluorine along with beryllium, rare-earth elements (REE), scandium, titanium, zirconium, thorium, and uranium. The NYF family of pegmatites results from fractionation of subaluminous to metaluminous A- and I-type granites. The A- and I-type granites may be derived from depleted crust or mantle contributions. This can be compared to the LCT family of pegmatites, which exhibits an accumulation of lithium, niobium, cesium, and tantalum along with rubidium, beryllium, tin, boron, phosphorous, and fluorine. These are derived mainly from peraluminous S-type granites, and less commonly from I-type granites (Černý and Ercit, 2005). The pegmatites in the Nuristan rare-metal pegmatite AOI belong primarily to the LCT family.

24A.4 Economic Geology

24A.4.1 Pegmatite Provinces, Belts, Fields, and Groups

Pegmatite provinces are defined by the total pegmatite fields (or belts) within metallogenic provinces (Černý, 1982a). Pegmatite belts consist of pegmatite fields, which are related to large-scale linear structures such as lineaments, deep faults, or margins of granite plutons (Černý, 1982a). Two major pegmatite belts are associated with the Alingar Pluton. The Nuristan pegmatite belt lies along the eastern flank of the pluton, and the Hindukush belt lies along the western flank (figs. 24A–2, 24A–3). Each belt consists of several pegmatite fields, which, in turn contain one or more named pegmatites and probably numerous unnamed pegmatites.

Pegmatite fields are areas that contain related pegmatites in a common geological-structural environment, and with a common age and igneous source (Černý, 1982a). The Hindukush belt consists of the Mundol, Nilaw-Kolum, Nilaw, Alingar, Samakat, and Sahidan pegmatite fields. The Nuristan pegmatite belt consists of the Iska-Sem, Pacigram, Paran (Jamanak-Pasghushta), Kantiway, Darrahe Pec, Cawgao, Surkhrud, and Darrah Nur pegmatite fields (Rossovskiy and Nuiskov, 1974b) and extends beyond the northern and southern boundaries of the Nuristan rare-metal pegmatite AOI. The Iska-Sem, Cawgao, Surkhrud, and Darrah Nur pegmatite fields of the Nuristan pegmatite belt also lie outside of the Nuristan pegmatite belt. A summary of the pegmatite fields that lie mostly within the Nuristan rare-metal pegmatite AOI is presented in table 24A–1. The reporting of the presence of economic minerals is no guarantee a viable deposit is present without subsequence evaluation identifying grade, size, and other factors.

Table 24A–1. Pegmatite fields and their reported economic minerals in the Nuristan rare-metal pegmatite area of interest.

[Be, beryllium; Cs, cesium; ESCAP, United Nations Economic and Social Commission for Asia and the Pacific; Li, lithium; Nb, niobium; Rb, rubidium; Sn, tin; Ta, tantalum]

Locality/deposit name	Province	Approximate size (square kilometers)	Commodities	Significant minerals or materials (other than quartz, mica, feldspar)	Selected references
Paron (Jamanak-Pasgushta)	Nuristan	1,158	Li, Ta, Nb, Sn, Cs, Rb	columbite, cassiterite, schorl, garnet, beryl	ESCAP, 1995; Abdullah and Chmyriov, 2008
Pacigram (Pachigram)	Nuristan	221	Li, Be, Sn, Nb	spodumene, schorl spodumene, tantalite,	ESCAP, 1995; Abdullah and Chmyriov, 2008
Darrahe Pec (Darra-i-Pech)	Kunar	85	Be, Nb, Ta, Li, mica	spodumene, beryl, columbite-tantalite, pollucite	ESCAP, 1995; Rossovskiy, 1977; Abdullah and Chmyriov, 2008
Kantiway	Nuristan	130	gemstones, Li, quartz	kunzite, spodumene, tourmaline, cassiterite, cleavelandite,	ESCAP, 1995; Abdullah and Chmyriov, 2008

Locations of pegmatite fields, deposits, and individual pegmatites were derived by rectifying and digitizing locations shown on a map by Rossovskiy and Nuiskov (1974a,b). Because of the scale of the original map, some uncertainty as to exact locations of these features is to be expected. A summary of the named pegmatites, their locations, approximate elevations, and their mineralogy is presented in table 24A–2.

Pegmatite groups include a local group of closely spaced pegmatites of a single type, with a common geological-structural position within a pegmatite field (Černý, 1982a). Although pegmatite groups in the Nuristan rare-metal pegmatite AOI are not generally referred to as pegmatite groups, descriptions of pegmatite deposits suggest that many of these can be referred to as pegmatite groups.

Table 24A–2. Pegmatites, pegmatite fields, locations, and significant minerals.

[**Data are from** United Nations Economic and Social Commission for Asia and the Pacific (1995) and Abdullah and Chmyriov (2008). Al, aluminum; Ca, calcium; Ta, tantalum]

Pegmatite name	Pegmatite field	East longitude	North latitude	Elevation above sea level (meters)	Mineralogy
Paprok (Papruk)	Paron (Jamanak-Pasghushta)	71.1501	35.5987	4,060	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite, cassiterite
Pakavaipet (Pakawalpet)	Paron (Jamanak-Pasghushta)	71.1245	35.5757	3,450	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite, cassiterite
Alma	Paron (Jamanak-Pasghushta)	71.1872	35.5090	3,980	Spodumene, lepidolite, albite, microcline, beryl, polychromic tourmaline, columbite-tantalite, cassiterite
Jamanak	Paron (Jamanak-Pasghushta)	70.9798	35.3707	3,770	Spodumene, cirnolite (may be cirrolite, a Ca-Al phosphate)
Pasgusta (Pasghushta)	Paron (Jamanak-Pasghushta)	71.002	35.38	4,680	Spodumene, columbite-tantalite, cassiterite
Pasgusta-under (Pasghushta Lower)	Paron (Jamanak-Pasghushta)	71.021	35.369	4,470	Spodumene, muscovite, cleavelandite
Pramgal	Paron (Jamanak-Pasghushta)	71.0852	35.3663	3,500	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite, cassiterite
Drumgal	Paron (Jamanak-Pasghushta)	71.0093	35.3190	3,450	Spodumene
Paski (Pashki)	Paron (Jamanak-Pasghushta)	70.9507	35.3031	3,800	Spodumene, pollucite
Tsamgal (Tsamghal)	Paron (Jamanak-Pasghushta)	71.0419	35.2958	3,140	Spodumene
Camgal (Zamgal)	Paron (Jamanak-Pasghushta)	71.0444	35.3012	3,080	Spodumene
Insahar (Inshaghar)	Paron (Jamanak-Pasghushta)	70.9948	35.2403	2,245	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite, cassiterite
Boni (Bori)	Paron (Jamanak-Pasghushta)	70.8401	35.1830	2,660	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite, cassiterite
Aramc (Aranch)	Paron (Jamanak-Pasghushta)	70.9650	35.1438	2,370	Spodumene, lepidolite, albite, microcline, beryl, polychromic tourmaline, columbite-tantalite, cassiterite
Nangalam	Paron (Jamanak-Pasghushta)	70.8872	34.9915	1,360	Spodumene, rubellite
Wasgul (Wozgul)	Paron (Jamanak-Pasghushta)	70.9956	35.4771	3,920	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite, cassiterite
Yorigul (Yorigal, Yarigul)	Paron (Jamanak-Pasghushta)	70.8665	35.3624	4,190	Prospective for Ta
Kantiway	Kantiway	70.7346	35.2941	3,480	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite, cassiterite, kunzite, quartz crystal
Dara-i-Pech	Dara-i-Pech	70.6167	34.9998	2,596	beryl

