Chapter 7
Kyrgyzstan

Uranium deposits of three types occur in the *eastern Karamazar* and *northeastern Fergana region* in central-western Kyrgyzstan: bituminous carbonate-type hosted in Paleogene limestone, sandstone-type in Neogene sandstone, and vein-type. Surficial karst cavern-type deposits occur in the *Tyuya-Muyun District* to the south of the Fergana Valley, SW Kyrgyzstan. Uraniferous coal deposits are reported in the *Min-Kush* and *Naryn* Jurassic basins in central Kyrgyzstan, and the *Sogut–Issyk-Kul* Basin in east-central Kyrgyzstan, south of Lake Issyk-Kul (Fig. 7.1). No minable resources are recorded for the country.

Deposits mined include *Tyuya-Muyun, Mailuu-Suu* (or *Mailisu*), *Mailisay, Shakaptar*, and uraniferous lignite deposits in the *Min-Kush* and *Sogut* coal basins. Cumulative production is estimated by some sources to be on the order of 11 000–13 000 t U while other sources estimate only some 2 000 t U.

A mill with a nominal annual capacity of 1.5 million t of ore or 3 600 t U was built at *Kara Balta*, some 60 km west of the capital Bishkek (formerly Frunze) to process ore from central Kyrgyzstan, southern Kazakhstan (Pribalkhash region), and Russia. Yuzhpolymetal Mining and Metallurgical Combinate was the former operator of the mill. Its successor is the Kara Balta Ore Processing Combinate. Uranium ore processing started in 1955 and lasted until 1989 when conventional mining in southeast Kazakhstan was abandoned. A total of 30 million t of mill tailings indicate an average annual throughput of about 0.9 million t of uranium ore. Subsequently, the mill has processed yellow cake slurries from ISL operations in southern Kazakhstan. Since 1994, the process rate has been 1 000 t yr^{-1} of concentrate containing 40–45% U yielding a final product of approximately 400 t U. In recent years the circuit has been partly reconfigured to treat commodities other than uranium, including gold ore.

Ore from the west Kyrgyzstan mines was mainly processed at the Leninabad mill, near Khudzhand (formerly Leninabad) in NW Tajikistan (see Chap. 12: *Tajikistan*).

Sources of information. Boitsov 1999, pers. commun.; IAEA 1995; Kazansky 1970; Kazansky and Laverov 1977; Laverov et al. 1992a–c; OECD-NEA/IAEA 1993, 1995, 2001; Savchenko et al. 2003; Thoste 1999; unless otherwise cited.

Historical Review

Earliest uranium reports came from the Alai Range to the south of the Fergana Valley in the former Russian territory of Turkestan where, in 1902, U-V ores were detected near the Tyuya-Muyun pass. Extended prospecting found additional uranium occurrences in that region scattered over an area of 2 500 km^2. Later on, uranium was discovered in the eastern Karamazar region, Mailuu-Suu in 1934, Shakaptar and Mailisay in 1946, and Charkasar in 1954–1955. Uraniferous lignite was discovered at Dzhilkoye in 1947.

First mining of uranium in the Russian Empire for recovery of radium was in or near the Fergana Valley and dates back to 1908. Famous mines were at Tyuya Muyun in the Alai Range where vanadium-uranium ore was recovered from karst caverns in Carboniferous limestone. Copper was mined from deposits in this area possibly as early as in the Bronze Age. Post World War II mining started in 1946 and lasted until the end of the 1960s. Deposits mined include those mentioned earlier.

7.1 Eastern Karamazar-Northeastern Fergana Region, Central-Western Kyrgyzstan

This uranium region is located in Osh Province at the northeastern margin of the Fergana Valley in the northwestern Tien Shan mountains. A larger town is Tash Kumyr on the Naryn river. The region is the eastern extension of the Karamazar uranium region, which covers parts of NW Kyrgyzstan and adjacent terrane in Tajikistan and Uzbekistan (see respective chapters and Figs. 7.1, 7.2).

Several deposits were exploited including the vein-type *Charkasar*, and the *Mayluu-Suu, Shakaptar,* and *Malisay* deposits (Fig. 7.2) referred to as bituminous limestone-type with structure controlled uranium mineralization in hydrocarbon-bearing carbonates. These four deposits were mined by underground methods between 1946 and 1968 and are depleted. Their cumulative production is thought to be between 11 000 and 13 000 t U. Grades ranged from 0.03 to >0.1% U (IAEA 1995).

