Chapter 11A. Summary of the Nalbandon Lead and Zinc Area of Interest

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Abstract

This report summarizes and interprets results of a compilation and review of the geological data for the Nalbandon area of interest (AOI) and its subareas from joint geologic and compilation activities conducted during 2009 to 2011 between the U.S. Geological Survey, the U.S. Department of Defense Task Force for Business and Stability Operations, and the Afghanistan Geological Survey.

The Nalbandon AOI is underlain by folded and faulted Mesozoic to Cenozoic sedimentary rocks, which are part of the Band-e-Bayan tectonic zone. Base metal occurrences in the AOI consist of epigenetic quartz-carbonate-sulfide veins and breccias, which occur mainly on east-northeast trending high angle faults of late Jurassic age. The predominant type of mineralization is lead, zinc, and (or) copper, with one gold occurrence in Mesozoic rocks and one mercury occurrence in Cenozoic sediments.

The Nalbandon AOI is underexplored. Of more than 50 mineral deposits or occurrences, only 2 have subsurface exploration and 6 have been sampled by surface trenching. The remainder have been visited and sometimes sampled in the course of reconnaissance exploration. The Nalbandon prospect, which was explored by trenching and a shallow adit, has an inferred resource of about 2 million metric tons grading 1 percent lead and 5 percent zinc. In addition, one trench at another prospect cut 18 meters of mineralized rock with a grade of 1.6 grams per metric ton gold.

The area warrants further exploration and has the potential for four types of mineral deposits: vein and (or) Mississippi Valley-type lead-zinc-±copper deposits; vein gold deposits; nonsulfide zinc deposits; and epithermal gold deposits below the Tilak mercury occurrence.

11A.1 Introduction

The Nalbandon area of interest (AOI), located in western Afghanistan (fig. 11A–1), contains a number of occurrences of lead-zinc mineralization, which were identified during work by the Afghanistan Geological Survey (AGS) in the 1960s and 1970s. The possibility that the prospects might represent Mississippi Valley-type (MVT) lead-zinc mineralization was highlighted during the assessment of nonfuel mineral resources in Afghanistan that was conducted during 2006 and 2007 by the USGS (Peters and others, 2007). Based on this assessment, the area was designated as one that warranted further work by the AGS, as it might attract investment in the Afghan mineral sector.

This report contains a summary of the geology and mineralization of the Nalbandon AOI based on a review of the available data. It is written to provide information for prospective investors in the Afghan mineral sector.

11A.2 Location and Access

The Nalbandon AOI is located in western Afghanistan about 160 kilometers (km) west of the national capital of Kabul (fig. 11A–1). The center of the AOI is about 64°12' E. longitude and 34°11' N. latitude.

Most of the AOI is within Ghor Province with the eastern half in the Shahrak District and the southwestern quarter in the Tulak District. The northwestern quarter of the AOI is in the Chisti Sharif

District of Herat Province. The provincial capital of Ghor Province, Changheharan, is located about 100 km east-northeast of the center of the AOI.

There are no paved roads within the AOI. Access to the area is via improved unpaved roads and tracks from the provincial capitals. The area is sparsely populated but has numerous small villages, mainly located along valley bottoms. Farming is the primary local activity. Villagers in the area are also reported to engage in artisanal mining and smelting of lead.

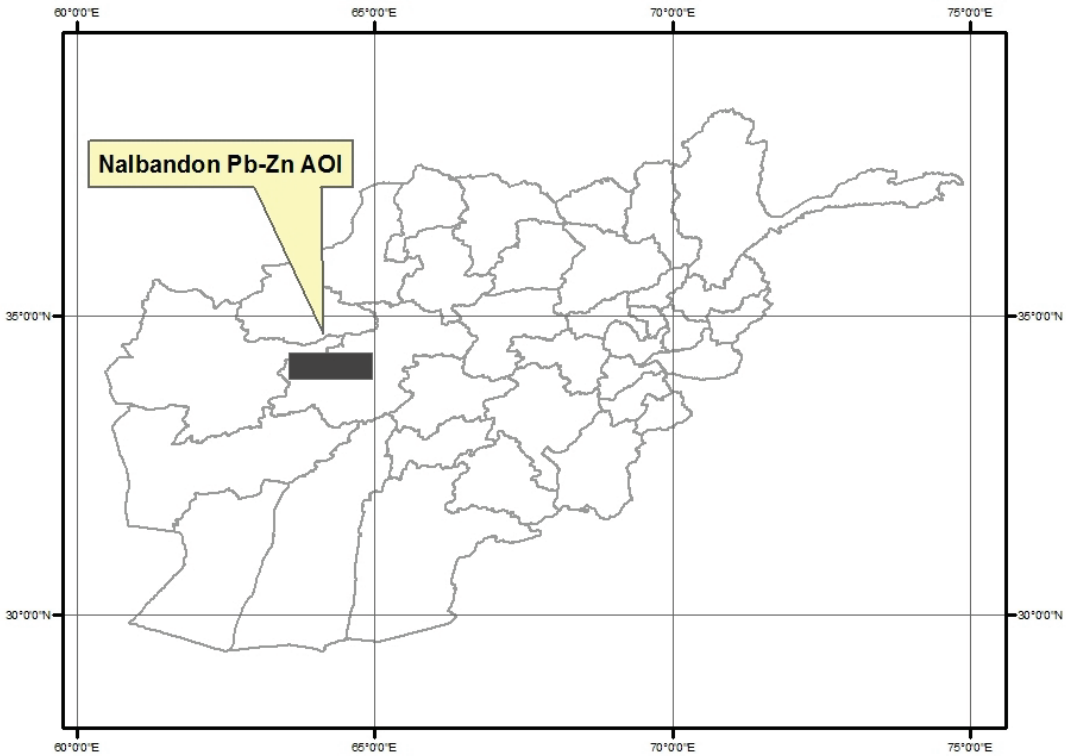

Figure 11A–1. Location of the Nalbandon lead and zinc area of interest.

11A.3 Previous Work and Available Data

11A.3.1 Previous Work

Field work in the Nalbandon AOI was conducted mainly between 1963 and 1978 by German and Russian geological teams working with the AGS (table 11A–1). The German Geological Mission worked in southwestern Afghanistan from 1963 to 1967 (German Geological Mission, 1969). The focus of their project was regional reconnaissance geological mapping at 1:250,000 to 1:1,000,000 scales. Technoexport of the USSR also worked in southwestern Afghanistan from 1966 to 1978 with a focus on mineral exploration in addition to geological mapping.

D. Weippert and H.P. Wittekindt of the German Geological Mission were shown ancient or artisanal mines, which exploited lead mineralization in the Nalbandon area while carrying out regional geological mapping in the summer of 1963 (Siebdrat, 1964, Siebdrat and Kastner, 1964, Siebdrat and Wirtz, 1964). An initial examination of the showings was completed in 1965 and further work was recommended (Siebdrat, 1965, Scheer and others, 1969). In 1966, a team from Technoexport also visited the area and completed brief examinations of several prospects (Khasanov and others, 1967). The Russian team recommended further work, which was awarded to the German Mission.

In 1967, Bergbau-Planung of Germany was contracted to conduct more detailed exploration and preliminary economic evaluation of the showings (Scheer and others, 1969). An initial survey of lead-zinc showings in the area was completed in the fall of 1967. Further work was recommended at the Siah Sang (Sarghol) and Nalbandon prospects. In 1968, a short adit was driven at Nalbandon and six shallow drill holes were completed at Siah Sang, followed by metallurgical testing and a preliminary economic evaluation of the Nalbandon prospect in 1969 (Scheer and others, 1969).

From 1967 through 1971 Technoexport conducted 1:500,000-scale geological mapping and mineral exploration in southwestern Afghanistan (Dronov and others, 1970, 1973). This work consisted of systematic traverses, stratigraphic studies, heavy mineral concentrate sampling, and prospect examinations in accordance with standardized Technoexport procedures. The program included prospecting over the entire Nalbandon AOI in 1969 and 1970, which resulted in the discovery of numerous base metal occurrences and one mercury occurrence. The Tilak mercury occurrence, located within the Nalbandon AOI, was one of many discovered in the course of the program, which led to southwestern Afghanistan being recognized as a mercury province (Dronov and others, 1973). Further work was recommended on the lead-zinc and mercury occurrences.

In 1970, a separate program focusing on mercury exploration was established by the AGS using Technoexport as a contractor. This project consisted of two field teams who worked in west-central Afghanistan in 1972 and 1973. As a part of this program, geological mapping, sampling, and trenching were completed at the Tilak mercury prospect in the Nalbandon AOI (Kornev and Arvanitaki, 1974).

In 1977 and 1978, the Herat mapping team of Technoexport conducted 1:200,000-scale regional mapping and exploration in the western part of the Nalbandon AOI (Tutubalin and others, 1979). The program included additional geologic mapping, systematic heavy mineral concentrate sampling, a large ground geophysical (SP) survey and detailed mapping, sampling, ground geophysics, and trenching at several prospects in the region including Nalbandon.

The area was covered by a regional aeromagnetic survey in 1966 (PRAKLA, 1967; Bosum and others, 1968). The Afghanistan Geological Survey summarized the geology and mineralization of the area in the early 1970s as a part of a compilation of the geology and of a minerals database for the country (Abdullah and others, 1977). In 1995, the United Nations Economic and Social Commission for Asia and the Pacific published a summary of the geology and mineral resources of Afghanistan as part of their Atlas of Mineral Resources series (United Nations Economic and Social Commission for Asia and the Pacific , 1995). This report was based largely on Abdullah and others (1977).

The U.S. Geological Survey reviewed and compiled the data on the geology, geophysics, mineralization, and mineral potential of the area as a part of an assessment of the mineral resources of Afghanistan (Orris and Bliss, 2002; Doebrich and Wahl, 2006; Sweeney and others, 2006a, b; Peters and others, 2007). As a result of the USGS mineral assessment, the Nalbandon area was designated as an AOI, which might attract further investment. In the course of the USGS project, new 1:250,000-scale geological maps of the area were compiled from existing larger scale maps (Bohannon and Lindsey, 2005a,b; Bohannon and Yount, 2005; McKinney and others, 2005; Williams, 2005) and true color Landsat image mosaics were prepared (Davis and Hare, 2007).

Table 11A–1. Summary of field work in the Nalbandon area of interest.

Period	Group	Work completed	Reference
1963-66	German Geological Mission	Reconnaissance prospecting, mapping, discovery of lead-zinc mineralization at Siah Sang.	Siebdrat, 1964; Siebdrat and Wirtz, 1964
1966	Technoexport	Lead-zinc prospect examinations.	Khazanov and others, 1967
1967–69	German Geological Mission	Topographic and geologic mapping, adit, trenching, drilling at Siah Sang, Sarghol and Nalbandon.	Scheer and others, 1969
1969–70	Technoexport	Regional prospecting. Discovery of the Tilak mercury anomaly.	Dronov and others, 1970, 1973
1972–73	Technoexport	Detailed heavy mineral concentrate sampling, geologic mapping, trenching at the Tilak mercury occurrence.	Kornev and Arvanitak, 1974
1977–78	Technoexport	Geologic mapping, trenching, sampling, stream sediment sampling, geophysical (SP) surveys.	Tutubalin and others, 1979
2008	Vilnius University	Geologic observations, petrologic analyses, rock geochemistry.	Motsuza and Šliaupa, 2008

The most recent field work in the AOI was conducted in 2008 by a team from the Department of Geology and Mineralogy of Vilnius University, Lithuania (Motuza and Šliaupa, 2008). They conducted regional geologic work and compiled data from previous work. During their field work in July 2008, they traversed through the eastern part of the AOI.

11A.3.2 Available Data

This report is a compilation of data from previous work. The AGS has an extensive archive of reports, maps, and data, which was inventoried by the British Geological Survey in 2007 (British Geological Survey, 2008). The majority of the reports relating to mineral resources are in Russian and Dari. Many have map legends with both Russian and English text, and a few reports were translated into English. Will Stetner and Karine Renaud of the USGS electronically scanned many of the reports, which pertained to the Nalbandon AOI in March 2011. As a result, much of the critical data on the AOI was available for review, with two important exceptions. The Russian text from the first Technoexport survey (Dronov and others, 1973) was not available and, although an English translation of the text was available, it did not contain the page-size figures or tables. Also, the text of the report by Tutubalin and others (1979) was incomplete so descriptions of some prospects were not available.

11A.4 Regional Geology

The Nalbandon AOI is located in west-central Afghanistan in a region dominated by strike-slip faults and compressional and extrusion tectonics related to the collision between India and the Eurasian Plate (Tapponier and others, 1981). The AOI covers part of the Band-e-Bayan tectonic zone and the northern part of the Farah Rod tectonic block or trough (Abdullah and others, 1977; Leven, 1997; Treloar and Izzat, 1993).

The majority of the AOI is underlain by rocks of the Band-e-Bayan zone, an east-west trending fold-thrust belt, which separates the Farah Rod to the south from the Feroz Koh to the north. The Feroz Koh is the southern margin of the North Afghan Platform. The Band-e-Bayan is bounded by the regional scale strike-slip faults including the Herat fault zone to the north and the Band-e-Bayan and Qarghanaw faults to the south. Between these faults are a number of discreet fault blocks composed of uplifted, folded and thrust blocks of dominantly sedimentary rock, ranging from Precambrian to Jurassic in age overlain by Neogene sedimentary rocks in fault bounded grabens (Kulakov, 1970; Dronov and others, 1973). The sedimentary rocks, which make up the individual blocks within the Band-e-Bayan zone, are equivalent to those in the northern Farah Rod. The Band-e-Bayan is considered by some to represent the deformed northern margin of the Farah Rod basin (Tapponier and others, 1981; Montenat, 2009). Deformation in the Band-e-Bayan reflects the Upper Jurassic to the Miocene compression and extrusion of western Afghanistan, which resulted from the collision between the Afghan block and Asia (Tapponier and others, 1981; Debon and others, 1987).

The Farah Rod block, or trough, is a west-opening wedge-shaped basin of mainly Mesozoic sedimentary rocks, which is bounded on three sides by major faults (Montenat, 2009). The northern boundary of the Farah Rod is the Qarghanaw-Band-e-Bayan strike-slip fault zone, which separates the Mesozoic basin sediments of the Farah Rod from the Band-e-Bayan fold-thrust zone. The southern margin of the Farah Rod is the northeast trending right lateral Kash Rod fault zone. This fault forms the northern edge of the Panjaro Suture, which separates the Farah Rod from the Helmand block to the south (Tapponier and others, 1981). The Helmand block is the remains of the ancestral Afghan continental block (Treloar and Izzat, 1993). To the west near the Iranian border, the Farah Rod is bounded by the north trending right-lateral strike-slip Hari Rod fault (Montenat, 2009), which marks the eastern edge of the Sistan suture zone (Tirrul and others, 1983).

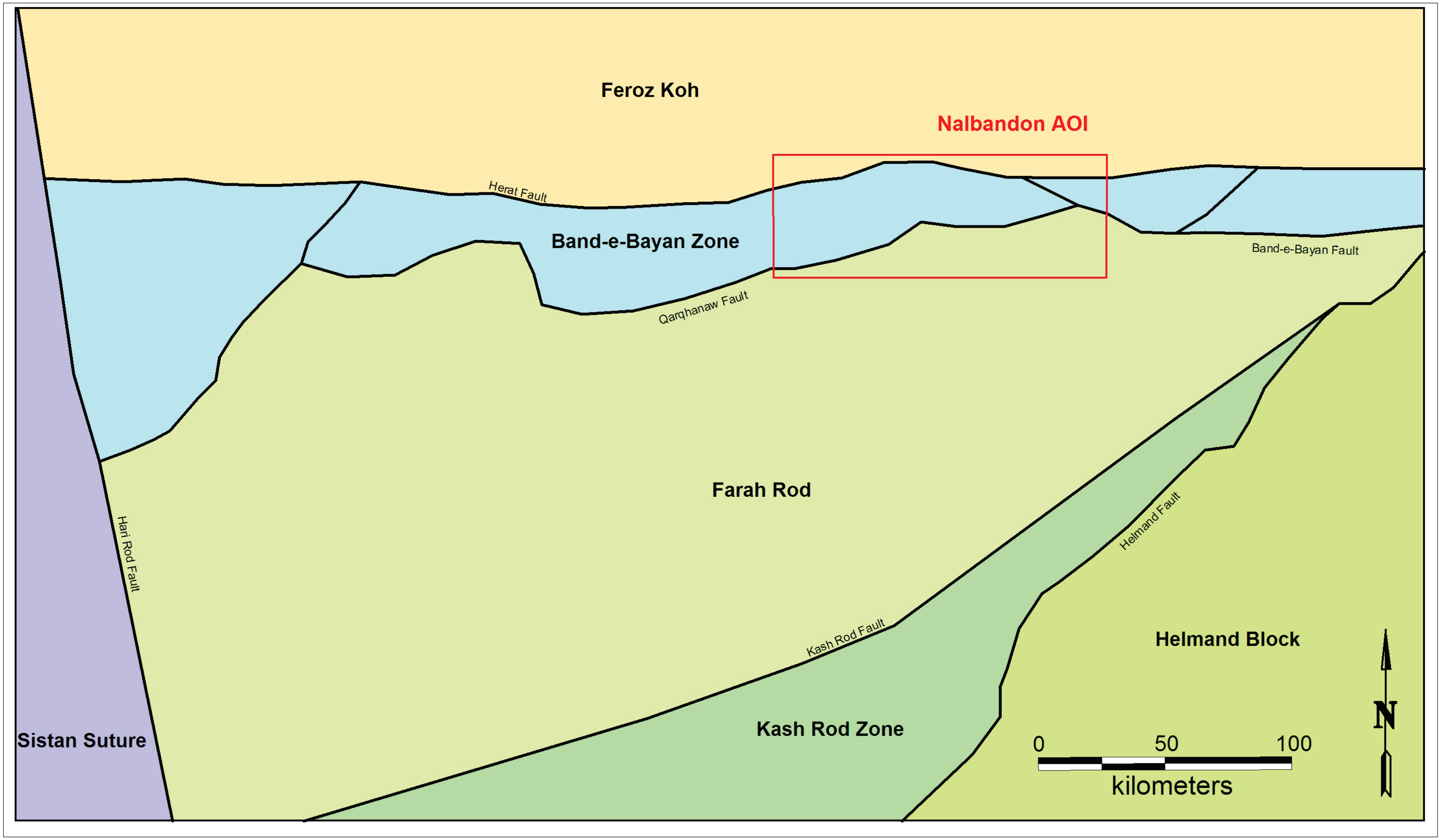

Figure 11A–2. Nalbandon area of interest (AIO) Regional Geologic Setting. Compiled from Abdullah and others (1977), Tapponier and others (1981), Debon and others (1987), Stocklin (1989), Treloar and Izzat (1993), Montenat (2009).