Pegmatite name	Pegmatite field	East longitude	North latitude	Elevation above sea level (meters)	Mineralogy
Dara-i-Pech (Vora Des)	Dara-i-Pech	70.7413	34.9276	2,100	beryl, columbite-tantalite, spodumene
Gursaisk (Ghursalak)	Dara-i-Pech	70.7259 (70.7389)	34.9644 (34.9631)	1,495	beryl, columbite-tantalite, cassiterite
Awlaghal	Dara-i-Pech	70.7234	34.9434	1,914	Spodumene, cassiterite, beryl, schorl
Darrahe	Dara-i-Pech	70.7201	34.8976	2,680	Beryl, pollucite
Paciram (Pachigram)	Pachigram	71.1762	35.7682	4,170	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite, cassiterite
Tsamgal	Pachigram	71.0419	35.2958	3,145	Spodumene
Canigal	Pachigram	71.1184	35.7278	3,690	Spodumene
Dega (Degha)	Pachigram	71.0641	35.6381	4,270	Spodumene, lepidolite, albite, microcline, polychromic tourmaline, columbite-tantalite
Tsotsum	Pachigram	71	35.5833	3,945	Tourmaline
Mualevi	Pachigram	71.0832	35.7667	4,702	Tourmaline

24A.4.2 Pegmatite Fields

24A.4.2.1 Paron (Jamanak-Pasghushta) Pegmatite Field

The Paron (Jamanak-Pasghushta) pegmatite field (figs. 24A–2, 24A–3) is situated in the north-east of the Nuristan Province in Early Proterozoic metamorphic schists, as well as in slightly metamorphosed sedimentary rocks of Late Triassic age (Abdullah and Chmyriov, 2008). The Paron field pegmatites were intruded adjacent to an Oligocene granite intrusion. The Paron field is important primarily for lithium, which occurs here in the lithium-bearing pyroxene, spodumene. This field contains two long zones (groups) of spodumene dikes, the Paprok and Waygal, and two shorter zones (groups), the Pasgusta and Drumgal. In the Paprok zone, spodumene dikes have been defined at Pakawalpet, Jamanak, Pashki, and Boni.. In the Waygal zone, spodumene dikes have been defined at Alma, Tramgal, Samgal, Inshaghar, Aranch, and Nangalam. Five large lithium deposits are included in this field: Jamapak, Pasgusta, Drumgal, Canga, and Pasghushta Lower. Veins and vein zones of the spodumene-albite pegmatites are up to 1 to 5 km in length and 20 to 40 m wide (Abdullah and Chmyriov, 2008).

The types of pegmatites in this field include:

1. oligoclase-microcline biotite-muscovite (barren);
2. schorl-muscovite-microcline with beryl;
3. albitized microcline and albite with lithium phosphate;
4. spodumene-microcline-albite and spodumene-albite; and
5. spodumene-microcline cleavelandite with pollucite and tantalite (Abdullah and Chmyriov, 2008).

24A.4.2.2 Pacigram (Pachigram) Pegmatite Field

The Pacigram pegmatite field is confined to a narrow and long graben syncline (a term used by Adullah and Chyriov, 2008) that appears to indicate a graben containing rocks folded into a synclinal structure) involving Upper Carboniferous to Lower Permian schist and Proterozoic schist and gneiss that are intruded by Oligocene granite (figs. 24A–2, 24A–3). Three types of pegmatite dikes have been distinguished in the area:

1. oligoclase-microcline, schorl tourmaline-muscovite;
2. albite with much phosphate; and
3. spodumene-microcline-albite and spodumene-albite (Abdullah and Chmyriov, 2008).

The spodumene-microcline-albite and spodumene-albite pegmatites may be economic and are found at Dega, Canigal, and Pachigram. At least 100 pegmatite dikes are currently known. Thickness of the pegmatites ranges from 1 to 20 m wide, and they are 10 m to 1 km in length. Pegmatite samples can have 0.3 to 5 weight percent Li_2O, 0.001 to 0.01 weight percent Nb_2O_5, 0.001 to 0.01 weight percent BeO, and 0.006 to 0.04 weight percent Sn (Abdullah and Chmyriov, 2008).

24A.4.2.2.1 Pasgusta (Pashgushta) Deposit

The Pasgusta deposit (figs. 24.0A–2, 24A–3) contains a zone of steeply dipping pegmatite dikes in Upper Triassic schist. This zone varies in width between 30 and 250 m and extends for about 10 km. The largest dikes are up to 600 to 800 m long and 20 to 30 m wide. The pegmatites are of the spodumene-microcline-albite and spodumene-albite types and contain finely disseminated columbite-tantalite minerals and some cassiterite. Three spodumene dikes in the upper reaches of the Pasgushta River total 70 m in thickness and contain an average Li_2O content of 1.96 weight percent. In the area of Pasgushta Pass, a 20-m interval contains an average Li_2O content of 2.14 weight percent. Speculative Li_2O reserves of the Pashgushta deposit are 1,050,000 tonnes (t) to a depth of 100 m. The Rb and Cs content is less than a few hundredths of 1 percent. The Ta_2O_5 content varies between 0.002 and 0.007 weight percent (Abdullah and Chmyriov, 2008).

24A.4.2.2.2 Drumgal Deposit

The Drumgal pegmatite bodies were intruded into Upper Triassic schist (figs. 24A–2, 24A–3). The three spodumene-microcline-albite pegmatite dikes that currently comprise this deposit vary in thickness from 7 to 30 m and are between 1 and 2 km in length. The Li_2O content ranges from 1.38 to 1.58 weight percent. Speculative Li2O reserves were calculated to be 253,000 t to a depth of 100 m. In one pegmatite dike, a 30-m interval contains 0.06 weight percent Ta_2O_5 with a tantalum to niobium ratio of less than 5:1. The Ta_2O_5 content averages 0.03 weight percent over the full 60 m thickness of the dike (Abdullah and Chmyriov, 2008).