Sources of information. IAEA 1995; Laverov et al. 1992; Roslyi 1975; Thoste 1999; and other sources.

7.1.0.1 Mailuu-Suu

The depleted Mailuu-Suu (or Mailisu) deposit (Fig. 7.3) was discovered at the Mailuu-Suu River in central-western Kyrgyzstan, to the NE margin of the Fergana Valley in 1934. The deposit is subdivided into several sectors covering a mining area of 36 km^2. Six underground mines recovered uranium between 1946 and 1968 and produced in total some 10 000 t U from 9.1 million t of ore. Ore grades ranged from 0.03% to over 0.5% U. Ore produced had the following distribution of ore grade: 45% of 0.03–0.1% U, 30% of 0.1–0.2% U, 20% of 0.2–0.5% U, and 5% in excess of 0.5% U (Thoste 1999).

Roslyi (1975) provides a description of uranium mineralization in petroliferous carbonatic sediments of the Bedre sector in the NW section of the Mailuu-Suu deposit. Roslyi does not name the deposit locality but meanwhile available information identifies the locality as the Bedre sector. Although Roslyi describes only this sector, his presentation tends to illustrate the principal properties of this type of deposits.

Fig. 7.1.
Central Asian Republics. Uranium regions and districts in southern Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan (for location of U deposits in southern Kazakhstan, western Kyrgyzstan, and Uzbekistan see Figs. 6.1, 7.2, and 15.1 respectively)