The central part of the Farah Rod consists of a very thick, greater than 15,000-meter (m) section of flysch sediments, ranging from Upper Triassic to Lower Cretaceous in age (Dronov and others, 1973; Montenat, 2009). The basement of the trough is not exposed. The lower part of the Triassic is made up of a sequence of siltstone, shale, and polymict sandstone overlying a basal limestone unit. The Triassic rocks are overlain with angular unconformity by Lower to Middle Jurassic conglomerate, sandstone, and siltstone capped by a thin section of limestone. The upper contact of the Jurassic sediments is also an angular unconformity. Cretaceous terrigenous red sandstones and conglomerate capped by carbonate rocks are the uppermost basinal unit.

The Mesozoic basinal sequence is overlain by locally thick units of Paleocene continental volcaniclasitic rocks (Montenat, 2009). Both the Band-e-Bayan zone and the Farah Rod trough are intruded by sparse Cretaceous and Eocene-Oligocene intermediate to granitic intrusives, which are related to extensional phenomena associated with the later stages of the westward extrusion of Central Afghanistan on the Herat and Helmand fault zones (Debon and others, 1987).

11A.5 Geology

Most of the Nalbandon AOI is underlain by rocks of the Band-e-Bayan tectonic zone (fig. 11A–3). This belt is composed of fault bounded blocks, referred to as “structural facies zones” by Abdullah and others (1977), and made up of sedimentary and lesser volcanic rocks, ranging from Paleozoic to Mesozoic in age (Dronov and others, 1973). The fault blocks are in turn overlain by Cenozoic sediments, which occur in small extensional basins, and by recent surficial deposits. Three major faults cross the AOI (the Herat fault, the Qarghanaw fault, and the Band-e-Bayan fault), two of which form the northern and southern boundaries of the Band-e-Bayan zone.

The Herat fault crosses the northern quarter of the Nalbandon AOI and is a major Afghan tectonic feature, which trends roughly east-west and has dextral strike-slip displacement. In western Afghanistan, it separates the Feroz Koh tectonic block and Afghan Platform to the north from the Band-de-Bayan structural zone and the Farah Rod block to the south. The Band-e-Bayan fault is a dextral strike-slip fault, also trending generally east-west, which appears to be a northerly splay of the Qargahnaw fault zone. It extends into the eastern part of the AOI where it separates the Band-e-Bayan block from the Nalbandon block. The Qarghanaw fault zone crosses the southern quarter of the AOI where it separates the Band-e-Bayan tectonic zone from the Farah Rod block to the south. The fault is also a major feature, which extends from central to western Afghanistan. It roughly parallels the Herat fault zone and has dextral displacement.

North of the Herat fault zone, the AOI is underlain by elongate blocks of middle Proterozoic gneiss, quartzite, marble, and amphibolite with sparse intrusives consisting of diabase, gabbro, and plagiogranite (Motuza and Šliaupa, 2008). These rocks form the southern edge of Feroz Koh tectonic block (Treloar and Izzat, 1993).

The southern part of the AOI is underlain by Mesozoic sedimentary rocks largely covered by Pliocene to Quaternary conglomerate and sandstone (Dronovand others, 1973). These sediments form the northern edge of the Farah Rod block or basin (Abdullah and others, 1977, Montenat, 2009).

The central part of the AOI, within the Band-e-Bayan zone is made up of five discrete fault bounded blocks of folded Paleozoic to Mesozoic sedimentary rocks, referred to as “structural facies zones” by Abdullah and others (1977). From west to east, these blocks are the Rode Kafgan, Haftqala, Kwaja Morad, Nalbandon, and Band-e-Bayan (Dronov and others, 1973). The blocks of Mesozoic rocks are overlain by Cenozoic sedimentary and volcanic rocks, which occur in small basins and are intruded by small bodies of Mesozoic-to-Cenozoic intermediate-to-granitic igneous rocks. Descriptions of the individual blocks are given below. Unless otherwise noted, the summaries are based on data in Dronov and others, (1973) and Abdullah and others (1977).

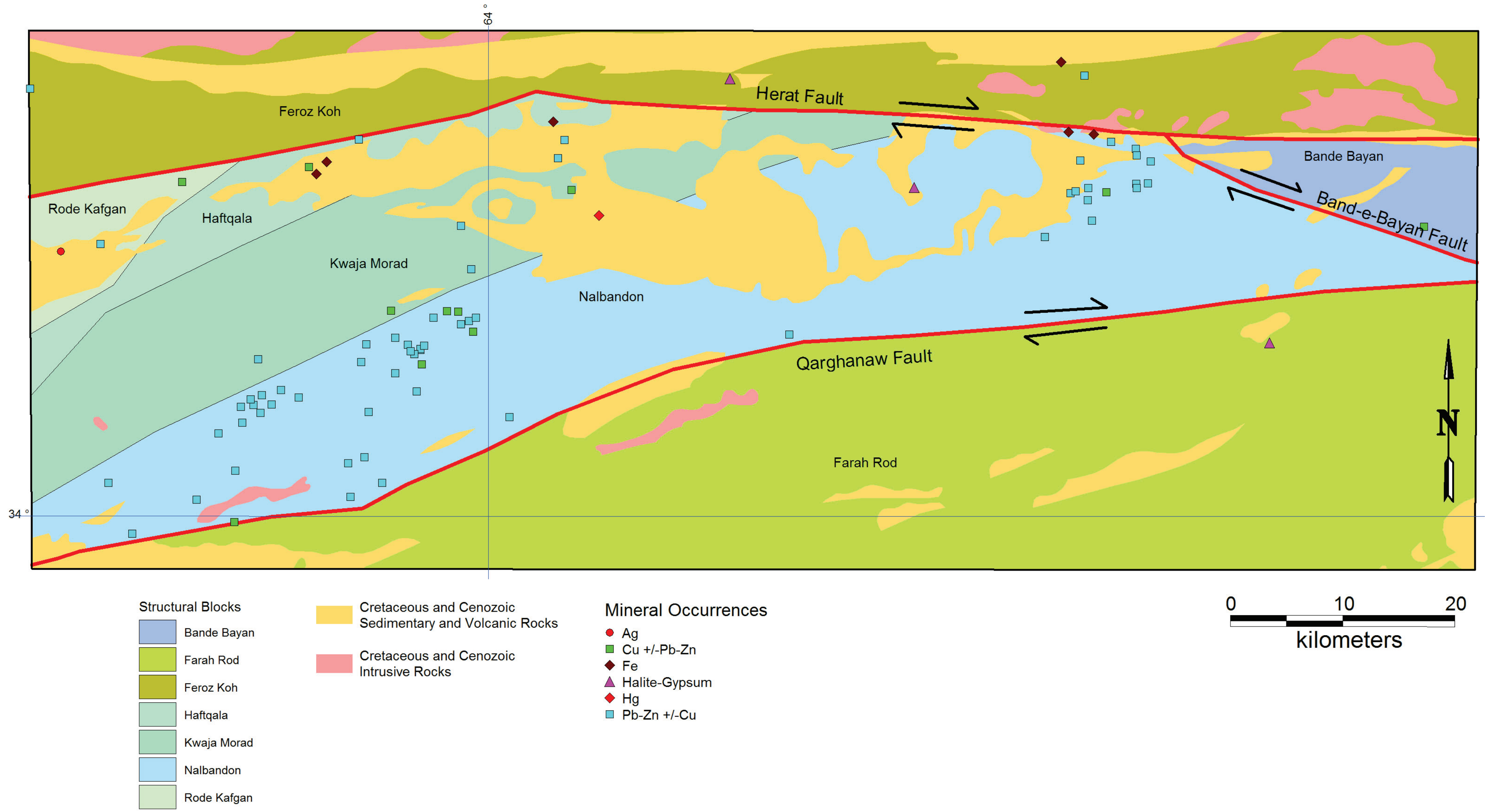

Figure 11A–3. Nalbandon area of interest tectonic map. Compiled from Dronov and others (1973), Abdullah and others (1977), and Tutubalin and others (1979).

The Rode-Kafgan block underlies a small triangular portion of the westernmost part of the AOI. According to Abdullah and others, (1977), the block is bounded on all sides by faults and is composed of a thick section of Norian to middle Jurassic terrigenous sedimentary rocks. The lower part of the section consists of 4,000 m of Norian-Rhaetian dark colored, sandstone, shale, and siltstone with abundant plant fossils. These are unconformably overlain by about 200 m of variegated sandstone and argillite of Lower Jurassic age capped by Middle Jurassic dark colored sandstone and siltstone. All of the rocks are deformed into northeast trending folds, which are overturned in the central part of the block.

The Haftqala structural facies zone is an elongate northeast trending fault bounded block, which crops out to the east of the Rod-i-Kafgan zone. About half of the northeastern part of the zone is covered with Cenozoic sedimentary and volcanic rocks. The Haftqala zone is composed of sedimentary rocks, ranging from Devonian to Upper Triassic in age. The thickness of the Devonian sedimentary rocks that make up the base of the section is not known. They are conformably overlain by 1,100 m of dominantly carbonate sedimentary rocks. The Carboniferous to Permian part of the section consists of 900 to 1,000 m of thinly bedded shallow water limestone and dolomite, and reefal limestone. Quartz sandstone and bauxite occur at the top of the Lower Carboniferous, indicating a break in sedimentation. Limestones with karst features occur at the base of the Upper Jurassic and are overlain by variegated sandstone, siltstone, and limestone. The entire section is deformed into northeast trending brachyform folds.

The Kwaja Morad structural facies zone is a northeast trending block, which underlies the west-central part of the AOI. The boundaries are not exposed but are assumed to be fault bounded. Parts of the northeastern portion of the zone are covered by Cenozoic sediments and volcanics. The Kwaja Morad block consists of a section of Carboniferous to Triassic sedimentary rocks. The lower part of the section consists of 4,000 to 5,000 m of Carboniferous to Lower Permian black slate. This is overlain by 150 to 200 m of Upper Permian to Upper Triassic (Norian) carbonate rocks consisting of limestone, dolomite, carbonate conglomerates, marl, and sandstone. The top of the section is made up of 2,000 to 3,000 m of Upper Triassic (Norian-Rhaetian) terrigenous flysch. The entire section is folded into northeast trending linear brachyform folds.

The Nalbandon structural facies zone underlies most of the central part of the AOI. The eastern margin of the block is a fault. The western margin is not exposed but is assumed to be a fault. The Nalbandon block consists of a wider range of Paleozoic-Mesozoic rocks than the blocks to the west. The lower part of the section made up of sediments of Carboniferous to Lower Permian age is similar to the Kwaja Morad section of the same age, but the Upper Permian rocks are quite different. In the Nalbandon block, the Upper Permian to Upper Triassic (Carnian) beds consist of 150 m of deep water cherts. Middle Jurassic sedimentary rocks unconformably overlie folded Triassic and older rocks in the Nalbandon block. The Jurassic succession is 385- to 565-m thick. It consists of a thin basal conglomerate-sandstone unit overlain by alternating argillaceous limestone, marl, and shale (Dronov and others, 1973). The Jurassic sediments and underlying rocks are folded into east-northeast trending open folds and cut by steeply dipping east-northeast trending faults. In a number of places, the Jurassic sedimentary rocks are draped over the faults to form monoclines (Dronov and others, 1973).

In the central part of the block, undeformed Upper Cretaceous limestone, Eocene to Oligocene andesitic volcanic rocks and terrigenous conglomerates, and Neogene conglomerates overlie the Carboniferous to Jurassic section. Based on this relationship, Dronov and others (1973) concluded that the youngest episode of deformation was late Jurassic or possibly mid-Cretaceous.

The Band-e-Bayan structural facies zone underlies a triangular shaped area in the east-central edge of the AOI. The block is bounded to the north by the Herat fault zone and to the southwest by the Band-e-Bayan fault zone. The Band-e-Bayan block differs from the other structural facies zones in the AOI, because it is composed of lower Paleozoic sedimentary rocks. The section consists of Cambrian clastic sediments and volcanic rocks, lower to middle Devonian carbonates, and late Devonian to

Mississippian limestone, dolomite, marl, and chert. These are unconformably overlain by Oligocene to Pliocene clastic sediments.

Igneous rocks make up a relatively small part of the AOI. Patches of Eocene to Oligocene volcanic rocks composed of mainly andesitic basalt, basalt and related tuffs, and clastic sediments occur in elongate areas (probably grabens) along the south side of the Herat fault zone in the northwestern part of the AOI and overlying the Qarghanaw fault zone in the south-central part of the AOI (Dronov and others, 1973).

Upper Cretaceous calcalkaline granite and granodiorite intrusives crop out in several areas in the Feroz Koh north of the Herat fault zone and are the most common intrusives within the AOI (Debon and others, 1987). In the southern part of the AOI, two elongate granitic intrusive bodies of Oligocene age are present (Abdullah and others, 1977).

11A.6 Mineral Deposits

Abdullah and others (1977) and Orris and Bliss (2002) list 26 mineral occurrences in the Nalbandon AOI. Dronov and others (1973) include sketch maps of the Nalbandon and Gharghananaw areas, which show a number of additional mineral occurrences. Tutubalin and others (1979) show 44 mineral occurrences in the eastern third of the AOI, the area covered by their work. The copy of Dronov and others (1973) that is available to the USGS did not include the maps of the Nalbandon and Gharghananaw areas. However, Motuza and Shiaupa (2008) provided the USGS with photos of the maps they were able to take in Kabul. The USGS reconciled the locations of mineral occurrences from the various sources and compiled a new minerals database for the Nalbidon AOI (fig. 11A–4).

The mineral occurrences in the Nalbandon AOI are located mainly in two areas and referred to as the Nalbandon and Ghargananaw Districts. The description of the mineral occurrences starts with the Nalbandon District.

11A.6.1 Nalbandon District

The Nalbandon District is located in the southwestern part of the AOI (fig. 11A–4). The area is underlain by east-northeast trending folded sedimentary rocks, which make up the type area of the Nalbandon block within the Band-e-Bayan tectonic zone (Dronovand others, 1973). The southern part of the area is underlain by Carboniferous to Lower Permian dark sandstone, siltstone, and slate, which are overlain by Upper Triassic dark colored sandstone, siltstone, and shale (fig. 11A–5). The northern part of the area, which hosts the lead-zinc occurrences, is underlain by Lower to Middle Jurassic limestone, marl, sandstone, siltstone, and shale. Several small diorite intrusions and dikes are present in the northern part of the area.

11A.6.2 Nalbandon Lead-Zinc Prospect

11A.6.2.1 Previous Work

The Nalbandon prospect was recognized by the German Mission after their initial work in the area in 1963. A followup evaluation program was recommended and the work contracted to BPG Bergbau-Planung GmBH. Detailed topographic and geologic mapping were completed during the summer of 1967. This work showed that the prospect had high lead-zinc values and that the mineralized zone, which was exposed on a steep valley slope had a strike length of at least 800 m. Steep terrain in the area precluded drilling to test the subsurface extent of the mineralization, so underground exploration via an adit was recommended. The adit was originally planned to be 200 m in length, however, owing to flooding and logistical difficulties, only 51.5 m of tunnel was completed. Despite the difficulties, the adit succeeded in cutting the Nalbandon mineralized zone. A bulk sample was collected from the exposed mineralization and used for metallurgical testing in Germany. In addition to the adit, trenches are referred to by Scheer and others, (1969) but no trenches are shown on any of the maps in the report, so the number and amount of trenching completed is not known.

During the course of the 1967–68 exploration program, the geology and topography of the Nalbandon area were mapped at 1:5000 scale. A 1:500-scale outcrop map was prepared of the Nalbandon prospect area and the exploration adit was mapped at 1:100 scale. The results of the German program are summarized in Scheer and others (1969). Further exploration, including additional underground work and both underground and surface drilling, were recommended for 1969. This work, however, was not conducted. In June 1969, the Nalbandon and Sarghol areas were visited by geologists from Mitsui Mining and Smelting and Marubeni (Afghanistan Geological Survey, 1969). Several maps but no text were available from this visit.

During 1969–70, a Technoexport team completed regional reconnaissance over the Nalbandon AOI (Dronov and others, 1973). They prepared a map of the Nalbandon prospect area and sampled a number of nearby prospects but conducted no work on Nalbandon itself.

In 1977, the Herat Team of the Russian Geological Mission completed a regional geological and geochemical survey over the western third of the Nalbandon AOI (Tutubalin and others, 1979). At the Nalbandon prospect, the team completed 1:10,000-scale geological mapping, an SP geophysical survey and rock geochemical sampling over an area of 5.5 square kilometers (km^2) that surrounded the prospect (figs. 11A–6 and 11A–7). The geophysical and rock geochemical surveys were conducted at a station, and sample spacing was at a 60-m interval along the north-south lines, which were spaced 50- to 60-m apart. In addition, three 50-m-long trenches were excavated at a 60-m interval across the mineralized outcrops above the German adit.

11A.6.2.2 Geology

The Nalbandon deposit occurs within Upper Permian to Carnian (upper Triassic) limestone, marl, and cherts, which strike roughly east-west, dip to the south at 65° and form the northern flank of an east-west trending syncline (fig. 11A–8). The host rocks for the mineralization are a 10-m-thick unit of Triassic limestone, which is interlayered with carbonaceous shale and sandstone. The age of the rocks was determined by fossil assemblage (Dronov and others, 1973). Scheer and others (1969) describe the rocks in the immediate foot and hanging walls of the mineralization as "quartzite," but Tutubalin and others (1979) describe these rocks as silicified shales.

11A.6.2.2.1 Mineralization

The mineralized zone at Nalbandon ranges 3- to 9-m thick and outcrops discontinuously for 850 m along strike. At the surface, the mineralization is oxidized and includes anglesite, smithsonite, pyromorphite, siderite, and limonite. Galena is common in the outcrop, but sphalerite is less so. Surface grades from the Technoexport trenches are less than 1 percent lead and up to 2.5 percent zinc (table 11A–6). The Geman adit cut 5.5 m of sulfide mineralization with an average grade of 0.87 percent lead and 5.77 percent zinc (figs. 11A–9 and 11A–10). The sulfide mineralization consists of galena and sphalerite with lesser chalcopyrite, pyrite, boulangerite, burnonite, and stibnite. Scheer and others (1969) state that the sulfides occur in "porous limestone". Dronov and others (1973) and Tutubalin and others (1979) state that the sulfide minerals occur in a breccia zone, which trends obliquely to the strike of the host limestone unit. The host limestone is also reported to be silicified in the mineralized zone (Tutubalin and others, 1979). The grade of the mineralization is higher at the contact between the host limestone and the underlying siliclastic or silicified sediments (fig. 11A–10).

The mineralized zone exposed in the crosscut was channel sampled by cutting 7-cm wide by 4 cm deep channels that were 1-m long (fig. 11A–10). Assays of the 10 samples are shown in table 11A–3. The samples were assayed for lead and zinc by "more or less standard procedures" but no description of the actual analytical techniques is given (Scheer and others, 1969).

Table 11A–2. Nalbandon trench data.