24A.4.2.2.3 Jamanak Deposit

Pegmatites in the main part of the deposit were emplaced in Triassic age quartz-muscovite-biotite, garnet-staurolite-mica, and biotite schists over an area of about 2 km^2 (figs. 24A–2, 24A–3). Three types of pegmatite dikes are recognized:

1. spodumene-microcline-albite;
2. strongly albitized pegmatite with spodumene and cymatolite (a mixture of albite and muscovite usually replacing spodumene); and
3. albite (Abdullah and Chmyriov, 2008).

At the Jamanak deposit, the spodumene dikes make up four zones or groups. Those of the first zone range in width from 10 to 20 m and extend as far as 1 km, being composed of the following mineral assemblage:

1. 60 to 65 percent spodumene-microcline-albite;
2. 15 percent spodumene-microcline-quartz;
3. 15 to 20 percent spodumene-albite; and
4. 5 to 10 percent albite (Abdullah and Chmyriov, 2008).

The second zone ranges from 10 to 15 m thick; the third, 5 to 7 m thick, and the fourth, 2 to 6 m thick. The lengths of both the second and fourth pegmatite zones are 800 m, while the third zone exceeds 2 km in length. The Rb and Cs content of the pegmatite zones is 0.02 weight percent or less and the Ta_2O_5 content is 0.006 weight percent. The average Li_2O content of the deposit is 1.53 weight percent. The speculative Li_2O reserves to a depth of 100 to 250 m total 294,000 t for zones I, II, and III. The total Li_2O reserves of the entire deposit to a depth of 100 m are 450,000 t (Abdullah and Chmyriov, 2008).

24A.4.2.2.4 Yorigal (Yarigul) Deposit

The pegmatites of the Yorigal deposit occur in Proterozoic schist and gneiss (figs. 24A–2, 24A–3) and contain large crystals of muscovite, schorl, and beryl. The thickness of the pegmatite dikes ranges from 1.5 to 5.0 m, and the lengths are from 0.5 to 3.5 km. Pegmatite dikes are of the spodumene microcline-albite type. The speculative lithium oxide reserves are 130,000 t. The almost flat-lying dikes of the Yorigal deposit are similar to dikes in the Wasgul area, and may be tantalum-bearing (Abdullah and Chmyriov, 2008).

24A.4.2.2.5 Pasgusta-Under (Lower Pasgushta) Deposit

The Pasgusta-under deposit consists of two tabular pegmatite dikes in Upper Triassic schist (figs. 24A–2, 24A–3). Their thickness ranges from 20 to 25 m, and lengths are 500 and 750 m. The pegmatite, which is of the spodumene-albite type, has the following mineral composition: 10 to 15 volume percent microcline blocks, 25 to 30 percent spodumene crystals, 60 volume percent fine-grained muscovite-quartz-albite aggregates, and 1 to 3 volume percent other mineral aggregates (cleavelandite). The Li_2O is uniformly distributed within the dikes, with the content in the range from 2.00 to 2.31 weight percent (2.2 percent on the average). Possible Li_2O reserves to a depth of 100 m are 124,000 t (Abdullah and Chmyriov, 2008).

24A.4.2.2.6 Pashki Deposit

Pegmatites in the Pashki deposit were intruded into metamorphosed Upper Triassic sedimentary rocks (figs. 24A–2, 24A–3). Four types of pegmatite have been recognized within an area of approximately 7 km^2:

1. albitized microcline with densely disseminated phosphate minerals and scarce beryl;
2. spodumene microcline-albite;
3. heavily albitized, with spodumene; and
4. spodumene-cleavelandite microcline with pollucite (Abdullah and Chmyriov, 2008).

The principal types of ore-bearing pegmatites are those that contain spodumene, microcline, and albite. Two large dikes, Dikes 1 and 3, and Dike Zone 2 are of this type. Dike 1 is 1 km in length and ranges in thickness from 7.5 to 60 m. Dike 1 is exposed for 600 m down dip by erosion and contains 15 to 25 volume percent spodumene. Dike 3 is 600 m in length and 2 to 8 m in thickness. This dike contains 15 to 20 volume percent spodumene. Pegmatite dikes in Dike Zone 2 vary in thickness between 0.5 and 10 m and have a total thickness of 5 to 10 m. While Dike Zone 2 may extend for a distance of 2.5 km, individual pegmatite dikes may range from 5 to 300 m. In some places, the spodumene dikes are arranged en echelon, and in other places they form a complex network of subparallel dikes. The dikes contain between 0.01 and 0.02 weight percent Rb and Cs and between 0.002 and 0.008 weight percent Ta_2O_5. Dike 1 contains an average of 1.46 weight percent Li_2O; Dike 3 contains an average of 1.56 weight percent Li_2O. Pegmatites in Dike Zone 2 contain an average of 2.1 weight percent Li_2O. Total possible Li_2O reserves of Dikes 1 and 3 and dikes in Zone 2 to a depth of 100 m are 127,000 t (Abdullah and Chmyriov, 2008).

24A.4.2.3 Darrahe Pec Pegmatite Field

The Darrahe Pec pegmatite field is located mainly within the Early Cretaceous age Nilau igneous complex at the southern end of the Nuristan rare-metal pegmatite AOI (figs. 24A–2, 24A–3). The pegmatites are emplaced in gabbro and diorite. This is a rather small field, on the order of 85 km^2. The Darrahe Pec pegmatite field contains the following types of pegmatites:

1. oligoclase-microcline, schorl tourmaline-biotite-muscovite (barren) pegmatite;
2. albitized microcline pegmatite with coarse beryl; and
3. spodumene-microcline-albite pegmatite.

Albite-bearing pegmatites contain beryl and disseminated columbite-tantalite. The field includes the Darrhe-Pec deposit, which contains economic concentrations of lithium, beryllium, tantalum, tourmaline, and kunzite.

24A.4.2.4 Kantiway Pegmatite Field

The Kantiway pegmatite field is located within Proterozoic metamorphic rocks (figs. 24A–2, 24A–3). This field is on the order of 130 km^2 in area. This field contains four types of pegmatites which are similar to those from the Darrahe Pech:

1. oligoclase-microcline, schorl tourmaline-muscovite (barren);
2. albitized microcline;
3. albite; and
4. spodumene-albite.