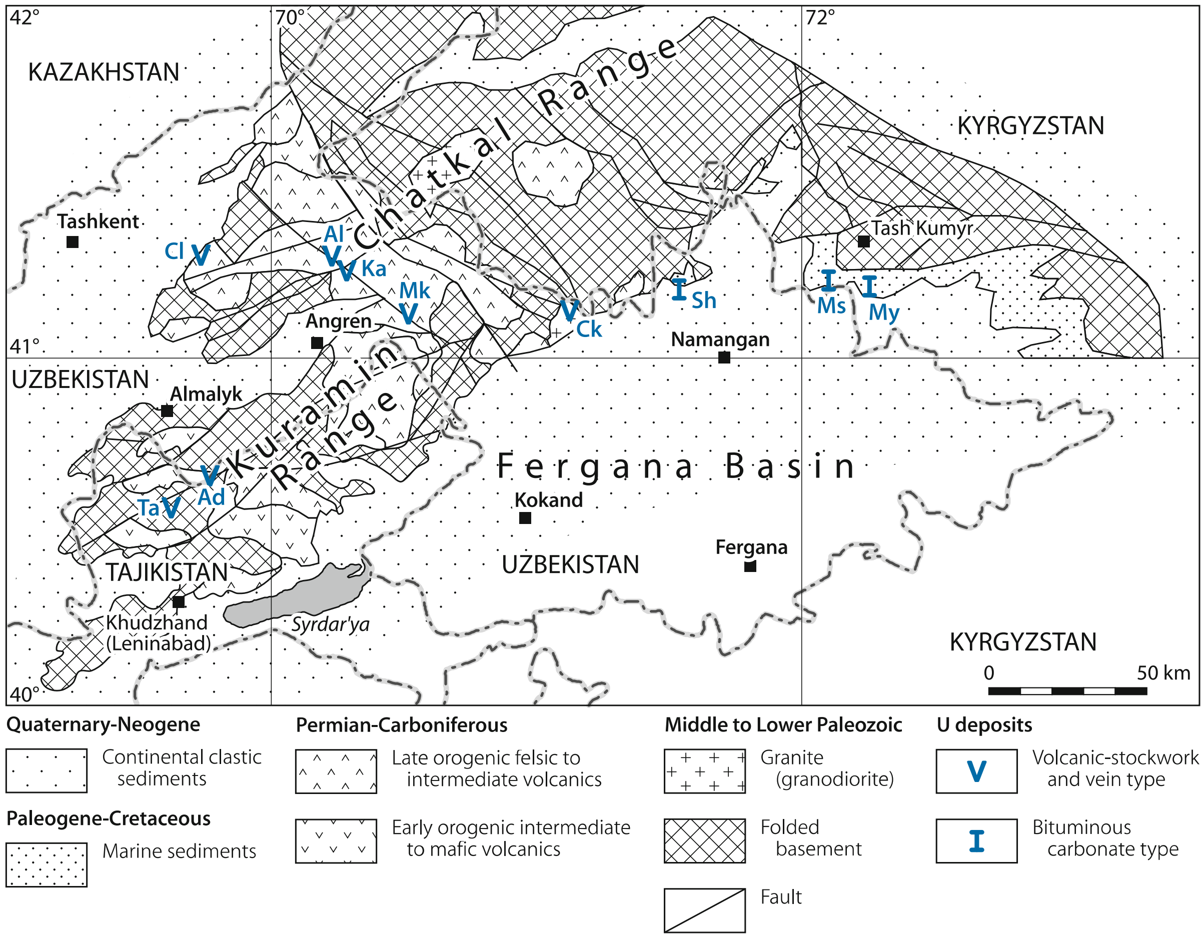


Fig. 7.2.

Karamazar region, generalized geological map with location of volcanic-stockwork-type U deposits in the Hercynian Chatkal-Kuramin uplift and bituminous carbonate-type U deposits in adjacent areas (after Laverov et al. 1992c). *Vein or volcanic-stockwork-type deposits* in *Tajikistan: Ta* Taboshar, *Ad* Adrasman; in *Uzbekistan: Cl* Chauli, *Al* Alatanga, *Ka* Kattasay and Djekindek, *Mk* Maylikatan; in *Kyrgyzstan: Ck* Charkasar. *Bituminous carbonate-type deposits* in *Kyrgyzstan: Sh* Shakaptar, *Ms* Mayluu-Suu, *My* Maylisay

Bedre Sektor of Mailuu-Suu

The Bedre sector contributed approximately 20% of total Mailuu-Suu U production. Ore grades ranged from 0.03 to over 0.5% U. The Bedre sector (Fig. 7.4), as documented by Roslyi (1975), is characterized by the following features.

Geological Setting of Mineralization

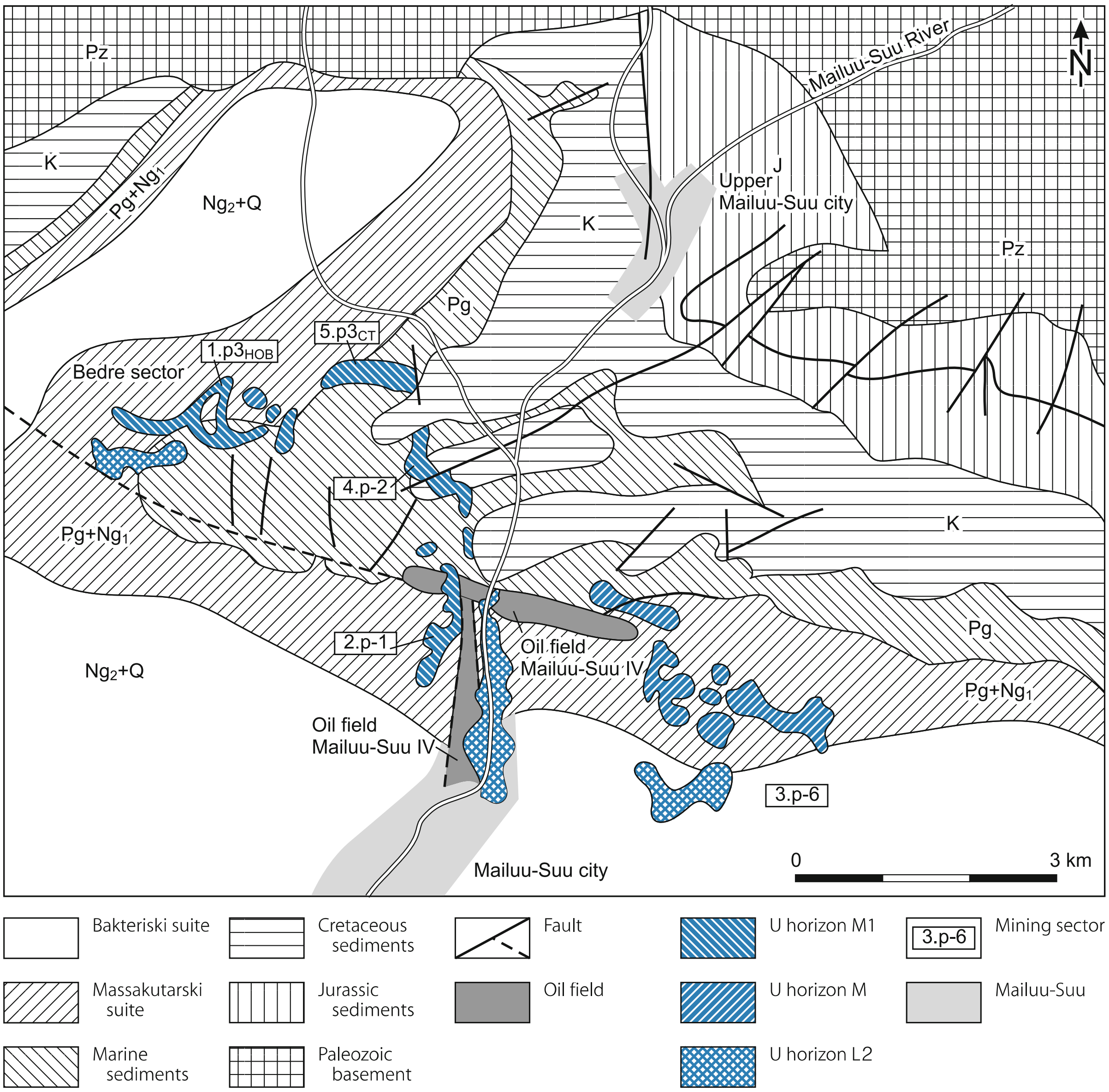
Carbonate-hosted uranium mineralization is restricted to Oligocene-Paleocene bituminous/petroliferous calcareous sediments. The sediments are folded and ore bodies are positioned on the wings of anticlines, the crests of which are eroded. Host rocks include oolitic and dolomitic limestone, dolomite, and marlstone intercalated with sandstone or gritstone. The Bedre zone is located on the NW flank of a domal uplift where strata dip in a northwesterly direction.