[From Tutubalin and others, 1979]

Trench name	Length, meters	Interval, meters	Lead, percent	Zinc, percent
K-1	50	16-20	0.38	1.00
K-2	50	25-40	0.61	0.60
K-3	50	23-32	0.32	2.54

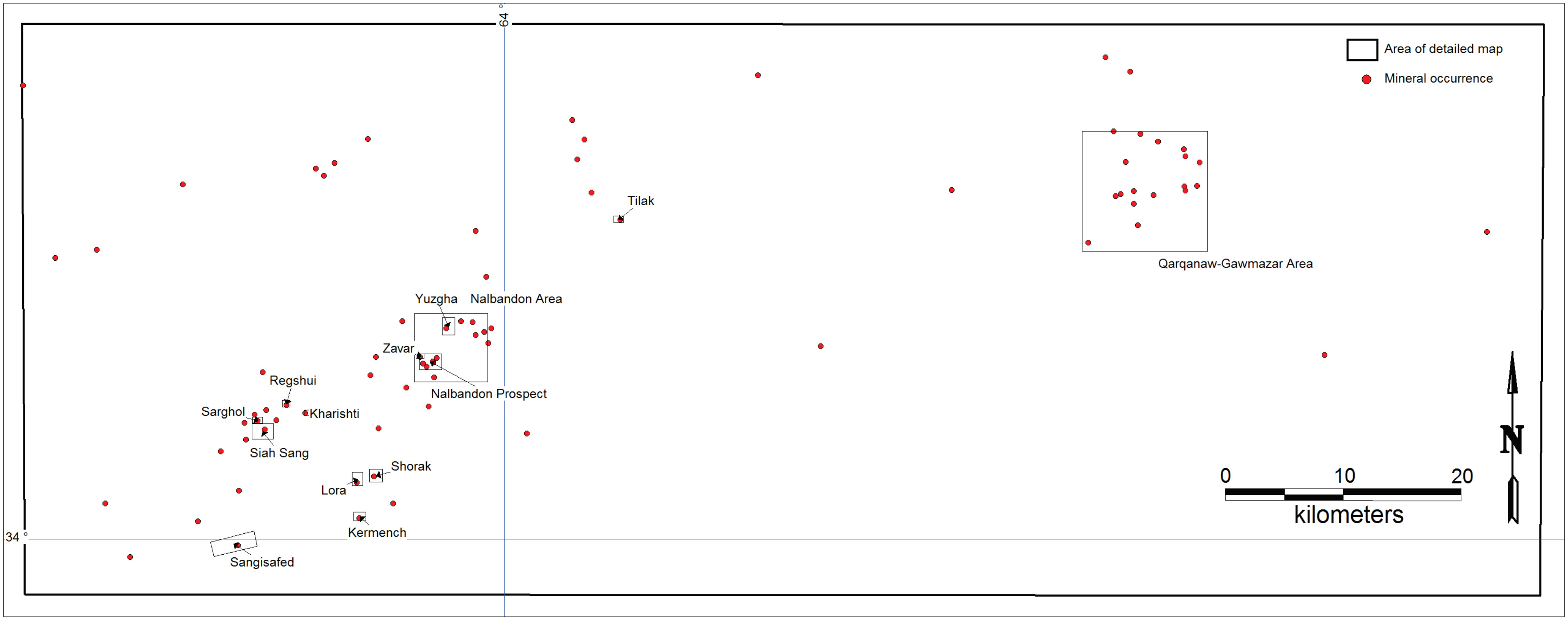

Figure 11A–4. Nalbandon area of interest index map showing mineral occurrences. Compiled from Scheer and others (1969), Dronov and others (1973), Abdullah and others (1977), Tutubalin and others (1979), and Orris and Bliss (2002).

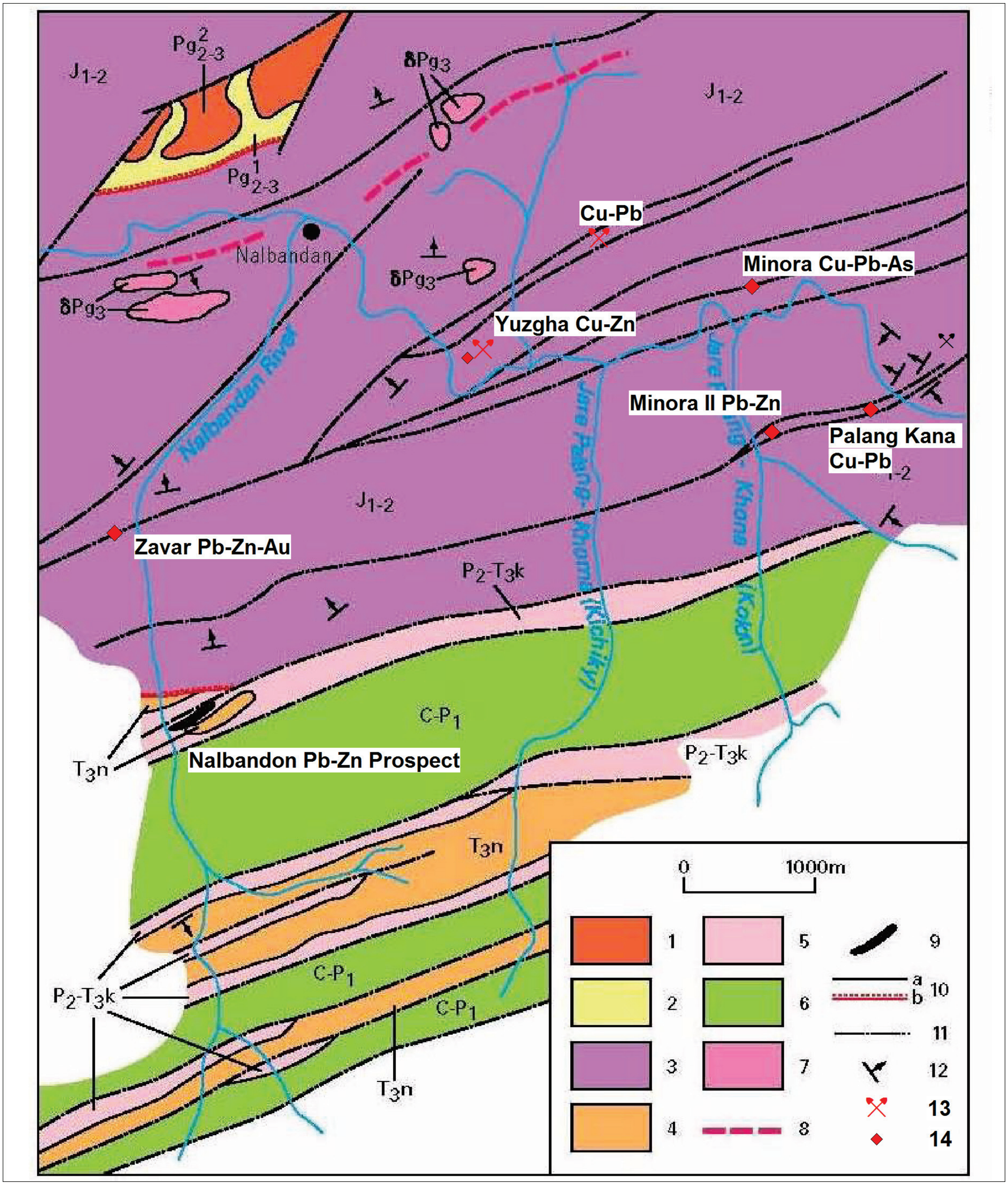

Figure 11A–5. Nalbandon Area geology and mineral occurrences. Modified from Dronov and others (1973) and Abdullah and others (1977). 1, Eocene-Oligocene andesite; 2, Eocene-Oligocene red sandstone and conglomerate; 3, Lower-Middle Jurassic limestone, marl, sandstone, siltstone, shale; 4, Norian-Rhaetian dark sandstone, siltstone and shale; 5, Upper Permian-Carnian limestone, marl, chert; 6, Carboniferous-Lower Permian dark sandstone, siltstone and slate; 7, diorite porphyry; 8, diabase and diorite porphyry dikes; 9, Nalbandon mineral deposit; 10, boundaries a. between rock units of different ages; b. between transgressive rock units; 11, fault lines; 12, strike and dip of beds; 13, artisanal mine workings; 14, mineral occurrence.

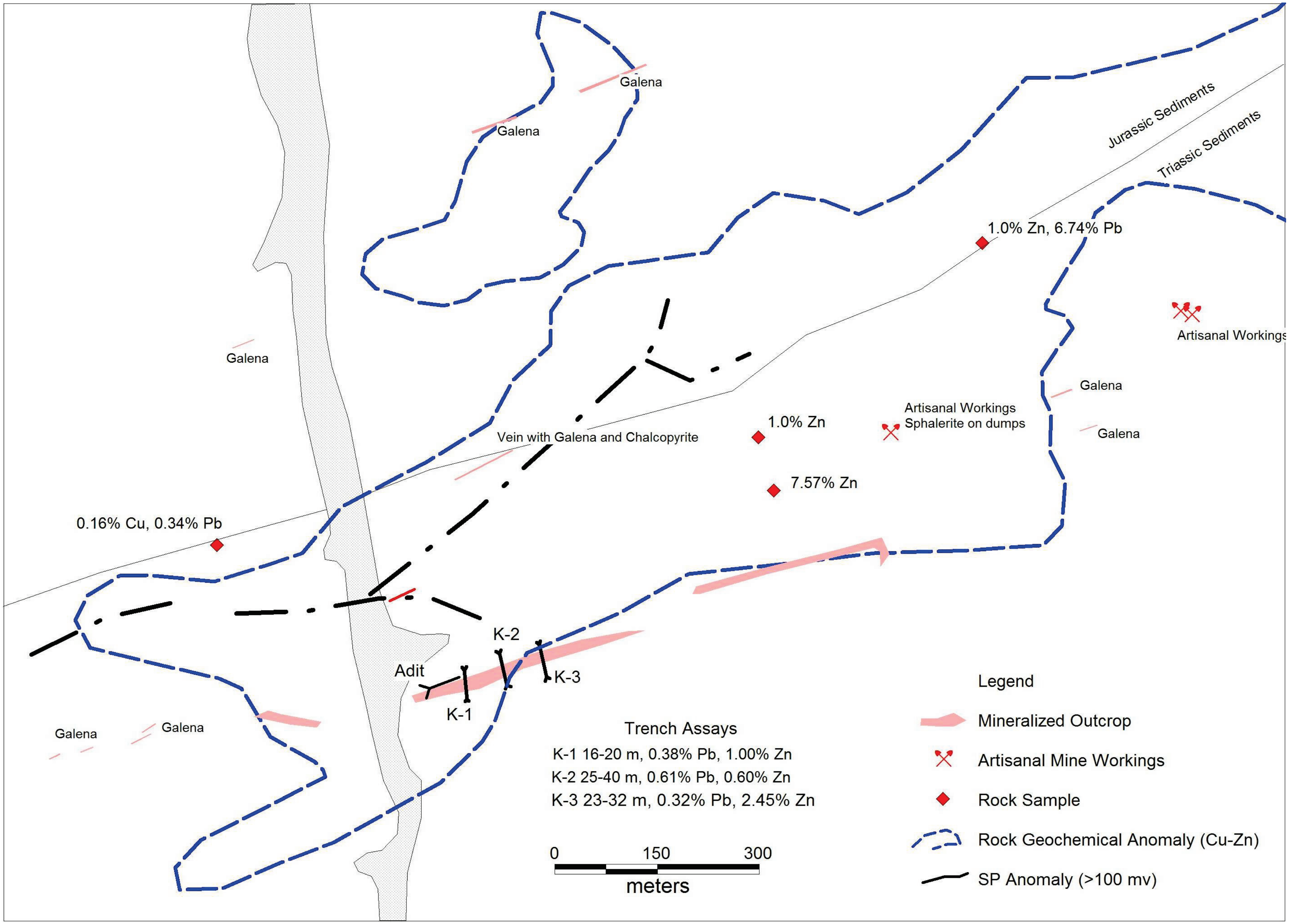

Figure 11A–6. Nalbandon prospect exploration map. Compiled from Scheer and others (1969) and Tutubalin and others (1979).

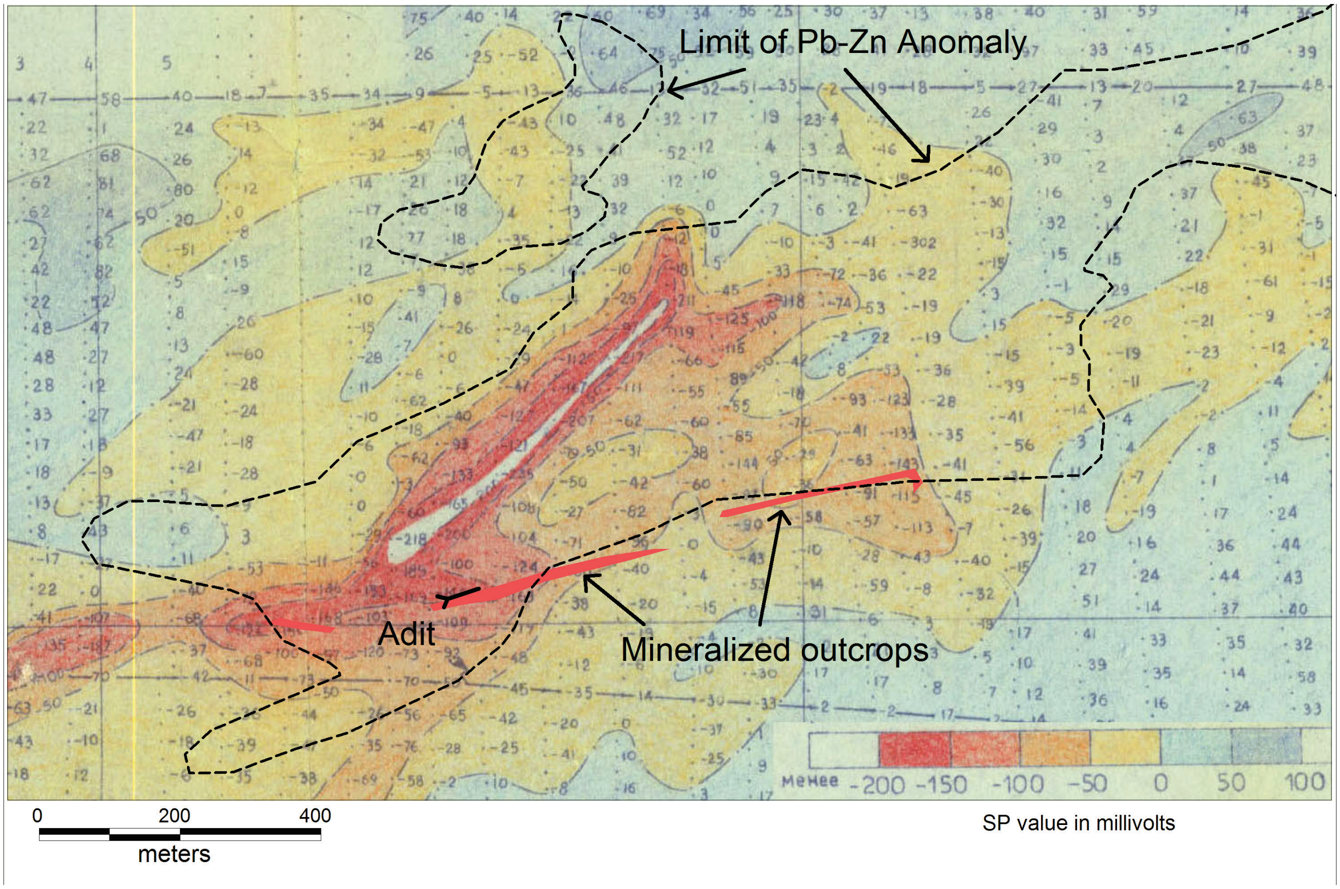

Figure 11A–7. Nalbandon lead-zinc (Pb-Zn) prospect, geophysics (SP) with mineralized outcrops and lead-zinc lithogeochemical anomaly. Modified from Tutubalin and others (1979).

Table 11A–3. Nalbandon adit crosscut channel sample assays.

[From Scheer and others, 1969; values are listed in meters]

Sample	From	To	Width	Lead percent	Zinc percent
1	0.0	1.0	1.0	0.03	0.20
2	1.0	2.0	1.0	0.05	tr
3	2.0	3.0	1.0	0.27	tr
4	3.0	4.0	1.0	0.04	tr
5	4.0	5.0	1.0	4.65	6.70
6	5.0	6.0	1.0	3.20	8.12
7	6.0	7.0	1.0	0.41	4.91
8	7.0	8.0	1.0	0.14	4.91
9	8.0	9.0	1.0	0.24	3.67
10	9.0	10.0	1.0	0.13	3.72

Tutubalin and others (1979) conclude that the mineralization is controlled by several subparallel fault zones, which trend obliquely to the host rock layering based on the results of their geophysical and rock geochemical surveys over the prospect area. The geophysical survey ("Electrical Potential"; probably self potential) of the prospect and surrounding area shows a strong (greater than 100 Mv) anomaly trending 35° to 40°and extending for nearly 2 km to the northeast of the German adit (figs. 11A–6 and 11A–7). The geophysical anomaly roughly coincides with a litho-geochemical anomaly.

11A.6.2.2.2 Estimated Resources

Scheer and others (1969) made an estimate of the potential tonnage of mineralization at Nalbandon as a part of their planning for further exploration. Based on estimated thicknesses ranging from 2.5 to 5.0 m, an assumed specific gravity of 3.5, and a strike length of 800 m, the potential tonnage ranged from 638,750 to 1,277,500 metric tons (t). The potential tonnage was estimated only for the area above the elevation of the exploration adit. In current terms, this estimate would be referred to as an "inferred resource." At the grade of the bulk sample (0.87 percent lead and 5.77 percent zinc) the highest tonnage would contain a potential 11,115 t of lead and 73,710 t of zinc. Dronov and others (1973) and Abdullah and others (1977) state that the deposit contains 10,000 to 12,000 t of lead and 100,000 to 130,000 t of zinc, but the basis for these figures is not given.