Some of the large spodumene-albite pegmatite dikes are rich in tantalite, kunzite, piezooptic (a change in refractive index induced by a change in pressure) quartz, and tourmaline. One pegmatite dike which was examined in detail was on the order of 300 m long and 0.5 to 15 m thick (Abdullah and Chmyriov, 2008). One 150-m^2 section, containing cleavelandite aggregates with tourmaline and muscovite, was found to have cavities lined with smoky quartz, green tourmaline, and kunzite crystals. Cassiterite grains and manganotantalite lamellae are also present in that pegmatite (Abdullah and Chmyriov, 2008).

24A.5 Vertical Zonation and Structural Patterns of Pegmatites Within Pegmatite Fields

Pegmatites within many pegmatite fields exhibit a pattern of vertical zonation that is also a common characteristic of pegmatites throughout the Nuristan rare-metal pegmatite AOI. In addition, pegmatite orientations are peculiar to some pegmatite fields and are most likely determined by the dominant host rock of that field.

Fenogenov and Musazai (1989) documented a zonation in pegmatites over a vertical range of 1,500 to 2,000 m in the Darrahe Pec and Drumgal deposits (figs. 24A–5, 24A–6, 24A–7. From top to bottom that zonation is described as:

1. albite-spodumene with a large amount of microcline and a small admixture of cassiterite, beryl, and columbite;
2. essentially albitic with rare spodumene, small phenocrysts beryl and tantalite-columbite;
3. microcline-albitic with ore, screened beryl, and tantalite-columbite; and
4. essentially microcline with rare beryl.

A similar zonation was noted in the Nilau-Kulam field (Rossovskiy, 1981a, b) (figs. 24A–2, 24A–8). From top to bottom that zonation is described as:

1. lepidolite-spodumene-albite pegmatites;
2. albite pegmatites with spodumene, polychrome tourmaline, and lepidolite;
3. albitized microcline pegmatites with kunzite and vorobievite (this does not appear to be a valid mineral species); and
4. plagioclase-microcline and albitized microcline pegmatites with schorl and beryl.

The vertical zonation suggests differentiation of pegmatites from oligoclase-microcline-biotite-muscovite to lepidolite-spodumene-albite. This zonation pattern has important implications during the exploration of minerals of economic importance in a pegmatite field. If only the feldspar plus mica (barren) pegmatites are present, the upper pegmatites with minerals of importance have probably been removed by erosion.

Vertical zonation from a two-mica granite to muscovite-feldspar pegmatites to beryl pegmatites and to lithium-rich pegmatites is a well documented fractionation trend in granitic magmas (Vlasov, 1961; Černý, 1982a; London, 2008). Increased albitization accompanies increased fractionation in these pegmatites (fig. 24A–8).

In zoned districts the generalized sequence of pegmatites is (Černý, 1982a):

1. barren pegmatites of granitic texture, with magnetite and biotite;
2. barren plagioclase-microcline pegmatites, partly graphic, with biotite and schorl;
3. microcline pegmatites, partly graphic, with schorl, muscovite, and beryl;

4. zoned microcline-albite pegmatites, partly albitized, with muscovite, schorl, beryl and Nb-Ta minerals;
5. zoned microcline-albite pegmatites, extensively replaced, with lithium, rubidium, cesium, tantalum, boron, phosphorous, and fluorine mineralization;
6. albite pegmatites with lithium, beryllium, tin, and tantalum mineralization;
7. relatively homogeneous albite-spodumene pegmatites with minor beryllium, tin, and tantalum mineralization;
8. essentially quartz veins with minor feldspar(s) and one or more of beryl, cassiterite, or wolframite.

The structural disposition of the pegmatites in various pegmatite fields is determined by either the host rock lithology or by the structural history of the host rocks, or both. Pegmatites are characterized as (1) steeply dipping veins, (2) flat to gently dipping sills, and (3) small intraformational lenticular bodies. Gently dipping pegmatite sills, which are characteristic of the Nilaw, Kulam, Darrahe Pech and some other fields, are developed mainly in gabbroic and diorite bodies of the Nilaw complex (figs. 24A–5, 24A–6, 24A–9, 24A–10). Some gently dipping and cross-cutting sills occur in Proterozoic gneiss in the Paran pegmatite field, also. Steeply dipping pegmatite veins in the Paran pegmatite field occur in schists and form linearly elongated zones which are conformable with the schistosity and fold patterns of the enclosing rocks (figs. 24A–10). Small intraformational lenticular bodies are associated with the contact zones of the Alingar Pluton.

Steeply dipping veins appear to contain most of the important lithium deposits and occurrences. The gentle to flat-lying pegmatites contain important concentrations of beryllium, tantalum, precious stones, piezo-quartz, and tourmaline. Those pegmatites closely associated with the granites are commonly considered to be likely non-economic (Abdullah and Chmyriov, 2008).

24A.6 Gemstone-Bearing Pegmatites

Relatively little is known about the potential of gemstone-bearing pegmatites in the Nuristan rare-metal pegmatite AOI. There is brief mention of gemstone-bearing pegmatites in the Kantiway pegmatite field. This field contains transparent crystals of green tourmaline and cassiterite grains, kunzite crystals, and manganotantalite lamellae (Abdullah and Chmyriov, 2008). Pegmatites in the Dara-i-Pech pegmatite field contain kunzite, and, as such, may also contain gem-quality tourmaline and beryl.

The more important and better known of the gemstone-bearing pegmatites in Afghanistan are in the Nilaw-Kulam pegmatite field (figs. 24A–2, 24A–3) which contain the Nilaw and Kulam deposits (Bariand, and Poullen, 1978; Bowersox and Chamberlain, 1995; Abdullah and Chmyriov, 2008). The Nilaw deposit consists of:

1. albitized microcline pegmatite with hand-sorted coarse-crystalline beryl;
2. albite pegmatite carrying tantalum mineralization; and
3. lepidolite-spodumene-albite pegmatite with tantalum mineralization, piezooptic tourmaline, and kunzite mineralization.

The Kulam deposit consists of a gigantic vein of albitized microcline pegmatite bearing kunzite, rock crystal, aquamarine, tourmaline, coarse-crystalline beryl, tantalite, and pollucite (Abdullah and Chmyriov, 2008).

24A.7 Estimation of Ore Reserves and Resources

In the Nuristan rare-metal pegmatite AOI, a number of economically viable pegmatites or pegmatite deposits, which may include one or more pegmatites, were proposed by Soviet geologists and noted in the succeeding literature (Abdullah and Chmyriov, 2008). The Pasgusta, Pasgusta-under, Camgal, Jamanak, and Drumgal deposits in the Paran pegmatite field (fig. 24A–3) are five large lithium deposits that also may contain economic concentrations of tantalum. The Darrahe Pec pegmatite field contains the Darrahe Pec deposit with potentially economic concentrations of lithium, beryllium, and tantalum. Lepidolite, amblygonite, pollucite, and petalite are noted in the Hindukush Alingar and Samakat pegmatite fields in the Hindukush pegmatite belt and in the Paran field in the Nurestan pegmatite belt (fig. 24A–2).