The ore-hosting sequence is about 4–5 m thick (Fig. 7.5) and composed of the following lithologies:

- *Hanging wall unit* (thickness 2.5 m): arenaceous-argillaceous continental sediments, pink in the upper part grading downward into greenish
- *Upper limestone unit*: oolitic, stylolitic and organic detrital limestones containing 1–3% insoluble residues and intercalated oyster beds
- *Lower limestone unit* (2 m thick): relatively dense argillaceous, dolomitic limestone with laminae of dolomitic marl
- *Footwall unit*: dolomitic marl and pink arenaceous-argillaceous continental sediments

Mineralized segments are characterized by intense structural disturbances including major faults, fractures/fissures, and shear zones. A prominent, curvilinear E-W-oriented, S dipping reverse fault with splay faults forms the southern boundary of the ore zone. Fracturing is particular abundant in the upper, purer limestone unit as reflected by a fracture density 4–5 times higher than in the lower argillaceous dolomitic limestone unit. Several fissure and shear-fracture systems are distinguished. NW-SE-oriented fracture zones extend in excess of 1 000 m and

Fig. 7.3.
Eastern Karamazar region, Mayluu-Suu deposit, schematic geological map with distribution of U-mineralized horizons and sectors (after Thoste 1999)



change strike direction particularly along NE-SW-oriented planes, which correspond to flexures of the limestone beds.