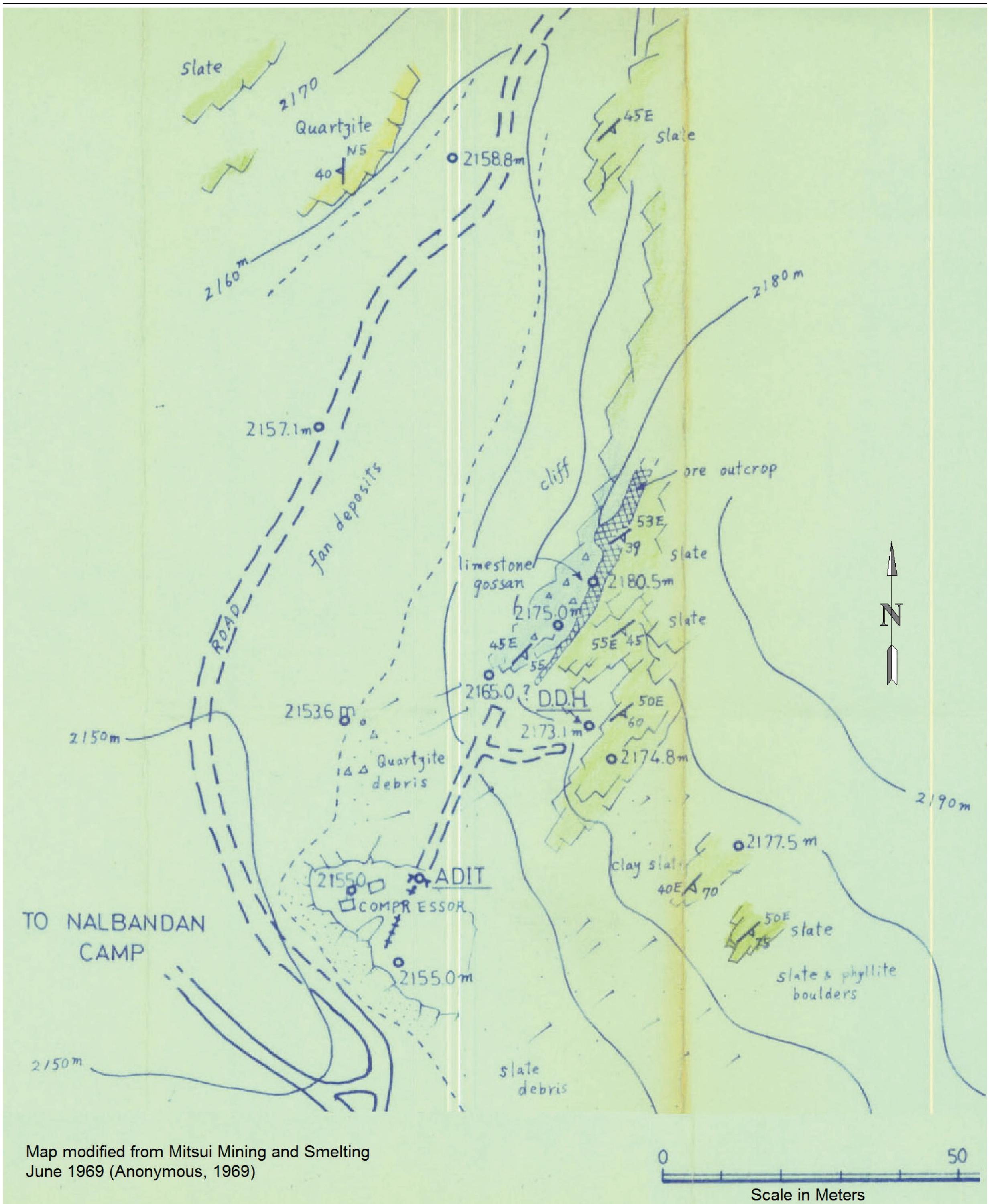

Figure 11A–8. Nalbandon adit area geology.

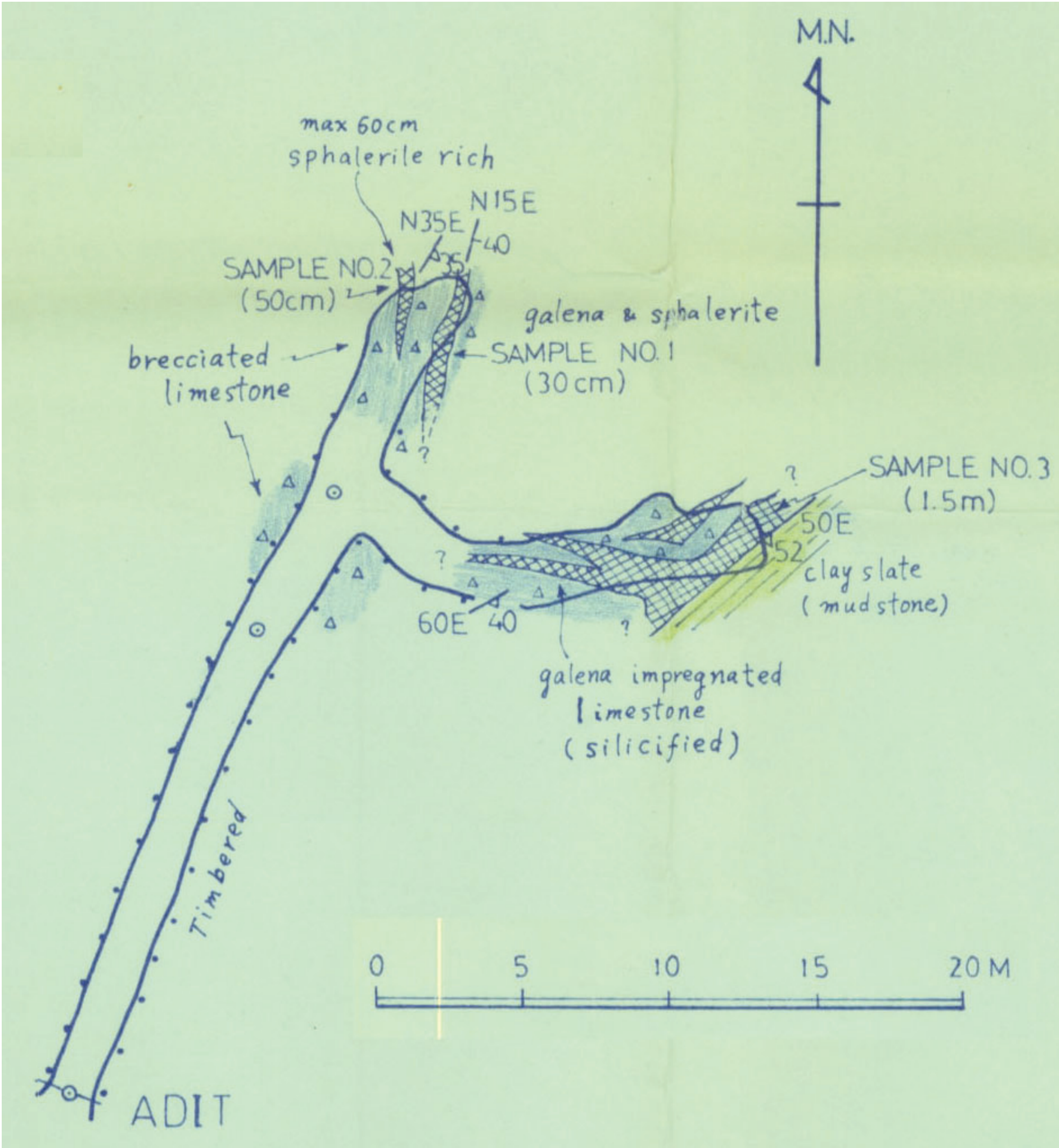

Figure 11A–9. Nalbandon adit, geological sketch map. Modified from Mitsui Mining and Smelting (Afghanistan Geological Survey, 1969).

11A.6.2.2.3 Metallurgy

Scheer and others (1969) carried out some laboratory scale metallurgical tests as a part of their economic evaluation. The test work was done on an 80-kg bulk sample collected from the crosscut. This sample was collected from a single channel, larger than the 7- by 4-cm channels that were cut for sampling, which was cut across the richer part of the mineralized zone. The bulk sample was split and 80 kg was sent to Germany for use in metallurgical test work. The tests completed included dense media concentration as well as flotation. The flotation results were very positive with 92 percent zinc and 91 percent lead recovery at concentrate grades of 57 percent zinc and 79 percent lead (table 11A–4).

Scheer and others (1969), Dronov and others (1973), and Tutubalin and others (1979) considered the mineralization at Nalbandon to be low temperature hydrothermal veins based on the proximity of the mineralized zones to Paleocene intrusive bodies. Orris and Bliss (2002) classed the Nalbandon and prospect as MVTmineralization but do not give the basis for this classification.

Table 11A–4. Nalbandon flotation test data

[Scheer and others, 1969; values are listed in percent]

Product	Weight	Lead	Recovery	Zinc	Recovery
Lead concentrate	1.29	79.73	91.60	1.65	0.56
Zinc concentrate	9.66	0.79	6.81	56.97	91.91
Tailings	89.05	0.02	1.59	0.52	7.73
Totals	100.00	1.12	100.00	5.99	100.00

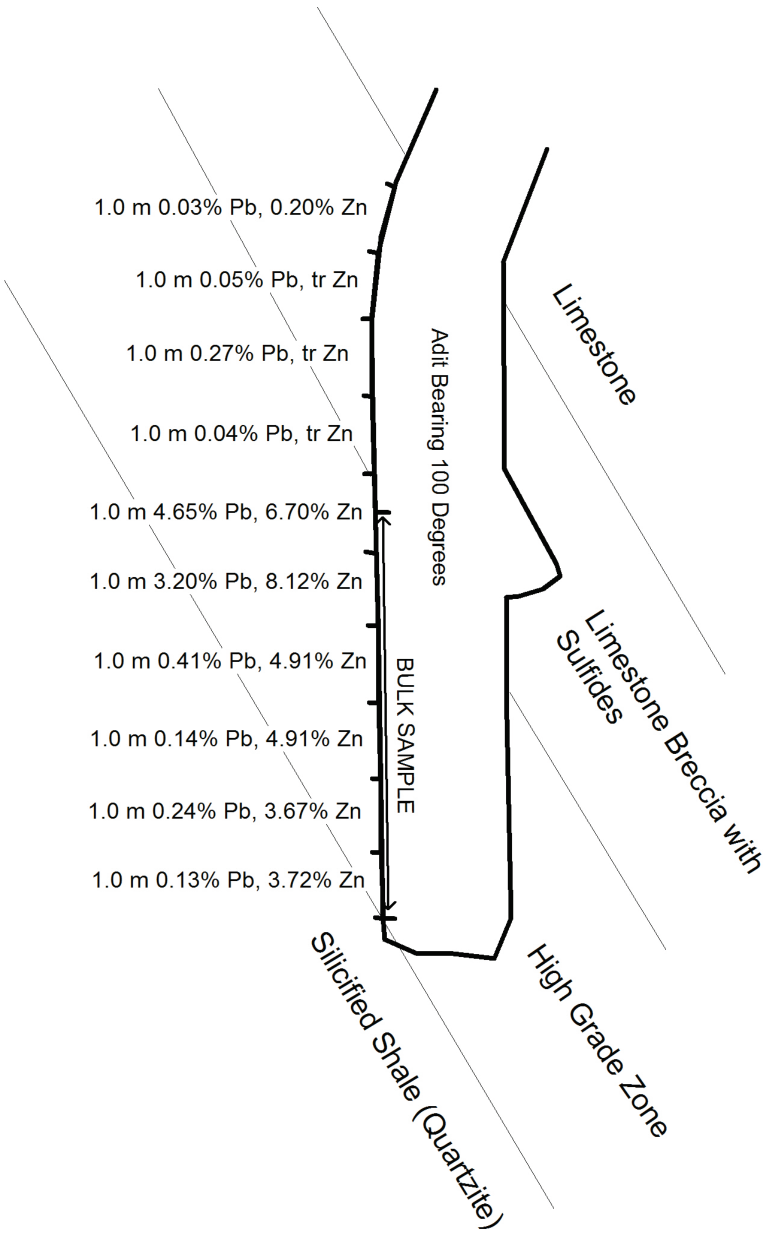

Figure 11A–10. Nalbandon adit crosscut, geology, and assay data. Compiled from Scheer and others (1969).

11A.6.2.3 Other Prospects in the Nalbandon Area

Several other prospects and showings are present in the immediate vicinity of the Nalbandon lead-zinc prospect (fig. 11A–4). These include the Zavar, Yuzgha, Minora, Minora II, and Palang Khana prospects as well as several artisanal workings anomalous sample sites shown on fig. 11A–6. The prospects with the most available data are described below.

11A.6.2.4 Zavar Lead-Zinc-Gold Prospect

The Zavar prospect, located 1 km northwest of Nalbandon (fig. 11A–11), was identified and sampled by Tutubalin and others (1979). The prospect consists of a 120-m-long-zone of quartz-sulfide veins and tectonic breccia, which trends 50° (fig. 11A–14). The mineralization was sampled by two trenches. Trench 4 cut two zones of mineralization; 1.0 m at 14.5 percent lead and 2.5 percent copper, and 1.8 m at 2.2 percent lead and 0.99 percent copper. Trench number 5 located 100 m to the northeast did not expose the quartz-sulfide zone; however, samples show 18 m at 1.6 gram per metric ton (g/t) gold.

Other mineral occurrences are present to the northeast and southwest along the strike from the Zavar prospect. About 1.7 km to the northeast along the strike of Zavar, there is a 120-m-long, greater than 100 Mv SP anomaly (fig. 11A–6). About 5 km to the northeast is a 1.5-km-long northeast trending group of three mineral occurrences (figs. 11A–4 and 11A–5). The occurrences to the northeast include Minora II, Palang Khana, and an unnamed artisanal mine shown by Dronov and others (1973). The Minora II occurrence consists of limonite-stained quartz veins localized within a fault zone, which is up to several tens of meters wide. The grade of this mineralization is reported as 0.1 percent lead, 0.02 to 0.12 percent copper, and 0.05 to 0.07 percent zinc (Abdullah and others, 1977). The Palang Khana occurrence consists of two brecciated zones 0.4- to 1.5-m wide containing sparse disseminated galena. The grade of the mineralization is reported at 0.3 percent lead, 0.5 percent zinc, and 0.01 to 0.07 percent zinc (Abdullah and others, 1977). Tutubalin and others (1979) show an unnamed lead-zinc occurrence 4.5 km to the southwest of Zavar (fig. 11.0-07). The total strike length of these occurrences is 4.3 km.

11A.6.2.5 Yuzgha Lead-Zinc Prospect

The Yuzgha prospect is located 3.6 km northeast of Nalbandon (figs. 11A–4 and 11A–5) and was mapped and sampled by Tutubalin and others (1979). The prospect consists of multiple zones of quartz-carbonate veins in fractured and kaolinized rock (fig. 11A–12). The host rocks are Triassic shale and limey siltstone interbedded with sandstone. The altered and fractured zone trends 70°, is up to 10-m wide and has been traced for more than 500 m along strike. The quartz-carbonate veins contain disseminated chalcopyrite and rare galena, and are stained with iron oxides, malachite, and azurite. One grab sample from a mineralized vein shows 1.54 percent copper and a heavy mineral concentrate from the area showed grains of gold.

Several other mineral occurrences are located to the northeast and southwest along the strike from Yuzgah (fig. 11A–4). Dronov and others (1973) show an unnamed artisanal mine working 1.2 km to the northeast. The Minora prospect is an additional kilometer to the northeast of Yuzgha. The mineralization at Minora is hosted by calcareous shale and siltstone and consists of veinlets of sulfides and secondary copper minerals in quartz veins. The veins range from several centimeters to several meters thick and occur in a shattered and ferruginous zone that is 50- to 150-m long and 1.5- to 2.0-m wide. The grade of the mineralization is reported as 0.44 to 2.46 percent copper, 0.03 to 0.1 percent lead, and 0.07 percent zinc (Abdullah and others, 1977). The Gau Kush occurrence is located 3.8 km to the southwest of Yuzgha and is described as 5-cm-wide veins with disseminated galena with a number of artisanal workings (Siebdrat, 1964). Tutubalin and others (1979) show an unnamed lead-zinc occurrence an additional 2.5 km to the southwest from Gau Kush. The presence of these occurrences aligned along the strike of the Yuzgha zone, and the similarity of the mineralization at Yuzgha, Minora, and Gau Kush suggests that the shear-vein zone could extend for more than 9 km.

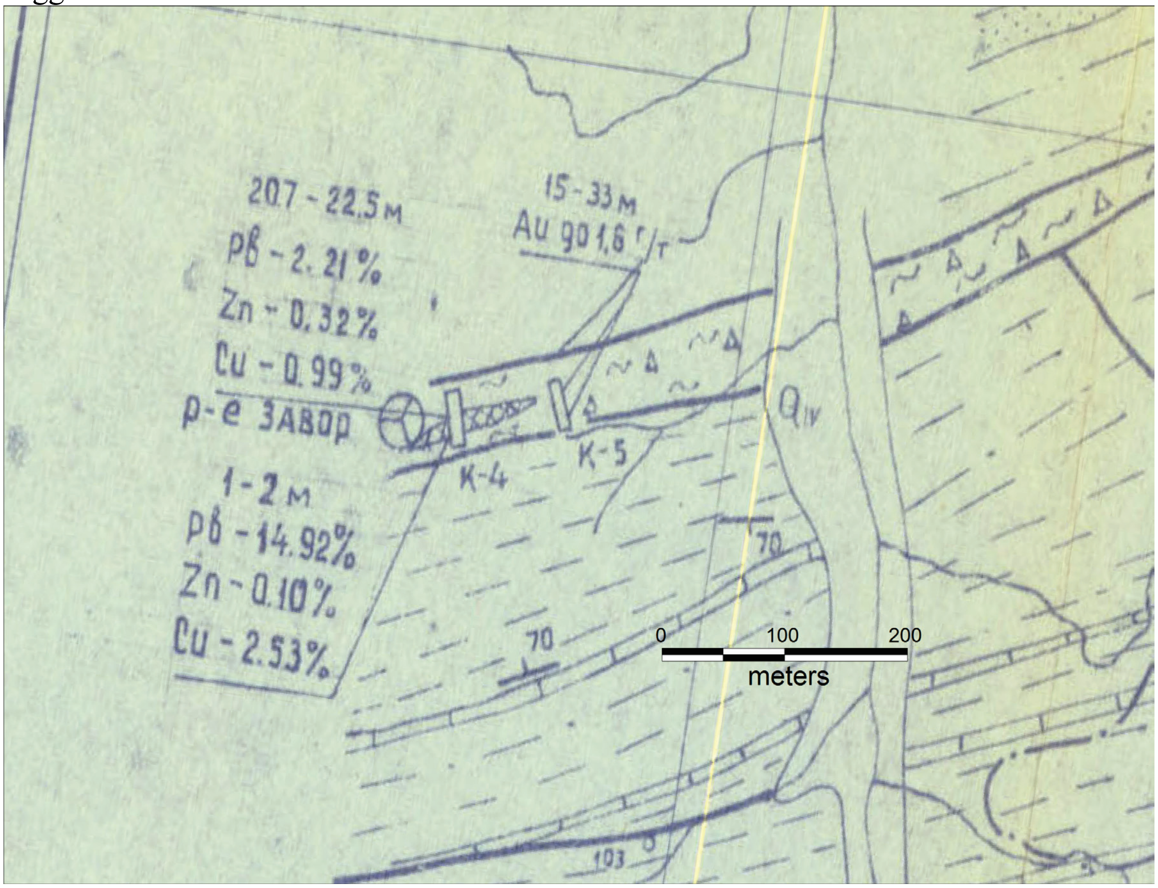

Figure 11A–11. Zavar lead-zinc-gold (Pb-Zn-Au) prospect map. From Tutubalin and others (1979).

11A.6.2.6 Siah Sang Lead-Zinc Prospect

The Siah Sang lead-zinc prospect is located south of the village of Sarghol about 15 km southeast of the Nalbandon prospect (fig. 11A–4). Lead-zinc mineralization at Siah Sang was reported by the German Geological Mission in 1963 (Siebdrat, 1964). The prospect was mapped in detail (1:500 scale) in 1967-68 (Scheer and others, 1969). Six trenches totaling 46.5 m were excavated and four were sampled in 1967. In 1968, four drill holes totaling 444 m of drilling were completed.