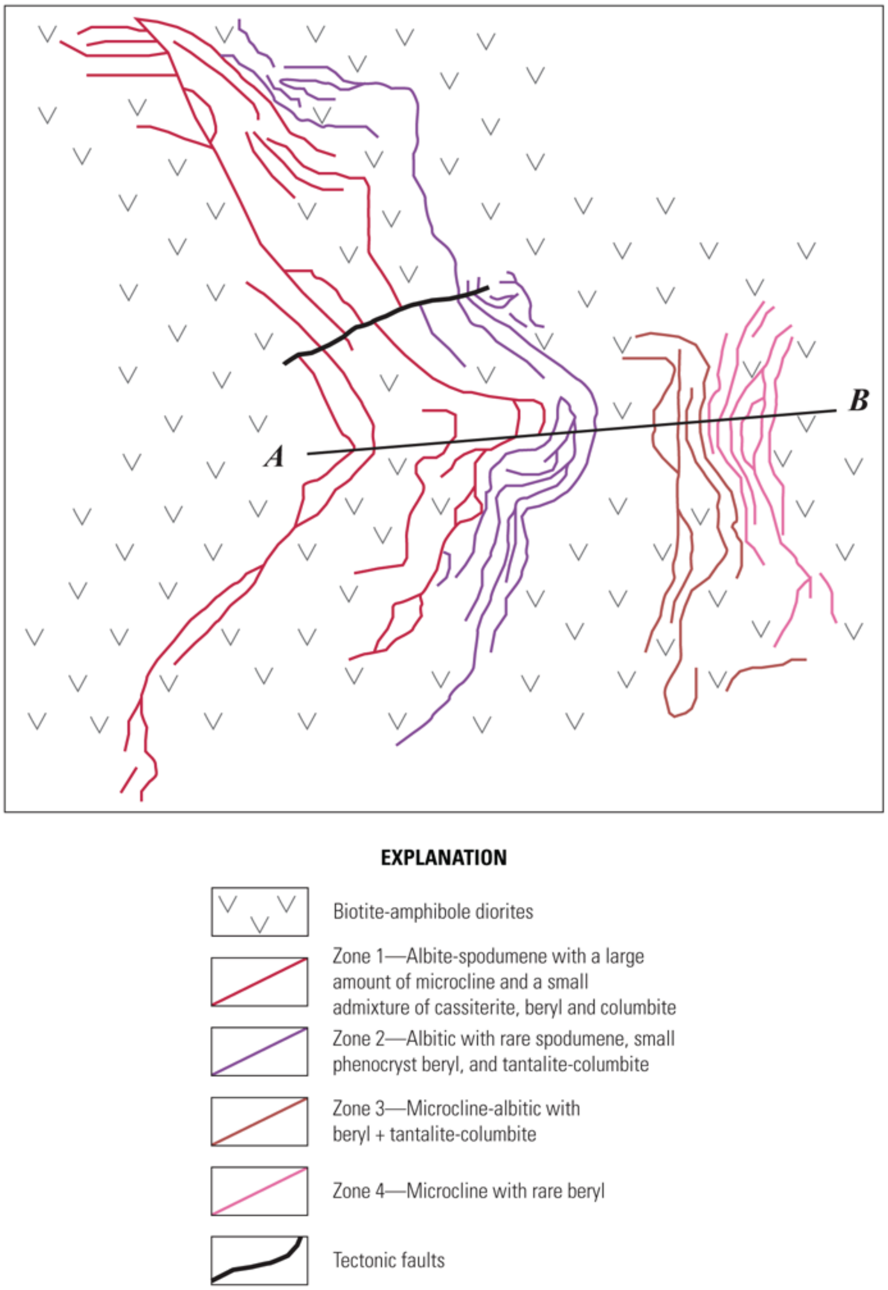

Figure 24A–5. Map of pegmatite zoning at Darrahe Pec (Darai-Pich) deposit (modified from Fenogenov and Musazai, 1989). Section A-B is shown in figure 24A-6.

Table 24A–3 contains mainly speculative estimates of Li_2O reserves and average concentrations of Ta_2O_5, rubidium and cesium calculated to a depth of 100 m. The calculations appear to be based on surface exposures and samples, as there are no indications of drilling, trenching, or underground workings. It is unclear when the information is shown as “NA” if there were no analyses requested or the analyses were below detection limits. The calculated reserves include only a few of the pegmatite deposits. It is unclear if these calculations represent only the perceived economic deposits or only the deposits investigated in detail. Unevaluated resources are probably much larger. No reserves are available for the gemstone-bearing pegmatites.

Table 24A–3. Speculative rare-metal reserves calculated to a depth of 100 meters and rare-metal grades.

[Data are from United Nations Economic and Social Commission for Asia and the Pacific (1995), Orris and Bliss (2002), and Abdullah and Chmyriov (2008)]

Pegmatite	Li_2O (metric tons)	Li_2O (weight percent)	Ta_2O_5 (weight percent)	Rb and Cs (weight percent)
Pasgusta	1,050,000	2.14	0.002 to 0.007	< a few hundredths
Drumgal	253,000	1.38 to 1.58	0.03	NA
Jamanak	450,000	1.83	0.006	0.02
Pasgusta-under	124,000	2.2	NA	NA
Pashki	127,000	1.46 to 2.1	0.01 to 0.02	0.01 to 0.02
Yorigal	130,000	NA	NA	NA
Total	2,123,000			