Host Rock Alterations

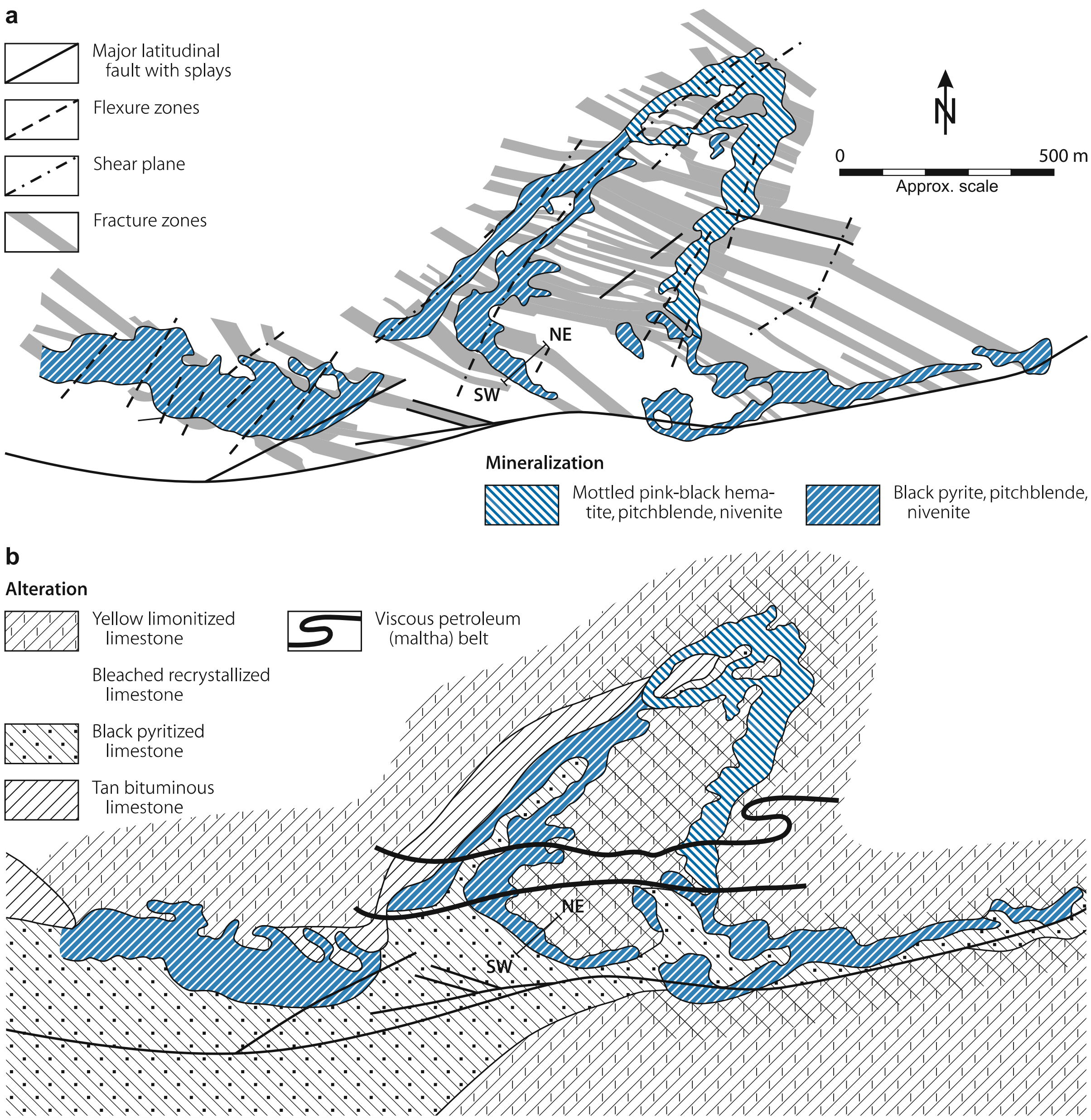
Alteration of ore-bearing calcareous sediments resulted from several reduction and oxidation processes (Figs. 7.5, 7.6a,b).

Pre-uranium stage alteration: The earliest alteration was by reduction of regional extent, which turned red beds over- and underlying the uranium bearing calcareous unit into green and light grey colors, respectively. It remains debatable whether this event also generated pyritization of limestone or not. Pyrite is present as finely dispersed inclusions in black limestone.

The earliest alteration in the carbonate unit is evidenced by limonitization; it imprinted a yellow hue on the rocks and locally on reduced super- and subjacent strata to a depth in excess of 500 m. Voids and fractures were filled with Fe-hydroxides during this process. Oxygenated waters considered responsible for the limonitization presumably entered the ore horizon from the north, the site of basement outcrops.

Subsequent alteration affecting permeable limestone of the upper and middle parts of the ore horizon includes first *leaching*, then *argillization* (*hydromicazation*) and *bleaching* associated with removal of iron. A subsequent lateral effect is indicated by *hematitization* due to redeposition of iron in form of lavender-pink hematite-hydrohematite rims at the margin of bleached, light beige-grey zones. Leaching took place in the most permeable, fractured, and stylolitic limestone. Two varieties are

Fig. 7.4.
Mayluu-Suu, Bedre sector (1.p3$_{HOB}$), a Structural pattern and distribution of mineral assemblages in the upper U mineralized carbonatic horizon (L1), and b associated wall rock alterations (after Roslyi 1975)