Siebdrat (1964) describes the mineralization as a vein system with a strike of 55° and dip of 85° to the north (fig. 11A–13). The mineralized zone, marked by artisanal mine workings, was traced for 3.2 km along the strike. The thickness of the vein zone ranges up to 10 to 15 m with an average of 3 to 5 m. Samples from outcrops, pits, and artisanal mine workings showed values of 10 percent lead and 10-15 percent zinc.

Khazonov and others (1967) visited the area briefly in 1966 and described the prospect as a zone of quartz veins and silicification, which is conformable with the host phyllites. The veins are described as massive milky quartz with lesser “vesicular” quartz. The vesicular quartz is strongly iron stained and contains sparse disseminated galena and encrustations of cerrusite. The highest grade mineralization occurs in crushed zones in the quartz veins.

Scheer and others (1969) describe the mineralization as occurring in lenses of silicified sandstone interlayered with limestone or shale. Mineralized outcrops that were trenched in 1967 measured 4.0- to 8.2-m wide (table 11A–5).

Scheer and others (1969) completed four drill holes totaling 444 m at Siah Sang in 1967-68 (fig. 11A–16, table 11–A6). About 60 percent of meterage was cored. Drill-hole assay results are shown in table 11–A7. All the holes were drilled toward the south with inclinations of -45°. They were sited to test beneath known mineralized outcrops and aimed to test vertically or steeply dipping targets. The best intercept was in BH-IV, which intercepted 1.5 m of sulfide mineralization at 100.0-m depth, which assayed 5.75 percent lead and 11.81 percent zinc. All the other drill holes intercepted only thin veins or zones of disseminated sulfide. It was concluded that the greater widths of mineralization in outcrop and trenches versus its virtual absence in the subsurface was owing to secondary enrichment at the surface. All of the outcrops were noted to contain significant amounts of secondary lead and zinc minerals (Scheer and others, 1969).

On completion of the 1967-68 program, Scheer and others (1969) recommended no further work at the Siah Sang prospect.

Table 11A–5. Siah Sang prospect trench data.

[From Scheer and others, 1969; m, meters]

Trench	Length (m)	From (m)	To (m)	Width (m)	Lead percent	Zinc percent
Siah Sang 2	9.0	0.38	7.54	7.16	3.20	6.38
Siah Sang 4	4.0	0.00	9.30	9.30	4.28	10.05
Siah Sang 5	8.2	0.00	4.00	4.00	2.14	4.61
Siah Sang 6	6.5	0.00	8.20	8.20	0.90	4.35

Table 11A–6. Siah Sang drill hole collar data.

[Scheer and others, 1969]

DH ID	Bearing	Inclination	Total depth (meters)
BH-I	160	-45	125.0
BH-III	180	-45	9.2
BH-IIIa	155	-45	126.3
BH-IV	155	-45	50.0
BH-V	160	-45	133.5

Table 11A–7. Siah Sang prospect drill hole assays.

[Scheer and others, 1969]

DH ID	From (m)	To (m)	Width (m)	Pb percent	Zn percent
BH-I	33.90	34.40	0.50	2.62	3.08
BH-I	35.30	35.80	0.50	0.17	9.21
BH-I	39.30	39.85	0.55	0.12	1.01
BH-IV	3.40	4.50	1.10	1.29	2.63
BH-IV	9.10	10.80	1.70	0.30	0.40
BH-IV	12.60	15.50	2.90	5.17	4.06
BH-V	99.30	100.00	0.70	0.44	3.51
BH-V	100.00	101.50	1.50	5.75	11.81

11A.6.2.7 Kharishti Lead-Zinc Prospect

The Karishti prospect is located 3.6 km to the northeast along strike from the Sian Sang prospect (fig. 11A–4) and was mapped and sampled by Tutubalin and others (1979). The prospect consists of a 60-m-long zone of silicified shear breccias exposed on the west bank of a wadi (fig. 11A–14). The shear zone is generally conformable with the enclosing Triassic shale. Within the shear, the shale is brecciated and kaolinized, and the fragments are cemented by quartz. Galena, lesser amounts of sphalerite and minor chalcopyrite and pyrite occur as veinlets and disseminations in the quartz. The outcrops are strongly oxidized and coated with iron and manganese oxides with sparse malachite and azurite staining. There are two artisanal mine workings at the site.

Tutubalin and others (1979) collected eight grab samples at the prospect. The samples assayed 0.7 to 19.2 percent lead and 0.7 to 2.2 percent zinc.

Two other lead-zinc occurrences are reported along strike to the southwest of the Siah Sang prospect. The Deadman occurrence is located 1.8 km to the southwest and the Nawad occurrence is

4 km further along strike. The Deadman occurrence consists of a group of artisanal workings on a 3-m-thick quartz vein. Grab samples from the vein assay 9 percent lead and 16 percent zinc (Siebdrat, 1964). The Nawad occurrence consists of two veins; one 1-m wide and the 0.5-m wide. Grab samples of the veins assay 1 percent lead and 4 percent zinc (Siebdrat, 1964).

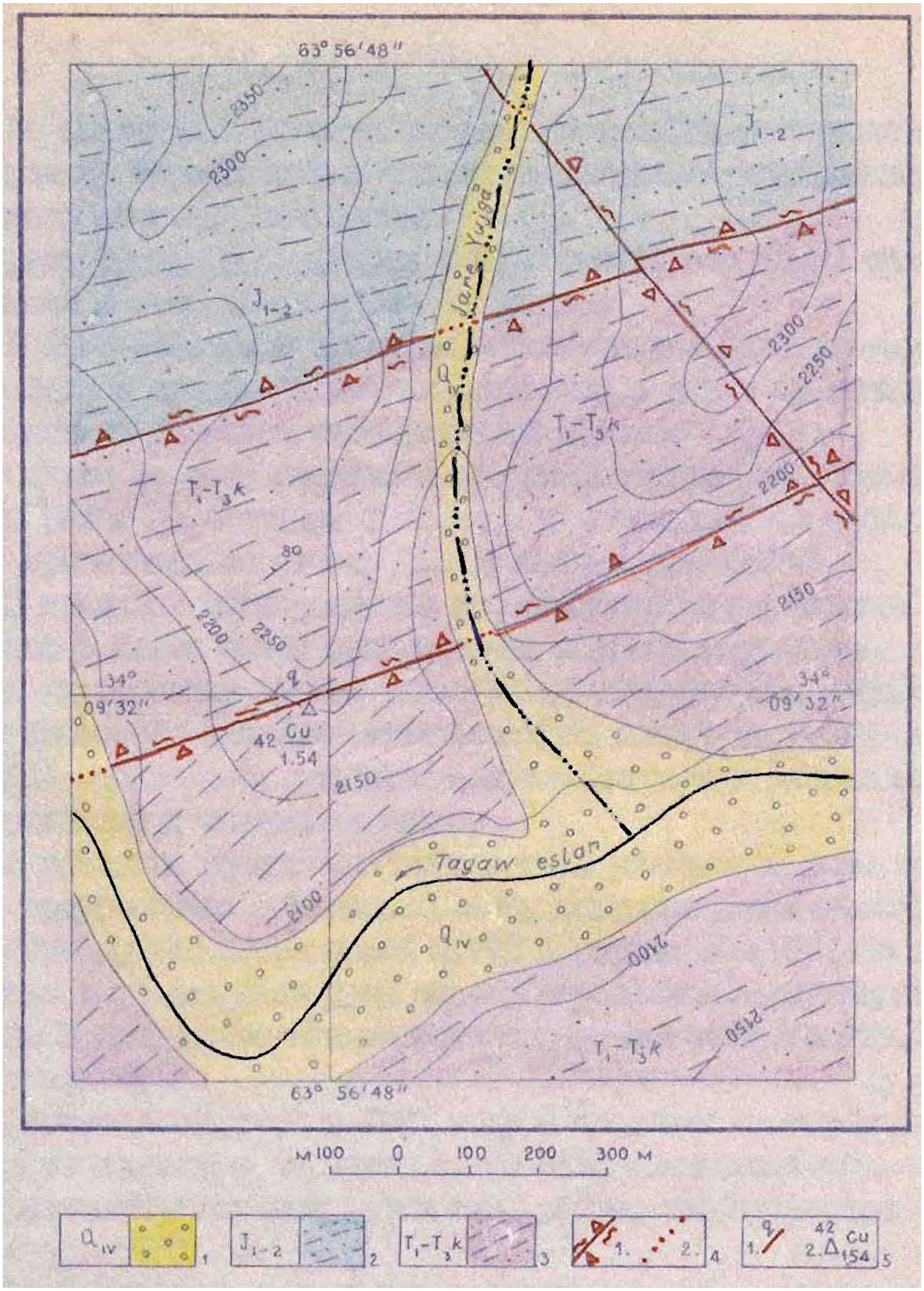

Figure 11A–12. Yuzgha copper-zinc prospect map. From Tutubalin and others (1979). 1, Recent alluvium; 2, Lower, Middle Jurassic siltstone, sandstone and shale; 3, Lower, Upper Triassic shale, siltstone and rare sandstone; 4, faults (1, exposed, 2, covered); 5, quartz veins with copper mineralization (1) and grab samples with copper assays (2).

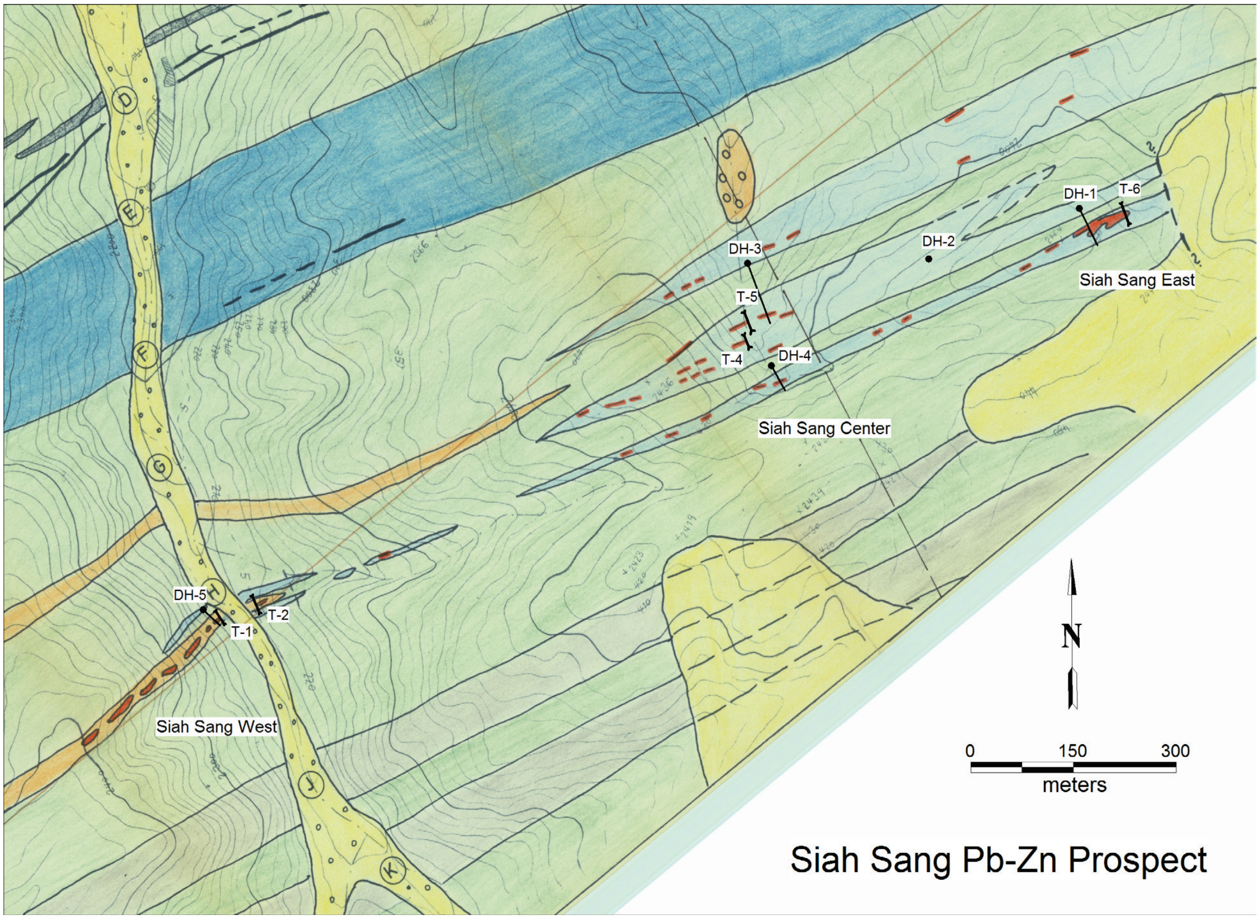

Figure 11A–13. Siah Sang lead-zinc (Pb-Zn) prospect map. Compiled from Scheer and others (1969). Light green- shale; Light and Dark Blue- limy shale, shaley limestone; Gray- quartz sandstone with limestone beds; Yellow- Alluvium; Red- mineralization.

The Kharishti, Deadman, and Nawad occurrences are similar to the Siah Sang prospect, each consisting of sulfide mineralization in veins and (or) silicified zones in northeast trending shear zones. The similarity in style and location along the same strike indicates that all four occurrences may be located along the same shear zone.

11A.6.2.8 Sarghol Lead-Zinc Prospect

The Sarghol lead-zinc occurrence is located 1 km northwest of the Siah Sang prospect (fig. 11A–4), and consists of two groups of the ancient mine workings and showings hosted by lower Jurassic black shale and sandstone (fig. 11A–15). The prospect was sampled by the German Mission (Siebdrat, 1964; Scheer and others, 1969), visited by Khazanov and others (1967), and examined by Dronov and others (1973) and Tutubalin and others (1979).

Mineralization at Sarghol consists of veinlets of galena and sphalerite in quartz veins within bleached and kaolinized black shales (Tutubalin and others, 1979). The mineralization is oxidized with abundant iron oxides and local cerrusite and anglesite. The quartz veins trend northeast, are 0.5- to 1-m thick and 10- to 20-m long. Eight grab samples collected by Tutubalin and others (1979) show grades of 0.14 to 19.25 percent lead and 0.25 to 10.72 percent zinc. One sample also contains 0.14 percent copper.

11A.6.2.9 Reghsui Lead-Zinc Prospect

The Reghsui prospect is located 2.7 km northeast of the Siah Sang prospect (fig. 11A–4). The prospect was visited by the German Geologic Mission (Siebdrat, 1964, Scheer and others, 1969) and later mapped and sampled by Tutubalin and others (1979). Siebdrat (1964) describes the showing as 2-m-thick quartz veins exposed over a length of 200 m and reports values from grab samples of 12.6 to 31.9 percent lead and 1 percent zinc.

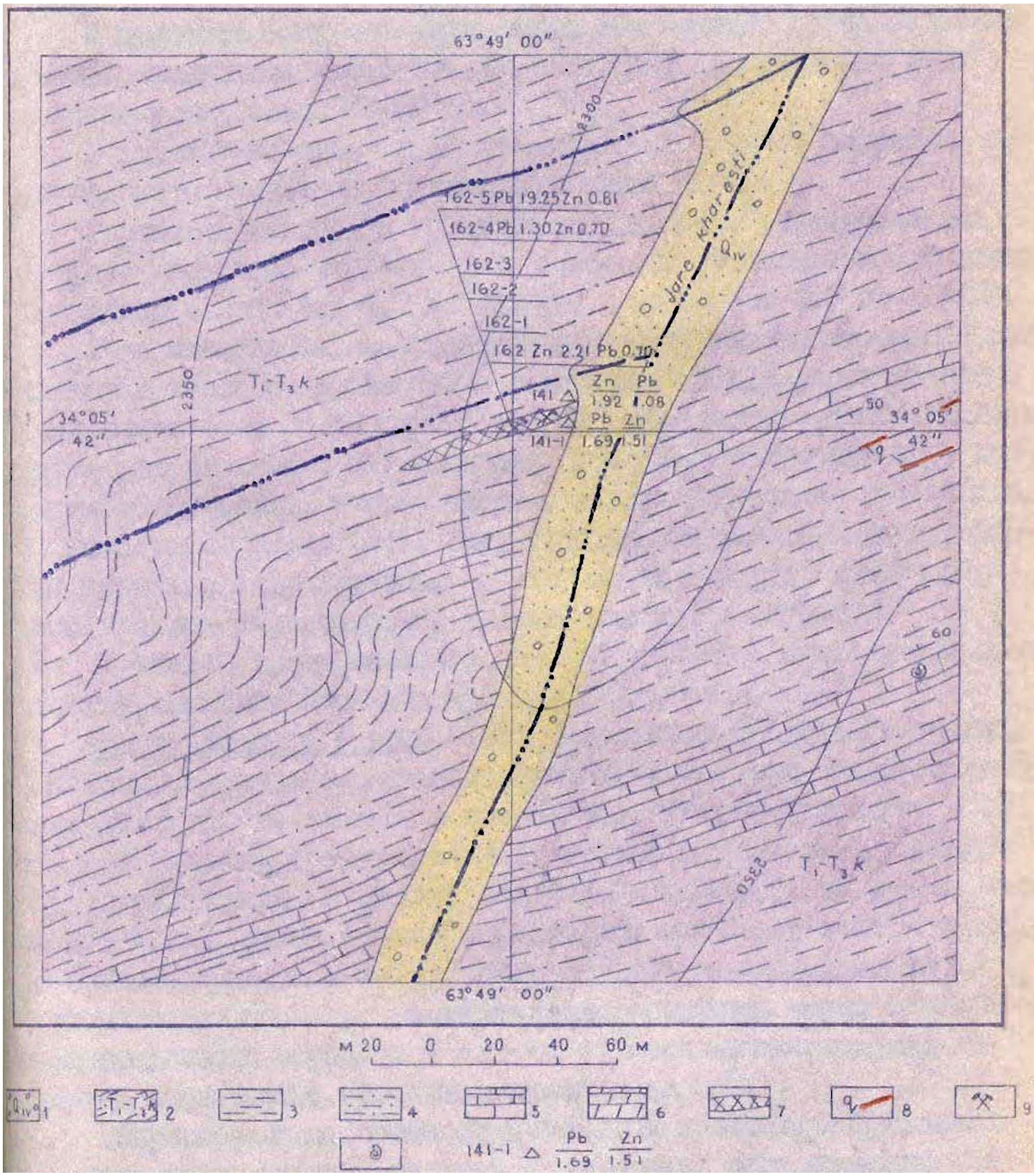

Figure 11A–14. Kharishti lead-zinc prospect map. From Tutubalin and others (1979). 1, Recent alluvial pebbles; 2, Lower-Upper Triassic deposits; 3, clayey shale; 4, siltstone; 5, limestones; 6, marl; 7, fracture zones, silicification zones with lead-zinc mineralization; 8, quartz veins; 9, ancient workings; 10, fossil locality; 11, grab sample with number and lead and zinc content in percent.

Tutubalin and others (1979) describe the prospect as a 200-m-long zone of quartz veins within silicified and bleached Jurassic sandstone (fig. 11A–16). The quartz veins and quartz breccias contain thin veins of galena and have coatings of iron oxides, malachite, and azurite. One grab sample assayed 19.16 percent lead, 0.16 percent zinc, and 3.43 percent copper.