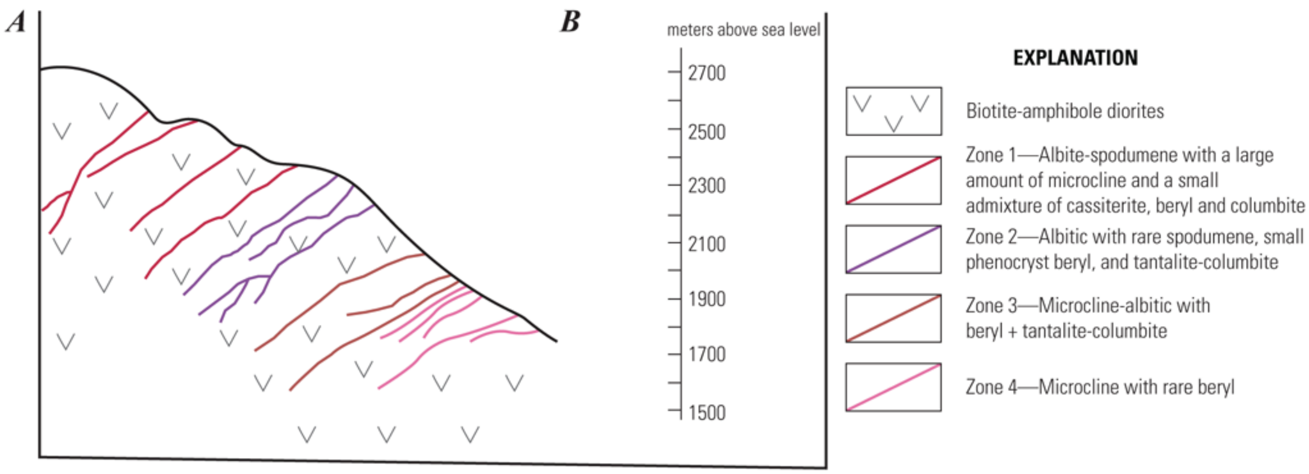

Figure 24A–6. Section *A-B* through the Darrahe Pec (Darai-Pich) deposit (modified from Fenogenov and Musazai, 1989). (Many maps and diagrams in the Russian literature lack vertical and horizontal scales.)

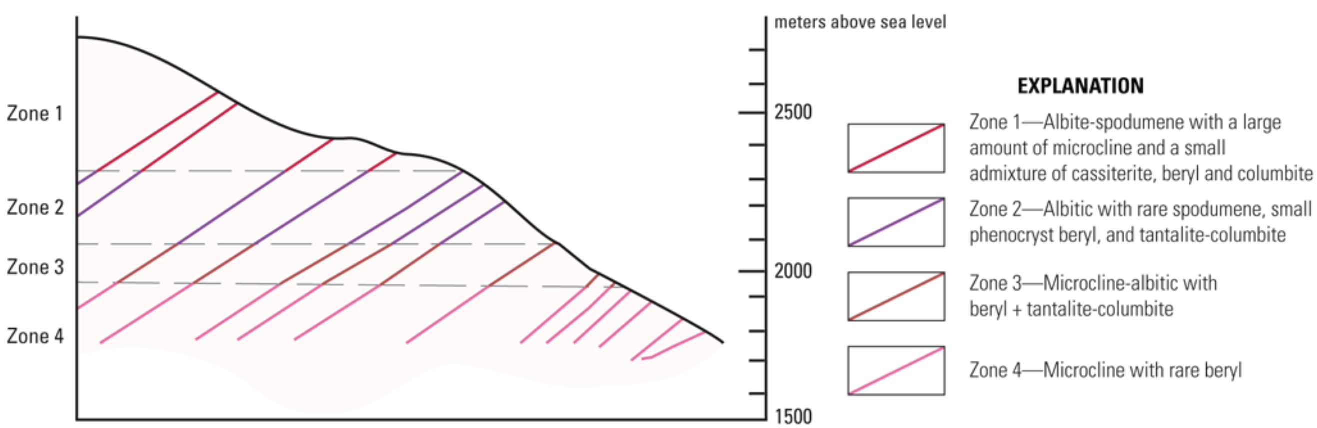

Figure 24A–7. Proposed vertical zoning of pegmatite mineralogy at the Darrahe Pec (Darai-Pich) deposit (modified from Fenogenov and Musazai, 1989). (Many maps and diagrams in the Russian literature lack vertical and horizontal scales.)

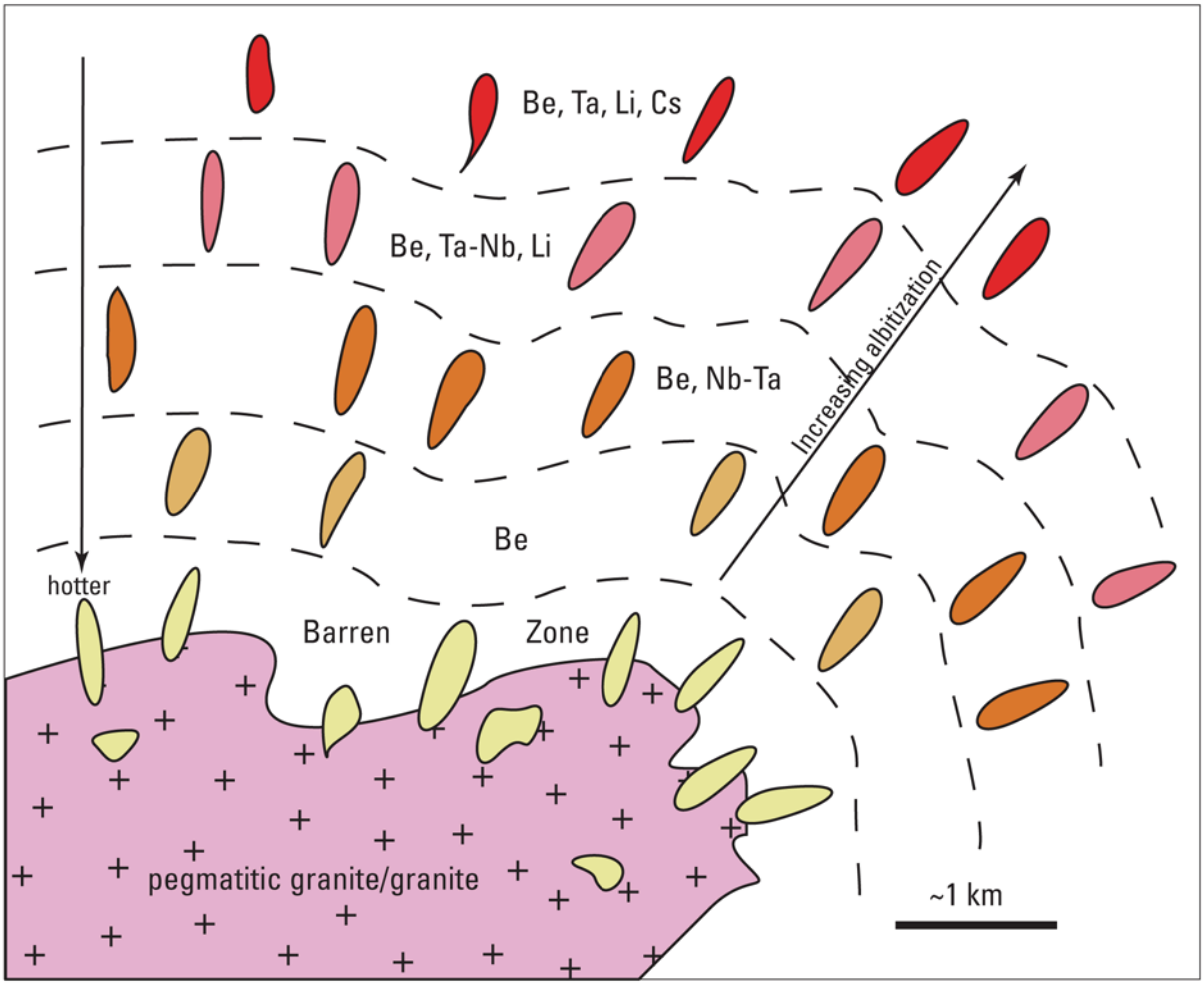

Figure 24A–8. Schematic distribution of pegmatite zoning peripheral to a granitic source (modified from Trueman and Černý, 1982).