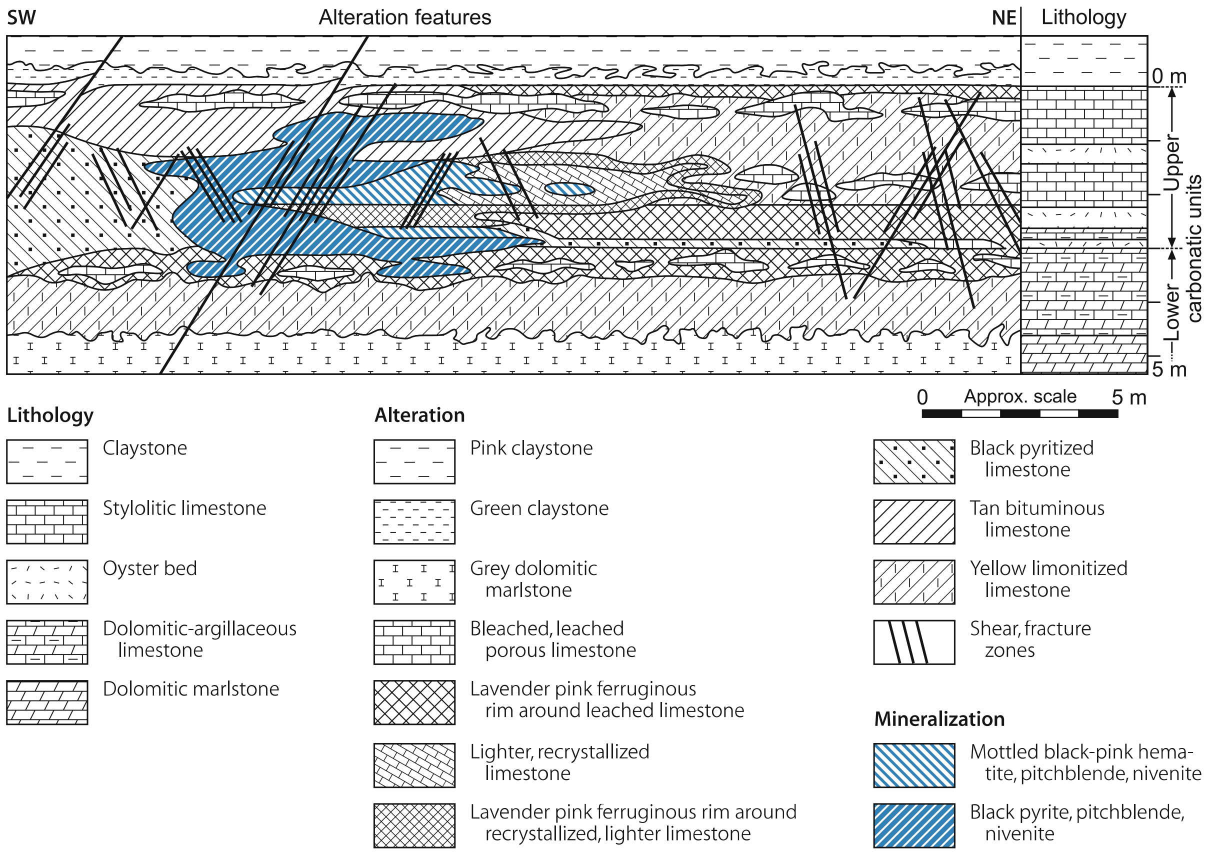


distinguished, *(a)* limonitic limestone with leached-out stylolite cavities and dispersed minute leaching pores and *(b)* bleached, porous, chalky facies present as lenses along leached-out stylolites in the former variety. Stylolites, sutures, and microfractures in both varieties contain greenish hydromuscovite. Leaching also occurred in argillaceous limestone of the lower part of the carbonate unit in the southern part of the ore field.

In a following stage both limonitized and bleached rocks were affected by *recrystallization* associated with *calcitization* and minor *pyritization*. Laminae of highly permeable, stylolitic, bleached limestone experienced a high degree of recrystallization. Porous, chalky facies of leached limestone turned into a white porcelain material. Limonitized facies lost their color as a result of loss of iron and acquired a lavender-pink ferruginous rim similar to that mentioned previously. Scattered specks of yellowish Fe-hydroxides are still preserved in the groundmass of the bleached recrystallized facies. Vugs and pores are filled or coated with coarse-crystalline calcite and minute crystals of pyrite. Stylolites, sutures, and microfractures contain hydromuscovite and minute crystals of pyrite. Pyrite is partly replaced by Fe-hydroxides suggesting a renewed oxidation period.