Three lead-zinc occurrences are located to the southwest along the strike for 3.9 km from the Reghsui Prospect (fig. 11A–7). Two are unnamed occurrences with no descriptions that are shown on the geological map of the Siah Sang-Sarghol area (Scheer and others, 1969). The third, Tangi Nabat, is located 2.9 km southwest of Regshui and is described as a large group of artisanal mine workings (Scheer and others, 1969).

11A.6.2.10 Lora Lead-Zinc Prospect

The Lora prospect is located in the southwestern part of the Nalbandon District (fig. 11A–4) and was mapped and sampled by Tutubalin and others (1979). The prospect consists of a sheared, altered, and veined zone along the contact between Triassic and Jurassic sedimentary rocks (fig. 11A–17). The rocks in the alteration zone are folded, bleached, argillized, and locally silicified. Galena veins and disseminations occur in the zones of silicification. Cerrusite and anglesite are also present. Tutubalin and others (1979) excavated three trenches at Lora. Samples from one trench (K-15) show 14 m with a grade of 0.44 percent lead and 4.24 percent zinc.

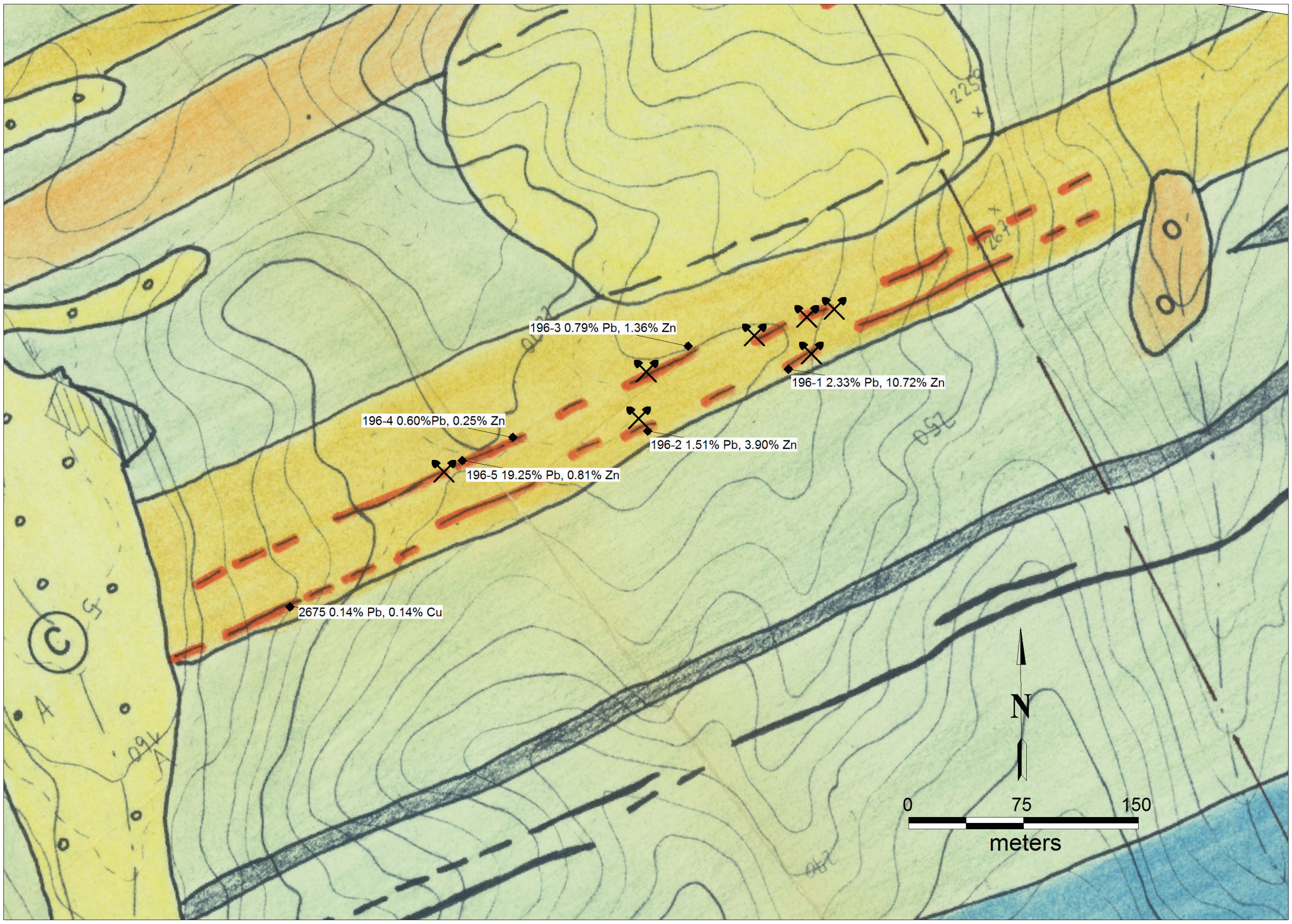

Figure 11A–15. Sarghol lead-zinc (Pb-Zn) prospect map. Compiled from Scheer and others (1969) and Tutbalin and others (1979). Light green, shale; light and dark blue, limy shale, shaley limestone; dark gray, tuff beds; orange, sandstone locally ferruginous and Pb-Zn bearing; light orange, siliceous shale to phyllite; yellow, alluvium; red, mineralization.

11A.6.2.11 Shorak Lead-Zinc Prospect

The Shorak prospect is located 1.5 km to the northeast of the Lora Prospect (fig. 11A–4). Several groups of artisanal mine workings occur over a distance of 1 km along an altered and veined zone within lavendar colored sandstones of Triassic age (Tutubalin and others, 1979). The veins are composed of quartz and are up to 10-m long and 1-m wide. The wall rocks show varying degrees of bleaching and silicification. In the areas of most intense quartz veining and silicification, veinlets of galena as well as sphalerite are present and have coatings of iron oxides, cerrusite, malachite, and azurite. Tutubalin and others (1979) excavated three trenches across a zone of intense veining and silicification. One sample from the trenches assayed 0.16 percent lead (fig. 11A–18).

11A.6.2.12 Salgisafed Copper Prospect

The Salgisafed prospect is located 12 km to the southwest along strike from the Lora prospect (fig. 11A–4) and was mapped and sampled by Tutubalin and others (1979). The prospect consists of zones of copper mineralization located within a large shear zone, which cuts Jurassic and Cretaceous sedimentary rocks (fig. 11A–19). The shear zone is up to 50-m wide and was mapped along a strike length of 5 km. The shear zone consists of fractured and brecciated rocks and local gouge zones.

Within the shear zone are smaller areas of quartz veining and silicification ranging from 1 to 50 m long and 10- to 15-m wide. Individual quartz veins are typically 1 to 2-m thick. The silicified rocks and veins have been fractured and sheared by later movement on the shear zone.

Chalcopyrite, pyrite, and rare galena occur as disseminations and veinlets within milky quartz veins and fractured silicified rock. Malachite, azurite, and antlerite are common. Tutubalin and others (1979) sampled the areas of most intense veining with six trenches totaling 245 m (table 11A–8). The width of the mineralization exposed in four of the trenches ranged from 10.0 to 19.5 m with grades ranging from 0.24 to 0.77 percent copper.

Table 11A–8. Salgisafed prospect trench data.

[Tutubalin and others (1979)]

Trench	Length (m)	From (m)	To (m)	Width (m)	Cu percent
K-Ba-20	35	2.0	17.0	15.0	0.24
K-Ba-21	40	12.0	27.6	15.6	0.45
K-Ba-22	40	12.0	31.5	19.5	0.77
K-Ba-23	50	20.0	30.0	10.0	0.30
K-Ba-24	30	–	–	–	–
K-Ba-25	50	–	–	–	–

11A.6.2.13 Kermench Lead-Zinc Prospect

The Kermench prospect consists of an altered fracture zone with several artisanal mine workings, which is located 3 km south of the Lora-Shorak prospects (fig. 11A–4). The prospect was mapped, sampled, and trenched (5 trenches totaling 160 m) by Tutubalin and others (1979). The fracture zone occurs along the contact between Jurassic sandstone and argillite and trends 80° with a dip of 70° to the northwest (fig. 11A–20). Within the fracture zone, the sediments are bleached, silicified, and locally kaolinized. Artisanal mines are reported over a length of 800 m, and trenching and sampling were completed over a strike length of 400 m in the area of most intense alteration.

Table 11A–9. Trench data for the Kermench prospect.

[Tutubalin and others, 1979. Cu, copper; m, meters; Pb, lead]

Trench	Length (m)	From (m)	To (m)	Width (m)	Pb percent	Cu percent
K-6	40	–	–	–	–	–
K-7	30	25.0	29.0	4.0	0.12	0.20
K-8	30	0.0	1.0	1.0	0.14	0.29
K-9	30	5.0	6.0	1.0	0.40	–
K-10	30	–	–	–	–	–

Sphalerite and galena occur as veins and disseminations in silicified sedimentary rock and quartz veins. The sulfides are most common in areas of most intense alteration, veining, and brecciation. Samples from the trenches showed only low grade mineralization (table 11A–9). The best interval was 4 m at 0.12 percent lead and 0.20 percent copper in trench K-7.

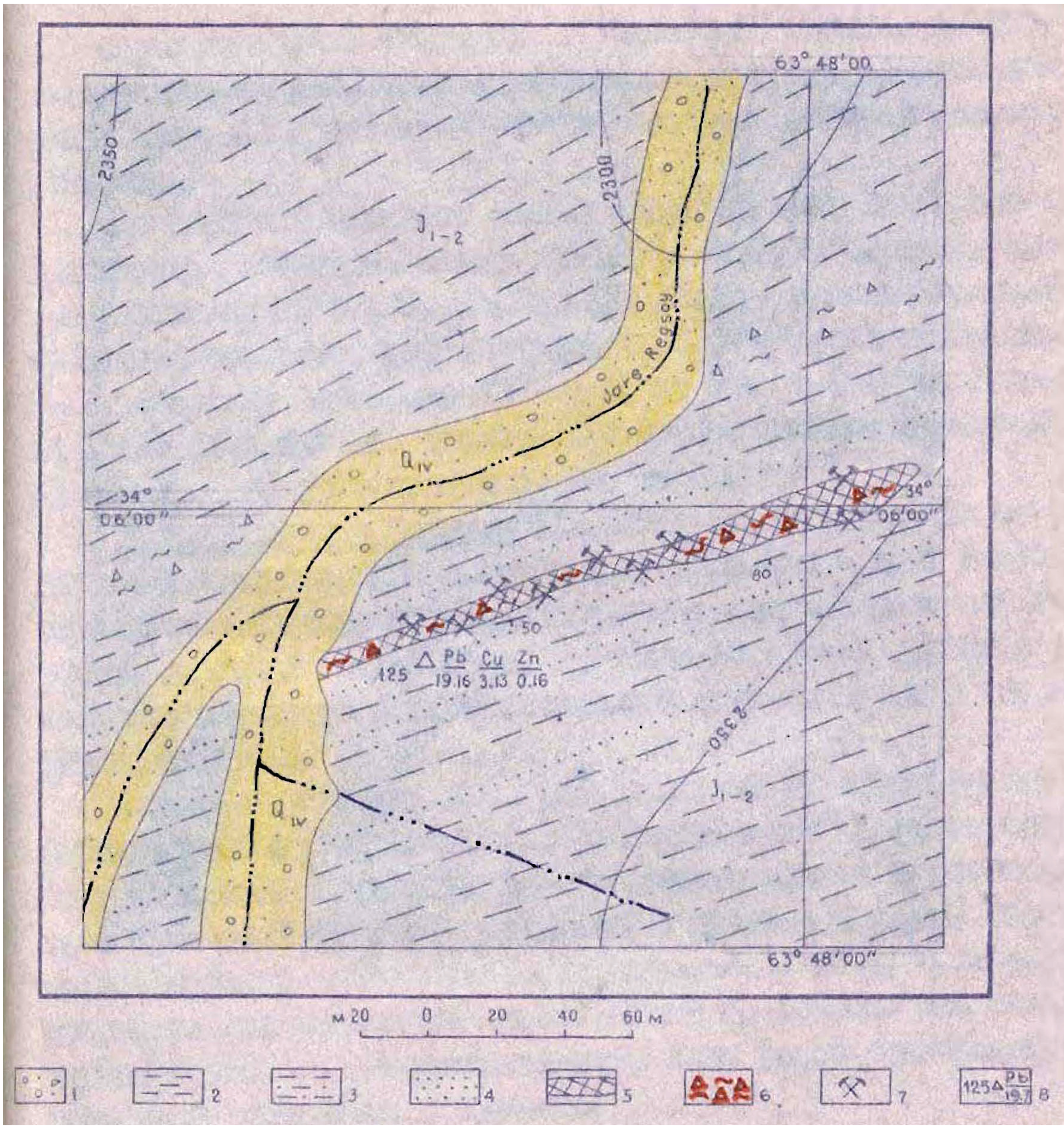

Figure 11A–16. Regshui lead-zinc-copper prospect map. From Tutubalin and others (1979). 1, Recent alluvial pebbles, Low –Middle deposits. 2. Clayey, limey-clayey shales. 3. Siltstones, 4. Sandstones, 5. Mineralization, 6. Fracture zone, kaolinization, 7. Ancient workings, 8. Grab sample with number and lead, copper and zinc content in %.

11A.6.3 Gharghananaw-Gawmazar District

The second cluster of 14 mineral occurrences in the Nalbandon AOI is located in the northeastern part of the AOI and is referred to as the Gharghananaw-Gawmazar District (fig. 11A–4). This area is underlain by Mesozoic sedimentary rocks of the eastern end of the Nalbandon tectonic block (fig. 11A–21). The Mesozoic rocks in the area are the same stratigraphic section as at Nalbandon and consist of upper Permian to upper Triassic limestone, marl, and shale; upper Triassic dark colored sandstone, siltstone, and shale; and lower to middle Jurassic limestone, marl, and shale (fig. 11A–23). The Mesozoic rocks are underlain by Carboniferous to lower Permian dark colored sandstone, siltstone, and slate, which are probably correlative with similar rocks in the Nalbandon area. In this area, however, the Mesozoic rocks are overlain by Eocene volcanics and Pliocene sandstone and conglomerate, which fill younger graben basins (Dronov and others, 1973; Abdullah and others, 1977).

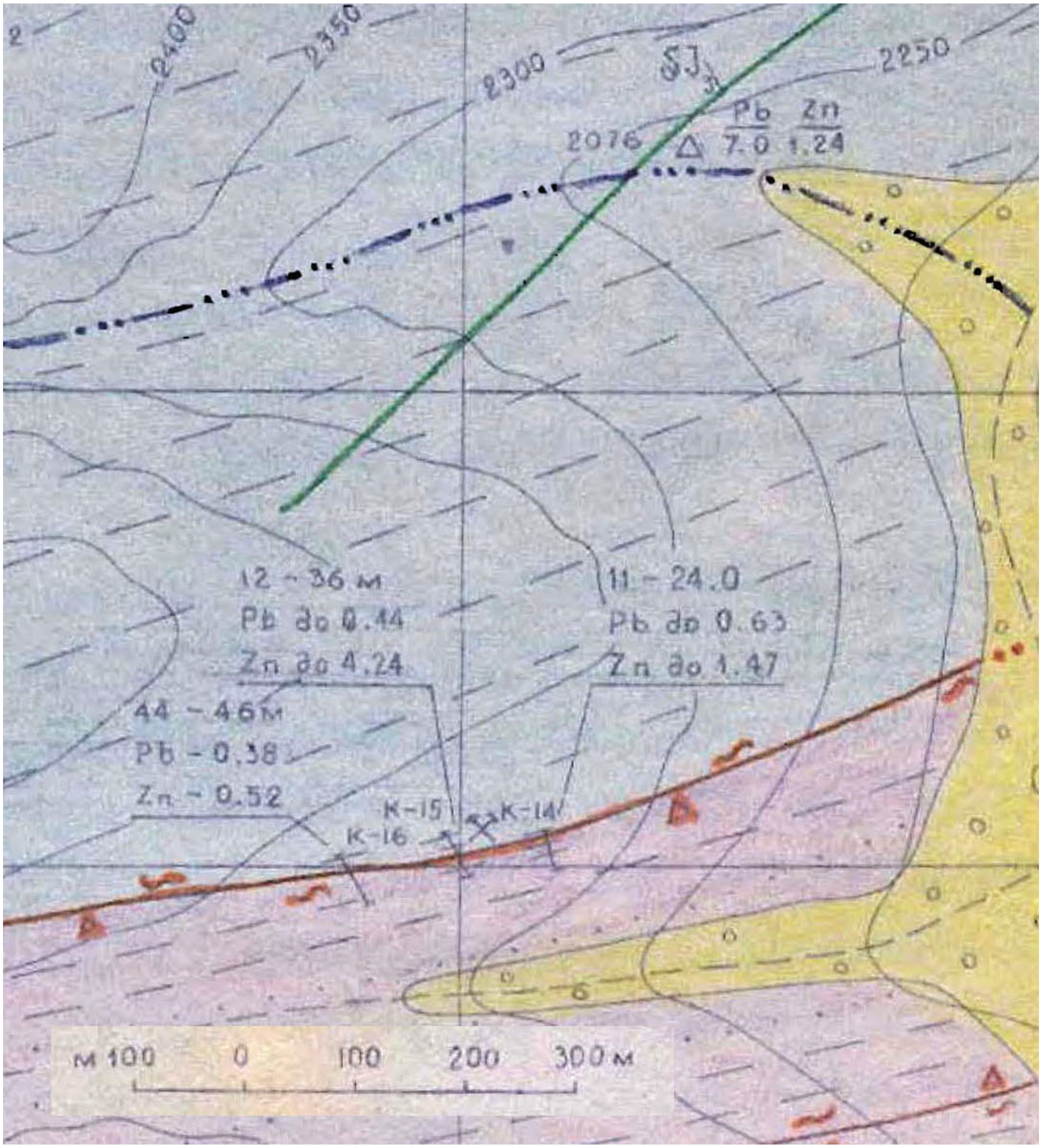

Figure 11A–17. Lora lead-zinc prospect map. From Tutubalin and others (1979). Blue, Lower-Middle Jurassic siltstones, clayey shale, horizons of sandstones; red, Lower-Upper Triassic siltstones, sandstones, coaly-clayey shales; yellow, Recent alluvium; red, fault zones.

The Gharghananaw-Gawmazar District was mapped at 1:200,000 scale by the Technoexport team in 1969–70 (Dronov and others, 1973). The copy of the Dronov report available to the USGS was incomplete and did not have the annexes containing the descriptions of individual mineral prospects or detailed prospect maps. A photograph of the map of the Gharghananaw-Gawmazar area, which also showed the locations of mineral occurrences, was given to the USGS by Gendiminas Motuza of Vilnius University. This map was used in the compilation of the mineral occurrence database for the Nalbandon AOI. A colored version of the Dronov map, lacking mineral occurrences, was included in Abdullah and others (1977) and was used as a base for figure 11A–21.