24A.8 Genesis of the Pegmatite Deposits

Mapped zoning patterns and the pegmatites' mineralogy and geochemistry, noted above, indicate that the pegmatites are related to fertile, two-mica granites of the Oligocene-age Laghman intrusive complex.

Studies regarding genesis of the rare-metal types of pegmatites have evolved considerably during the past 30 years (Crouse and Černý, 1972; Stewart, 1978; Černý, 1982a,b, 1991a,b, 2005; Černý and Meintzer, 1988; Page and Page, 1998; Černý and Ercit, 2005; Linnen and Cuney, 2005; London, 2005, 2008; Stilling and Černý, 2006). Further discussions regarding the genesis and evolution of the pegmatites in this part of Afghanistan must wait for more detailed mineralogical and geochemical data.

24A.9 Further Evaluation of Pegmatites

Further evaluation of the pegmatites should involve more detailed work on the known pegmatites, as well as exploration and documentation of pegmatites for which there is little or no information. Selected chemical analyses for potassium, rubidium, and cesium of blocky K-feldspars demonstrate enrichment trends that could be used to distinguish those pegmatites or pegmatite fields that may be enriched in lithium, cesium, beryllium, and tantalum or to define which pegmatite fields or pegmatites may or may not be economic (Trueman and Černý, 1982). Similar results are demonstrated for chemical analyses of muscovite (Cocker, 1992).

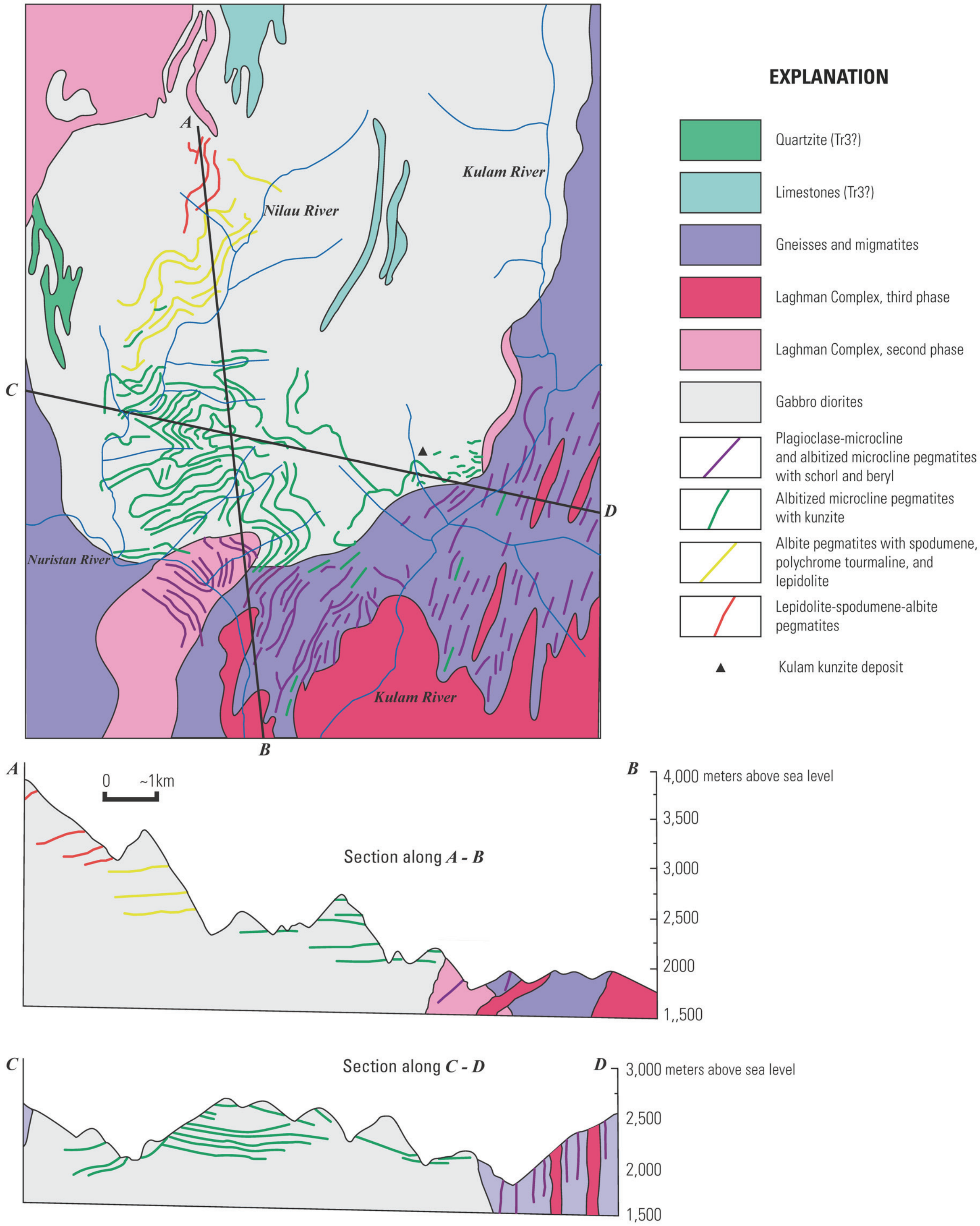

Figure 24A–9. Geologic map and cross sections *A-B* and *C-D* of the Nilaw-Kulam pegmatite field (modified from Rossovskiy, 1981b).