Syn-uranium stage alteration is reflected by hematitization followed by pyritization. Both are associated with deposition of pitchblende and nivenite. Intensive hematitization is manifested in front of pitchblende-nivenite mineralization and apparently preceded the U deposition (see also next paragraph).

Fig. 7.5.
Mayluu-Suu, Bedre sector, SW-NE section across a mineralized lode illustrating the distribution of principal ore assemblages and related alteration features (*left*) combined with a lithologic column (to *right*) (see Fig. 7.4 for position of section) (after Roslyi 1975)



Post-uranium stage alteration of a reducing nature is evidenced by bitumenization (colored, less commonly black, insoluble solid bitumens) imposing a tan hue on the limestone in a narrow zone along the NW and W margin of the ore zone. This process was followed by an – to-day still active – influx of viscous petroleum (maltha) into the calcareous unit. The maltha forms a band parallel to the major fault on the south side of the ore zone. Its position tends to be controlled by the pressure of fault-water on the viscous petroleum.

Most recent alteration is expressed by near-surface limonitization associated with the formation of hexavalent U-V minerals spreading in a NW direction from the eroded crest of a domal uplift in the SE.

Mineralization

All mineralization of the Bedre sector is restricted to the footwall block of the large, E-W-oriented and southerly dipping reverse fault. The host unit is a 4–5 m thick, variably altered, water- and hydrocarbon-bearing carbonate sequence in which mineralization occurs structure bound controlled by faults and fractured intervals.

Pitchblende, nivenite, and sooty pitchblende are the principal uranium minerals. About 20% of the ore contained U is bound to post-uranium bitumen (kerite). Minor amounts of U-V minerals occur in surface near zones. Associated ore minerals are either hematite or pyrite. Associated elements include up to 0.8% Fe, 0.1% V, 0.06% Mo, 0.06% As, 0.03% Pb, 0.03% Ni, and 0.01% Co.

U minerals are developed in stylolites, sutures, microfissures, interstices between carbonate grains, and on walls of leached-out voids, pores, oolite grains, fragments of oyster shells, small pelecypods, gastropods, and foraminifera. Microfissures and stylolites also contain greenish hydromuscovite, and colored and black solid bitumens. The latter often cement minute fragments of pitchblende and nivenite.

Two mineralization varieties are distinguished, an older mottled black-pink hematite-pitchblende-nivenite, which is practically free of pyrite, and a massive, black pyrite-pitchblende-nivenite assemblage (Fig. 7.6).

Mottled black-pink mineralization is present as small lenses in which the ore minerals fill stylolites, penetrate limestone along joints and hair fractures above and below the stylolites, and form globular to irregular shaped inclusions. Black aggregates of U minerals are surrounded by vivid lavender-red halos, some 3 cm wide, in the limonitic or pale rocks but a light colored, from a fraction of a millimeter to one centimeter wide fringe always separates both. Closely spaced, minute crystals of hematite and specks of pink Fe-oxides and hydroxides form the red aureoles. Mottled black-pink mineralization is restricted to fractured intervals in stylolitic, lighter colored, recrystallized limestones and denser, limonitic rocks adjacent to zones of recrystallization and bleaching of the about 2.5 m thick upper carbonate unit.

Massive black mineralization consists of pitchblende and nivenite intermixed with finely dispersed pyrite. The ore minerals occupy sutures, stylolites, microfissures, leached-out pores and coat oolites and shell fragments. Larger corroded stylolites are occasionally completely filled with lustrous black pitchblende, which penetrates and replaces the wall rock. Stringers of insoluble, solid bitumens cut pyrite-pitchblende-nivenite aggregates. Massive black mineralization occurs within and correlates to a large extent with the outer margin of black pyritized rocks of the upper carbonate unit and locally of the upper part of the lower carbonate unit (Fig. 7.6). Some isolated small lenticular ore bodies also occur in front of this zone within limonitic strata.