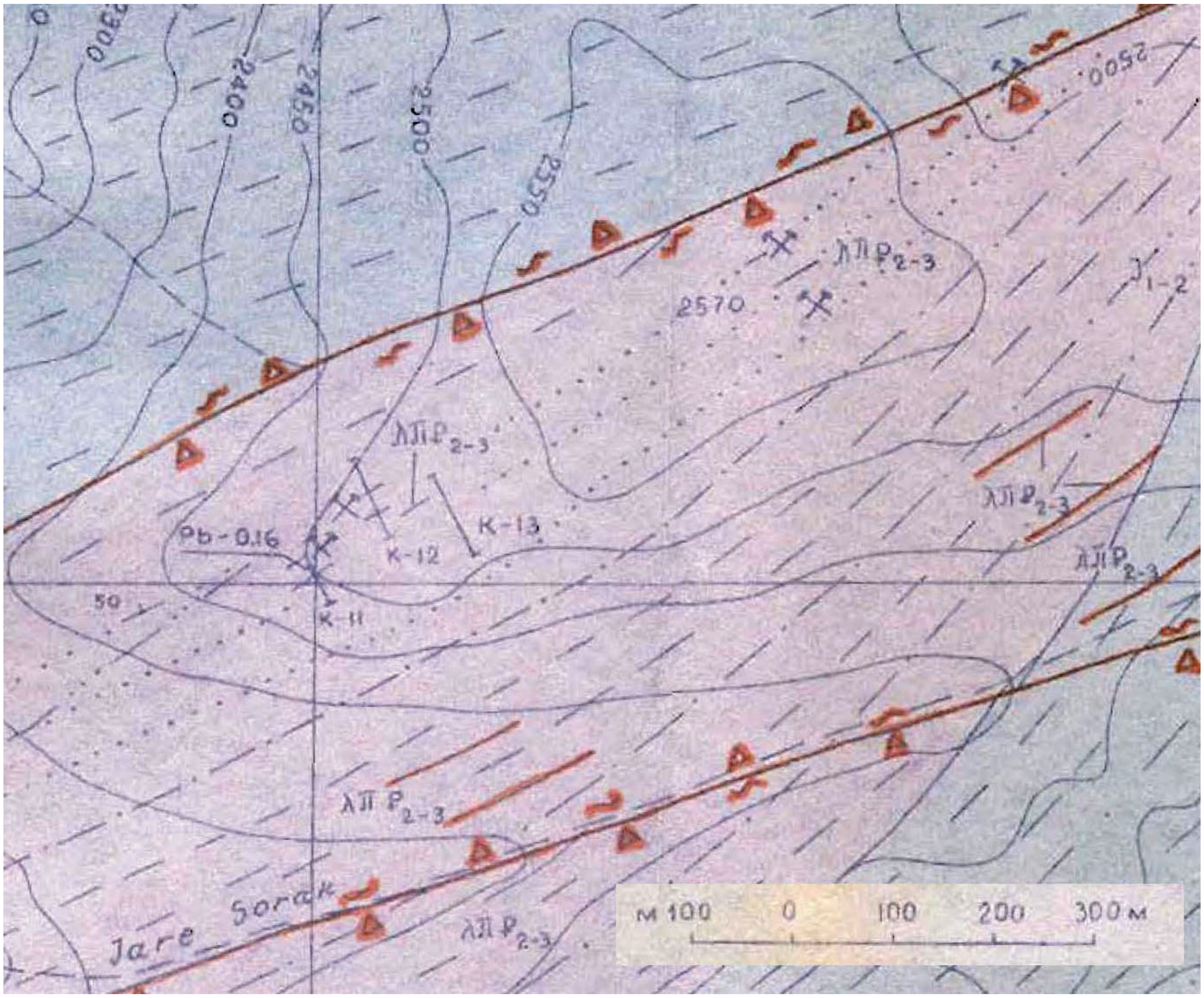

Figure 11A–18. Shorak lead-zinc (Pb-Zn) Prospect map. From Tutubalin and others (1979). Blue, Lower-Middle Jurassic siltstones, clayey shale, horizons of sandstones; red, Lower-Upper Triassic siltstones, sandstones, coaly-clayey shales; red, fault zones.

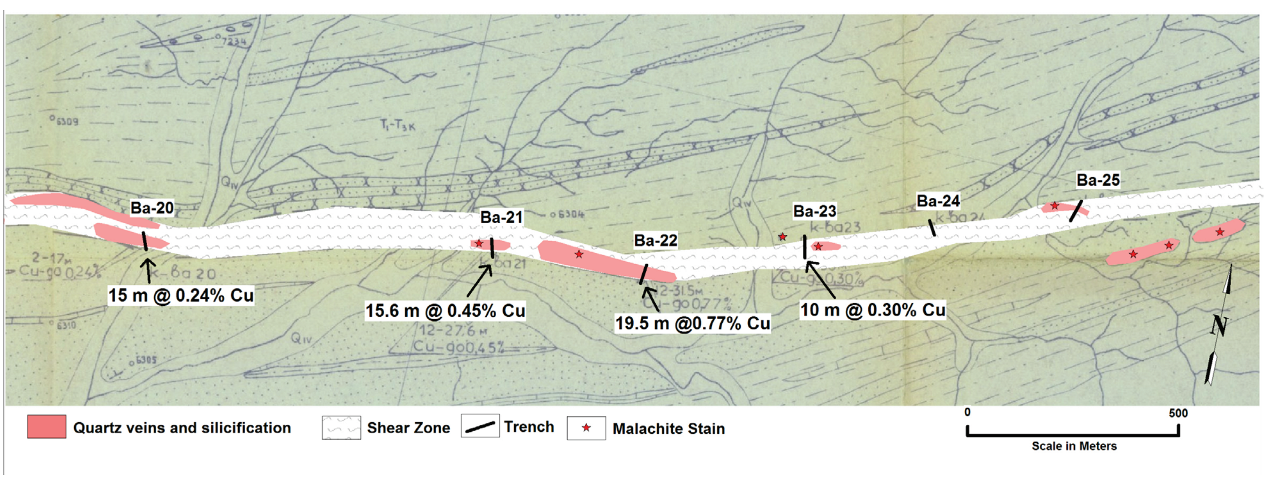

Figure 11A–19. Salgisafed copper-zinc (Cu-Zn) prospect map. Modified from Tutubalin and others (1979).

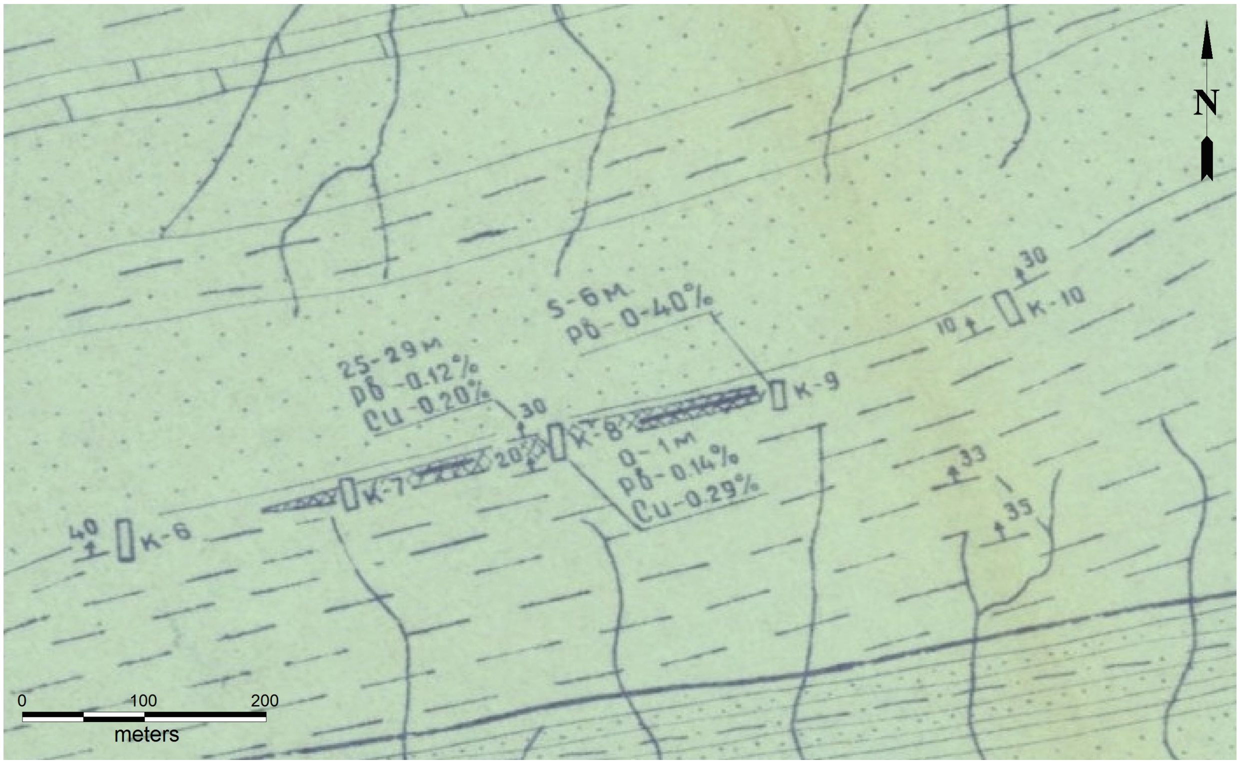

Figure 11A–20. Kermench lead-zinc prospect map. From Tutubalin and others (1979).

A total of 15 lead-zinc ±copper occurrences are present in the Gharghananaw-Gawmazar District. The general characteristics of the occurrences are summarized by Dronov and others (1973). The mineralization in the area consists of "occurrences" and "spots," but none of these have had sufficient exploration to be referred to as a "prospect." Mineralization consists of galena and sphalerite plus chalcopyrite in some places. One prospect has considerable arsenopyrite, two have anomalous antimony, and one shows anomalous gold. All of the showings are oxidized, and cerrusite is common. Iron staining or "ferruginization" is common and is a good prospecting guide, as is the presence of artisanal or ancient mine workings. The most common host rocks are cherts with intercalations of mid, to upper Jurassic limestone or in Carboniferous to Permian shale. The mineralization typically occurs in shear zones, which trend east-northeast to east-west and dip vertically. The shear zones are generally narrow (less than 1, to 2-m wide) and consist of zones of fracturing, silicification, quartz, veining, and intense ferruginization.

More detailed descriptions of individual mineral occurrences are given below. Unless otherwise noted, these are based on data from Abdullah and others (1977).

In the southernmost part of the area are four lead-zinc prospects: Gharghanaw II & III, Hasan Sansalaghay, Shaklawat, Gawmazar 1 & II, and Gwamazar III, that are hosted by Permian to Upper Triassic calcareous sedimentary rocks similar to those in the Nalbandon area. These sediments are folded into east-northeast trending anticlines cored by Carboniferous to Lower Permian clastic sediments.

The Gharghanaw II & III occurrence consists of galena disseminated in two shattered zones cutting lower to middle Jurassic limestone and shale. The breccia zones range from 5, to 20-m thick and are 50, to 100-m long. The rocks within the shatter zones are strongly silicified. The grade of the mineralization is reported as 1.6 to 12 percent lead, 1.0 to 1.6 percent zinc, and 0.05 to 0.07 percent copper.

Mineralization at the Hasan Sansalaghay occurrence also occurs in a shattered zone within middle Jurassic limestone and sandstone. The brecciated zone is 2.0, to 15-m wide but the length is not reported. The grade of the mineralization is up to 4.9 percent lead, 1 percent zinc, 0.9 percent copper, and 0.02 percent antimony.

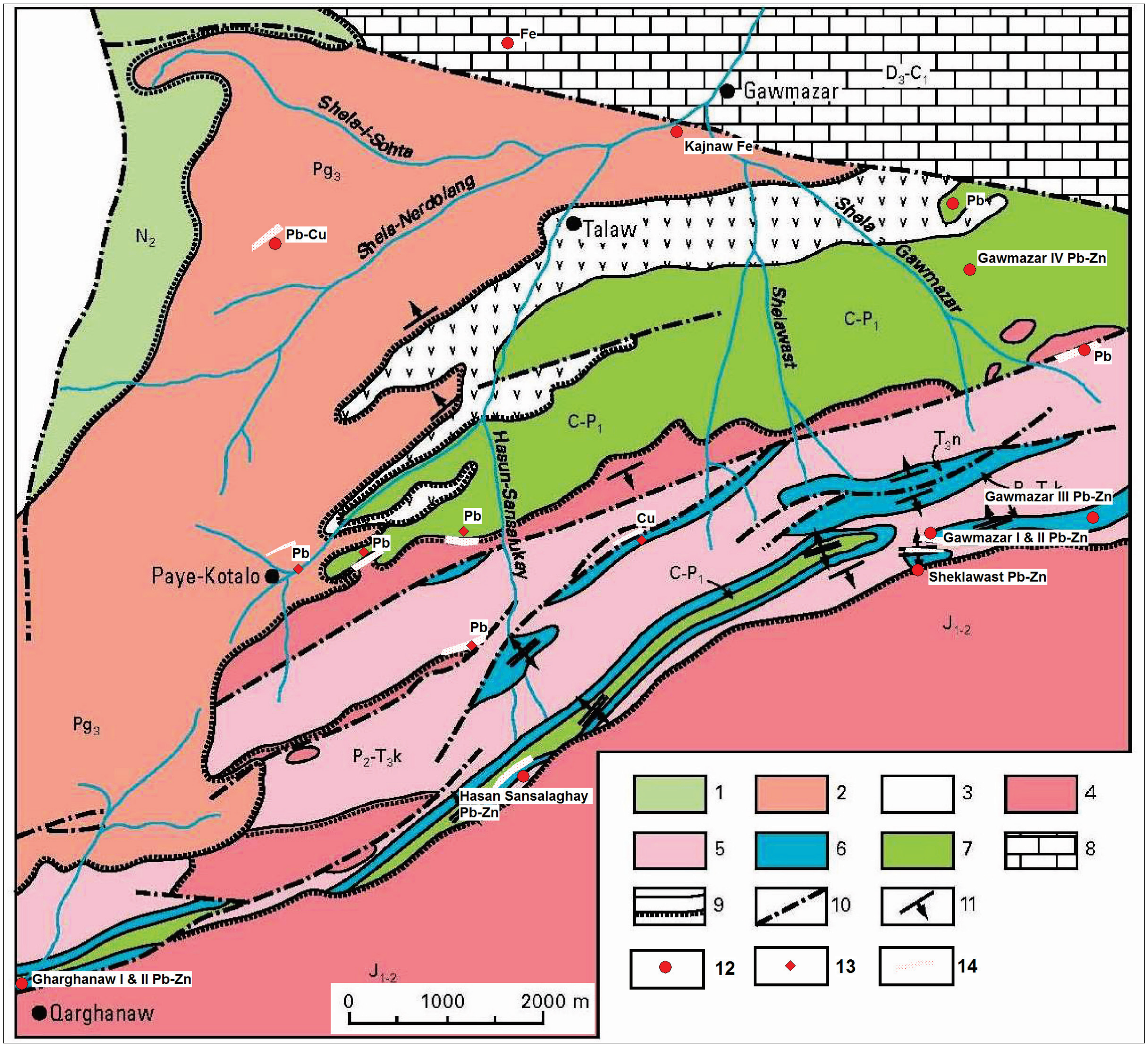

Figure 11A–21. Garghanaw lead-zinc area. Modified from Dronov and others (1973) and Abdullah and others (1977). 1, Pliocene coarse pebble conglomerate; 2, variegated sandstone, siltstone, conglomerate and gravelstone; 3, acid-to-intermediate volcanics of Eocene-Oligocene age; 4, Lower-Middle Jurassic limestone, marl, shale; 5, Norian-Rhaetian dark sandstone, siltstone, shale; 6, Upper Permian-Carnian limestone, marl, chert; 7, Carboniferous-Lower Permian dark sandstone, siltstone, slate; 8, Upper Devonian-Lower Carboniferous limestone; 9, boundaries: (a) between rock units of different ages; (b) between transgressive rock units; 10, fault lines; 11, strike and dip of beds; 12, mineral occurrence; 13, mineral showing or sample; 14, alteration zone.

The Shekhlawast occurrence consists of weak lead-zinc mineralization in shattered and silicified upper Triassic sandy-shaley rocks. The mineralized zone dips 40° to 45° to the south, is 50-m long, and 1.5, to 3.0-m wide. Samples of the mineralization show grades of 0.5 percent lead, 0.05 to 0.3 percent zinc, 0.1 to 0.3 percent arsenic, and 0.01 to 1.0 percent antimony.

Located about 400 m to the north, the Gawmazar I and II occurrence is also a mineralized breccia zone. The prospect is described as multiple shattered, silicified, “carbonitized” and”limonitized” zones in upper Triassic sandy-shaley rocks. Individual mineralized zones are up to 100-m long and

1.5- to 5-m wide. The grade is reported as 6.0 to 10 percent lead, 0.07 to 1.0 percent zinc, 0.16 percent copper, and up to 0.4 g/t gold.

About 1 km to the east along strike is the Gawmazar III occurrence where mineralization occurs in shattered and silicified sandy-shaley rocks of upper Permian age. The mineralized zones are 50-m long and 1, to 5-m wide. The grade is up to 10 percent lead and 1 percent zinc.

Other base metal mineral occurrences in the Gharghananaw-Gawmazar Area occur in a variety of host rocks. The Gawmazar IV and an unnamed lead occurrence are hosted by Permian rocks. Gawmazar IV is described as a shattered, silicified, and limonitized zone measuring 100-m long and 3 to 10-m wide. The grade of the mineralization is up to 10 percent lead and 1 percent zinc. An unnamed lead occurrence is located to the north, as shown on the map of Dronov and others (1973), but no description is available. The Kajnaw occurrence, located in the northern part of the district, consists of several lenticular hematite-limonite bodies within Upper Devonian to Lower Carboniferous sedimentary rocks. The lenses are 0.5, to 50-m thick and extend for 10 to 300 m along strike. The grade of the lenses is reported as 29 percent iron, 0.7 percent lead, 0.07 percent zinc, and 10 percent barium (Abdullah and others, 1977). Kajnaw was classified as an iron occurrence by Abdullah and others (1977), however, the USGS believes that it is probably a lead-zinc-barite gossan and has classified it as a lead-zinc occurrence for this review.

The Ustoowa occurrence is located in the northern part of the district. It consists of galena in quartz stringers within a zone of heavily limonitized Lower Carboniferous rocks. The maximum grade reported for samples is 5 percent lead and 1 percent zinc.

11A.6.3.1 Other Mineral Occurrences

A number of other mineral occurrences are present in the Nalbandon AOI. These include several undescribed base metal occurrences, one undescribed silver occurrence in the western part of the AOI, three evaporite occurrences [halite and (or) gypsum], six iron occurrences, and one mercury prospect (Tilak).

Three of the six iron occurrences are located in the northern part of the Gharghananaw-Gawmazar District (fig. 11A–7). These include the Kajnaw, one unnamed occurrence described in Abdullah and others (1977) and two occurrences shown as “hematite lenses” on the map of the Gharghananaw-Gawmazar District in Dronov and others (1973). Three other iron occurrences are located in the western part of the AOI but do not have descriptions.