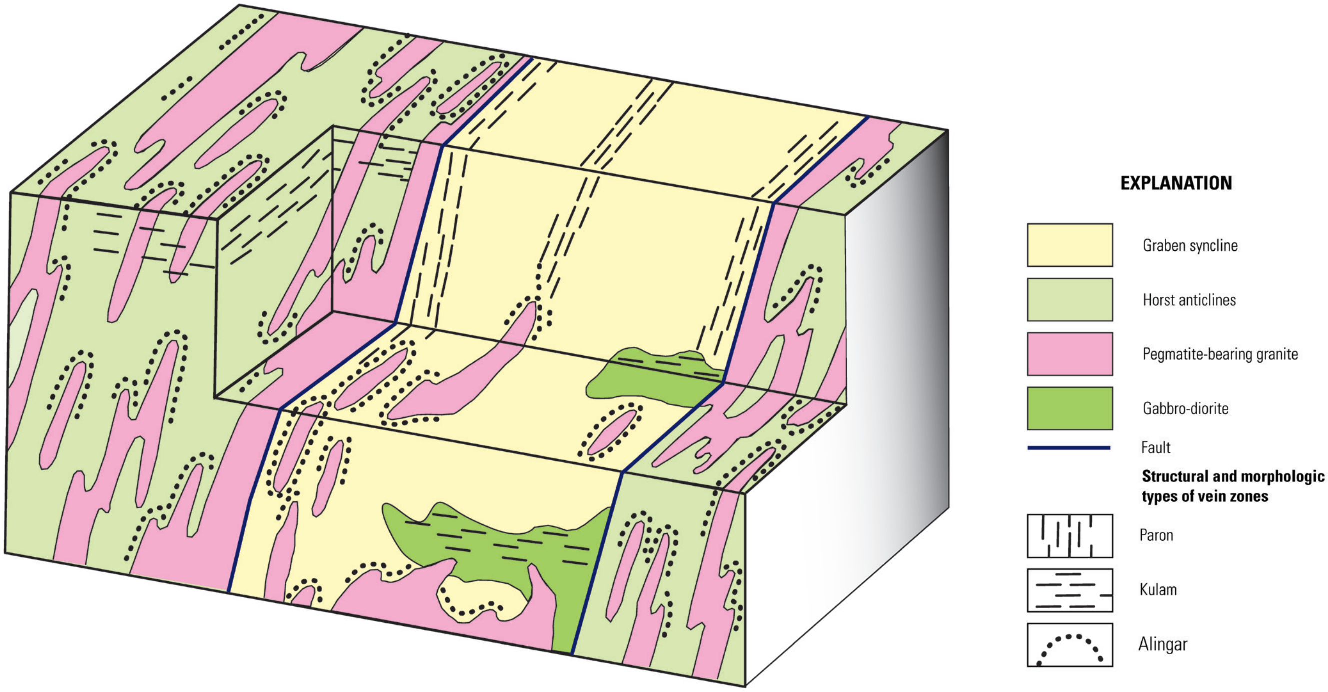

Figure 24A–10. Block diagram showing relations between rock structure and lithology with pegmatite orientations and pegmatite zone morphologies (modified from Bogatskiy and others, 1978). (Many maps and diagrams in the Russian literature lack vertical and horizontal scales).

Exploration “guidelines” for rare-metal pegmatites have been nonexistent until recently, because exploration has been limited to a few companies that have an interest in the development of these pegmatites. There are only a few published references regarding exploration for these types of pegmatites (Selway and others, 2005; Trueman and Černý, 1982). Specific guidelines for lithium-, rubidium-, and cesium-bearing pegmatites are not published but can be deduced from the following suggested exploration guidelines for generally tantalum-rich pegmatites (Selway and others, 2005):

1. Large, tantalum-bearing pegmatites tend to occur in proximity to regional faults.
2. The source for rare-metal pegmatites is more likely to be peraluminous fertile granite, and the majority of tantalum-rich pegmatites occur within 10 km of these types of fertile granite. Exceptions to this observation are the Greenbushes and Tanco pegmatites, where a source granite has not been located.
3. Rare-metal pegmatites commonly occur in greenschist to amphibolite metamorphic grade.
4. Amphibolites and metamorphosed ultramafic rocks are the most common host rock for world-class tantalum-bearing pegmatites.
5. The host rocks may be metasomatized in the vicinity of tantalum-rich pegmatites with the more common minerals including holmquistite (a lithium-bearing amphibole), (rubidium, cesium)-rich biotite, and tourmaline. Muscovite and garnet (almandine) may also occur in metasomatic aureoles.
6. Tantalum-bearing pegmatites generally contain spodumene or petalite as the dominant lithium-bearing mineral.
7. Spodumene is the most common lithium-bearing mineral in tantalum-rich pegmatites, although lepidolite, amblygonite, lithiophilite, petalite, eucryptite, and pollucite may be present or important lithium phases. The most important cesium-bearing mineral is beryl.
8. The most common tantalum ore minerals include manganotantalite, manganocolumbite, wodginite, and microlite. Other ore minerals include tapiolite, stibiotantalite, ixolite, and simpsonite. Tantalum-rich cassiterite is commonly associated with tantalum oxides in tantalum deposits.

9. Enrichment of tantalum tends to occur in the albite-rich zone, commonly with an aplite texture, and mica-rich zones such as the cleavelandite plus lepidolite zone. Tantalum-oxide minerals within aplites tend to be fine grained, whereas they are coarse grained in spodumene zones.

24A.10 Summary of Potential

Soviet geologists documented the geology, mineralogy, and geochemistry of the pegmatite fields in mountainous terrain with difficult access. The information that they obtained suggests the pegmatites in the Nuristan rare-metal pegmatite AOI may have a high probability for rare metals. However, much remains unknown about the geochemistry, mineralogy, internal mineral zoning, zoning patterns within pegmatite fields, or pegmatite groups and structural details of the pegmatites. Details essential for consideration of deposit development are lacking.

The pegmatites in the Nuristan rare-metal pegmatite AOI are genetically and spatially related to nearby fertile, two-mica granites of the Oligocene-age Alingar Pluton. Further studies and evaluations of the pegmatites should focus on the suggested techniques and guidelines noted above. Also, knowledge of the zoning relations and of the structural orientation preferences of the pegmatites in each field would be useful for purposes of evaluation and exploration.

The main physical difficulties to assessing the mineral resources found in pegmatites of the Nuristan rare-metal pegmatite AOI include the physical access to the mountainous terrain of this area. The road network into this region was damaged during the Soviet occupation of Afghanistan during the 1980s (Bowersox and Chamberlain,1995). Access to many of the pegmatites noted at the time was by jeep road to a certain point and then on foot for tens of kilometers on rough trails and over the few bridges over narrow gorges (Bariand and Poullen, 1978; Bowersox and Chamberlain,1995). Development of mining operations will require significant improvements to transportation network, a trained workforce, and dependable power and water supplies.

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