11A.6.3.2 Tilak mercury prospect

The Tilak mercury prospect, located in the central part of the AOI (fig. 11A–4), was discovered during the Technoexport reconnaissance in 1969-70 and followed up in more detail during the regional mercury exploration program in 1972-73 (Dronov and others, 1973; Kornev and Arvanitaki, 1974). Exploration at Tilak included extensive drainage sediment sampling, using heavy mineral concentrates, geologic mapping at a 1:1000 scale, as well as pitting and trenching (23 trenches totaling 915 m). The summary below,taken from Kornev and Arbvanitaki (1974), was translated by Karine Renaud.

The geochemical anomaly consists of a 6 mi^2 “halo anomaly” where cinnabar and other minerals were found in heavy mineral concentrates from stream sediments. The source of the drainage anomalies was traced to a zone of mercury mineralization in lower Oligocene sedimentary rocks (fig. 11A–22). The mineralization consists of disseminated and veinlet cinnabar associated with patchy gypsum in bleached sandstone. The bleached zone is localized at the contact between the sandstone and overlying conglomerate.

The bleached and mineralized zone is 6, to 15-m thick and was traced along strike for 650 m. Within the bleached zone, cinnabar is concentrated in a 1, to 2-m-thick horizon at the contact between the sandstone and conglomerate. The mercury content of 268 one-meter-chip samples ranges from less than 0.0006 to 0.13 percent mercury. Of the 268 total samples, 14 contain 0.01 to 0.04 percent mercury, 4 contain 0.05 to 0.09 percent mercury and 2 contain 0.12 to 01.3 percent mercury. Kornev and Arvanitaki (1974) considered the mercury grades too low to be of economic interest and recommended no further exploration at the prospect.

11A.7 Discussion of Exploration Potential

The available data indicate that the previous exploration work in the Nalbandon AOI was conducted in a systematic and technically sound manner. The discovery of so many apparently small showings indicates that the work was thorough. Nonetheless, with the exception of the Nalbadon and Siah Sang prospects, the exploration did not advance beyond the prospect-examination stage, and the best available geologic mapping for the AOI is at a 1:100,000 scale. As a result, the Nalbandon AOI must be considered underexplored.

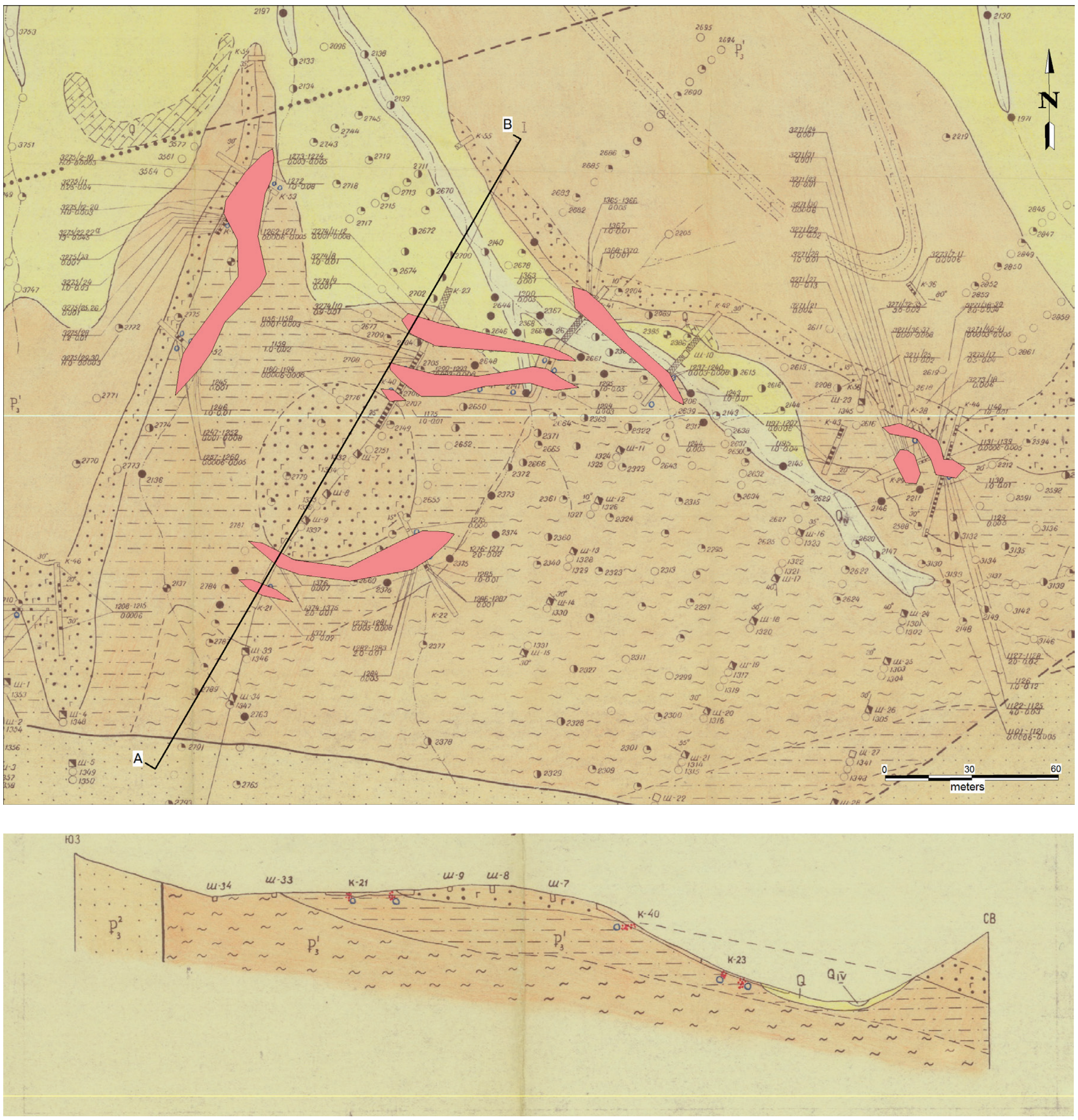

Figure 11A–22. Tilak mercury (Hg) prospect map and cross section. Modified from Kornev and Arvanitaki (1974). Cream and yellow units, Recent and Quaternary alluvium, shingle, sand, loess, and travertine; orange units, Oligocene sandstone and conglomerate; pink areas, mercury mineralization.

Sufficient work was conducted at the Nalbadon prospect to suggest the potential for a deposit in the range of 2 million metric tons grading about 5 percent zinc. A deposit of this size and grade would not attract outside investment. However, no drilling was done at Nalbandon, and the grade estimate is based on only a single section sampled in the German adit. The outcrops of mineralization at Nalbandon and geophysical anomaly indicate that there is potential for additional mineralization, so the prospect does warrant additional exploration work.

The question remains as to the nature of the lead-zinc ±copper mineralization in Nalbandon AOI, as this is critical to assessing the potential for additional mineralization. The Nalbandon AOI contains at least 81 mineral occurrences. Most of these are lead-zinc ±copper mineralization that occur in the Nalbandon structural block of the Band-e-Bayan zone (fig. 11A–4, table 11A–10).

Table 11A–10. Number and distribution of mineral occurrences in the Nalbandon area of interest.

[Ag, silver; Cu, copper; Fe, iron; Hg, mercury; Pb,lead; Zn, zinc]

Terrane	Pb-Zn	Cu ±Pb-Zn	Ag	Fe	Hg	Evaporite	Totals
Feroz Koh	2			1		1	4
Farah Rod						1	1
Band-e-Bayan zone							
Rode Kafgan	1	1	1				3
Hatfqala	1	1		3			5
Kwaja Morad	5	2			1		8
Nalbandon	50	6		2		1	59
Band-e-Bayan		1					1
Totals	59	11	1	6	1	3	81

The characteristics of lead-zinc ±copper mineralization in the Nalbandon AOI are summarized below.

- The mineralization is epigenetic.
- The mineralization is structurally controlled mainly by east-northeast trending steeply dipping faults and shear zones.
- The mineralization occurs in a variety of host rock types with ages ranging from Carboniferous, Permian to Middle Jurassic.
- No lead-zinc ±copper mineralization is reported in Cretaceous or younger rocks.
- The style of mineralization consists of veins and disseminations in vein minerals. No wall rock dissemination or massive sulfides have been reported.
- The primary minerals are galena and sphalerite with lesser pyrite, chalcopyrite, and boulangerite. A few prospects have arsenopyrite, stibnite, and barite.
- The main gangue minerals are quartz, calcite, and ankerite.
- Most prospects are strongly oxidized with prominent iron staining (referred to as ferruginization) of veins and host rocks and the presence of cerrusite, malachite, and azurite, in addition to iron and manganese oxides.
- The mineralization occurs in veins, fracture zones, breccias, and "shatter zones."
- The most common associated alteration is silicification with less common bleaching and local kaolinization.
- The geochemistry of the mineralization reflects the simple mineralogy and is dominated by lead and zinc, lesser copper, and only local arsenic, antimony, and bariu. Where reported, silver values in the mineralization are low (less than 10 to 15 parts per million). Gold is reported at only one prospect (Zavar) and in several heavy mineral concentrates.
- The mineralization is not directly associated with igneous rocks and no alteration is described for the relatively few intrusive centers or rock outcrops in the AOI.

- The age of the mineralization is younger than middle Jurassic and older than upper Cretaceous, as indicated by the presence of mineralization in middle Jurassic rocks and its absence in upper Cretaceous rocks.

The lead-zinc ±copper occurrences are present in groups, which are aligned along east-northeast lineaments visible on Landsat imagery (fig. 11A–23). These lineaments most likely correspond to east-northeast trending high-angle faults formed as part of the latest deformation event in the Band-e-Bayan, as reported by Dronov and others (1973).

The absence of mineralization in Cretaceous rocks indicates that the mercury mineralization at Tilak, which is hosted by Oligocene sedimentary rocks, formed later than the base metal mineralization, as a separate epithermal hydrothermal event.

Early workers (Siebdrat, 1964; Khasanov and others, 1967; Scheer, 1969; Dronov and others, 1973; and Tutubalin, 1979), as well as the Vilnius University team (Motuza and Shiaupa, 2008), considered the base metal mineralization in the Nalbandon AOI to be of hydrothermal vein type and related to Cenozoic intrusive rocks. This conclusion was based on the generally discordant nature of the mineralization, the presence of hydrothermal alteration, mainly silicification at many showings, and the general presence of intrusive rocks in the area. Orris and Bliss (2002) and Peters and others (2007) agreed with this classification for many of the occurrences but considered the Nalbandon and a number of other prospects in the AOI to be MVT prospects. MVT deposits are generally more attractive exploration targets than hydrothermal veins owing to their larger tonnage.

Leach and others (2005) list the principal characteristics of MVT mineralization as follows:

- They are epigenetic.
- They are not associated with igneous activity.
- They are hosted mainly by dolostone and limestone, rarely in sandstone.
- The dominant minerals are sphalerite, galena, pyrite, marcasite, dolomite, and calcite; barite is typically minor to absent and fluorite is rare.
- They occur in platform carbonate sequences, commonly at flanks of basins or foreland thrust belts.
- They are commonly stratabound but may be locally stratiform.
- They typically occur in large districts.
- The ore fluids were basinal brines with about 10 to 30 weight percent salts.
- They have crustal sources for metals and sulfur.
- Temperatures of ore deposition are typically 75 ° C to about 200 °C;
- The most important ore controls are faults and fractures, dissolution collapse breccias, and lithological transitions.
- The sulfides are coarsely crystalline to fine grained, massive to disseminated.
- The sulfides occur mainly as replacement of carbonate rocks and, to a lesser extent, open-space fill.
- Alteration consists mainly of dolomitization, host-rock dissolution, and brecciation.
- A comparison of the characteristics of MVT deposits listed above with the previous list of characteristics of mineralization in the Nalbandon AOI indicates a number of similarities, but also several important differences. The style of mineralization, mineralogy, and alteration of the base metal prospects in the Nalbandon AOI are more consistent with polymetallic vein type deposits than MVT deposits. Even though further exploration could clarify the nature of the mineralization, the weight of the available data indicates that the Nalbandon area is most likely a polymetallic vein district.

There is also potential for three other types of mineralization in the Nalbandon AOI—vein gold, nonsulfide zinc mineralization, and epithermal gold mineralization. Gold mineralization is reported at the Zavar prospect where a 17-m trench sample averaged 1.6 g/t gold. The sample was collected across a shear zone, which also hosts lead-zinc mineralization. Tutubalin and others (1979) also report several areas where gold grains were found in heavy mineral concentrates. Previous exploration relied primarily on prospecting and heavy mineral concentrate sampling of stream sediments, which are both both highly effective techniques. However, the prevalence of mineralized fault zones, in addition to a significant width of gold mineralization at one prospect, suggests that the use of modern geochemical techniques may also yield positive results and may be more effective.

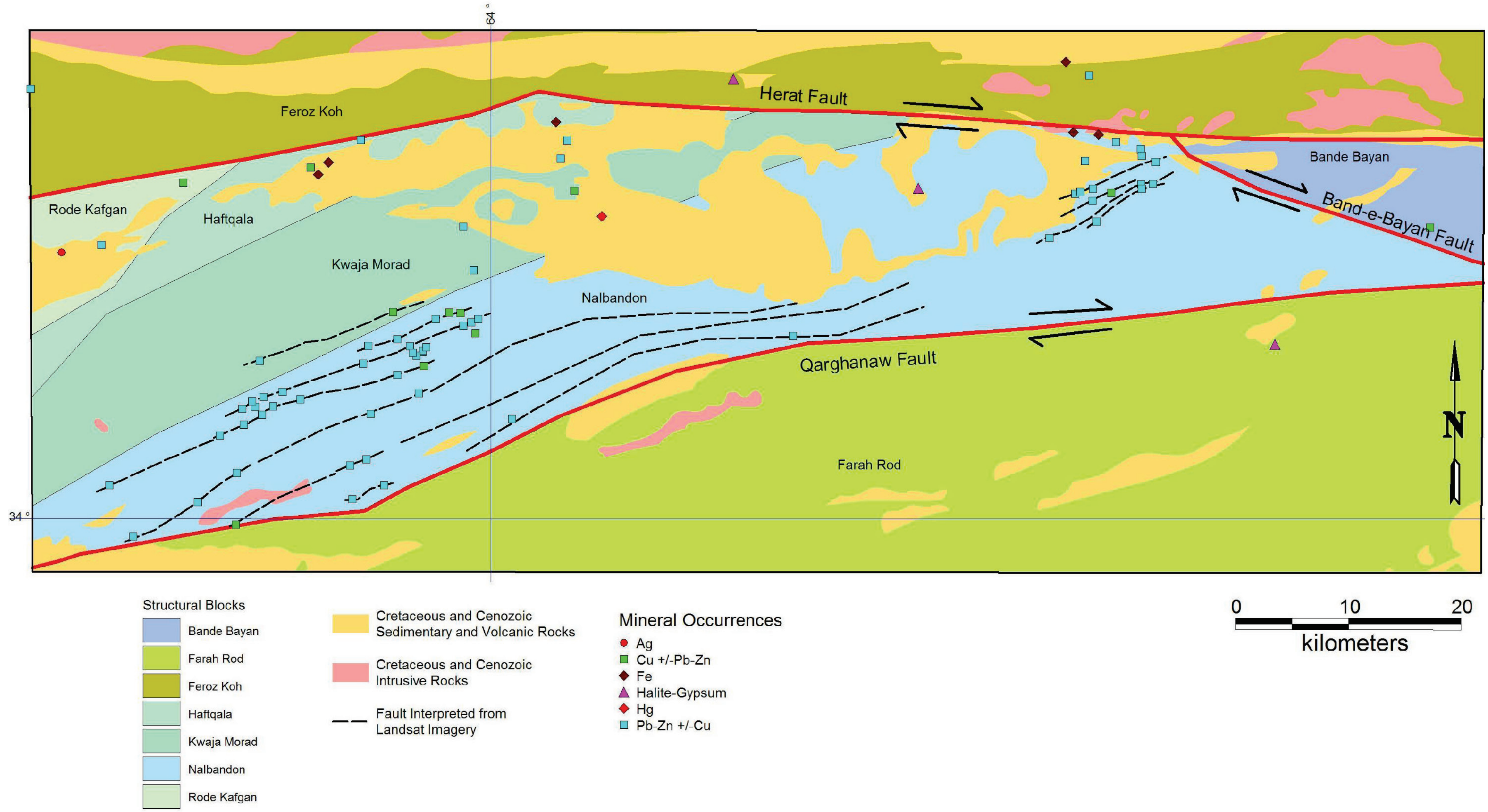

Figure 11A–23. Nalbandon area of interest distribution of mineral occurrences in relation to structure. Compiled from Dronov and others (1973), Abdullah and others (1977), and Tutubalin and others (1979). Faults interpreted from Landsat imagery.

Descriptions of several of the occurrences note the presence of secondary lead minerals, such as cerrusite and anglesite. Secondary zinc minerals are mentioned only at Siah Sang where more detailed mineralogical work was done. Supergene zinc mineralization is extremely difficult to recognize when it is not directly associated with sulfides. At the Jabali deposit in Yemen, for example, ancient miners extracted galena for lead and silver, but left behind smithsonite as waste (Al Ganad and others, 1994). Due to advances in processing technology, which allow direct treatment of nonsulfide zinc ores to directly produce zinc metal, nonsulfide zinc is considered an attractive exploration target (Hitzman and others, 2003). As with gold, the application of modern geochemical techniques could prove a more effective exploration approach.

The mercury mineralization at Tilak indicates the presence of an epithemal hydrothermal system in Tertiary time. Mercury-bearing epithermal systems are often zoned and may also contain gold mineralization (Rytuba and Heropoulous, 1992; Hedenquist and others, 2000). The Ivanhoe district in Nevada in the United States is an example of mercury mineralization hosted by Cenozoic lake sediments, which overly epithermal gold mineralization (Wallace, 2003).

11A.8 Conclusions

The Nalbandon AOI has numerous mineral occurrences, which were found through reconnaissance mapping and exploration. Most of the occurrences are fault controlled lead-zinc ±copper mineralization in the Nalbandon structural block in the Band-e-Bayan tectonic zone. The base metal mineralization appears to be of late Jurassic to mid-Cretaceous age and exhibits characteristics of both hydrothermal polymetallic vein and MVT styles of mineralization. Only two of the base metal occurrences have been explored beyond the initial examination stage. Results at the Nalbandon prospect were sufficiently positive to warrant further exploration. Most of the mineral occurrences are oxidized and have secondary lead minerals. The presence of mercury mineralization in Oligocene sedimentary rocks indicates that an epithermal hydrothermal system was active in Cenozoic time. The Nalbandon AOI warrants exploration for four targets:

- Vein or MVT lead-zinc mineralization in or adjacent to east-northeast trending fault zones.
- Gold mineralization in east-northeast trending trending fault zones.
- Nonsulfide zinc mineralization on and adjacent to lead-zinc occurrences.
- Epthermal gold mineralization below the Tilak mercury occurrence.

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