Shape and Dimensions of Deposits

The Mailuu-Suu deposit consists of several discontinuous ore trends/sectors irregularly spread over a total extension of approximately 10 km in a NW-SE, and up to 5 km in a N-S

Fig. 7.6.
Mayluu-Suu, NE part of Bedre sector. a and b Detailed sketch sections illustrating distribution of ore and alteration phenomena in leached carbonate beds (b is perpendicular to lower U horizon in a). c, d and e Sketches of specimens of mottled black and pink hematite-pitchblende-nivenite mineralization (after Roslyi 1975)

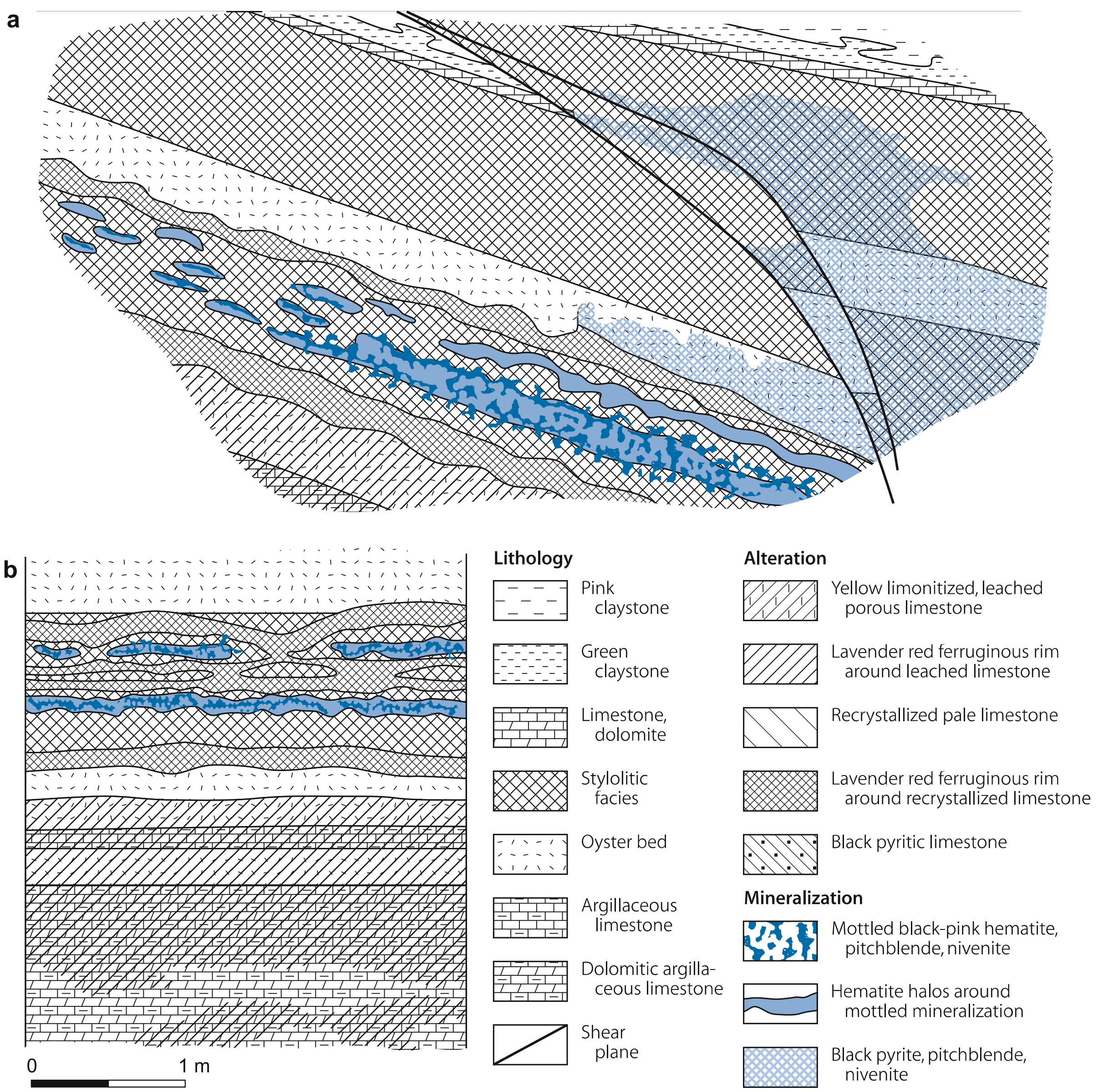
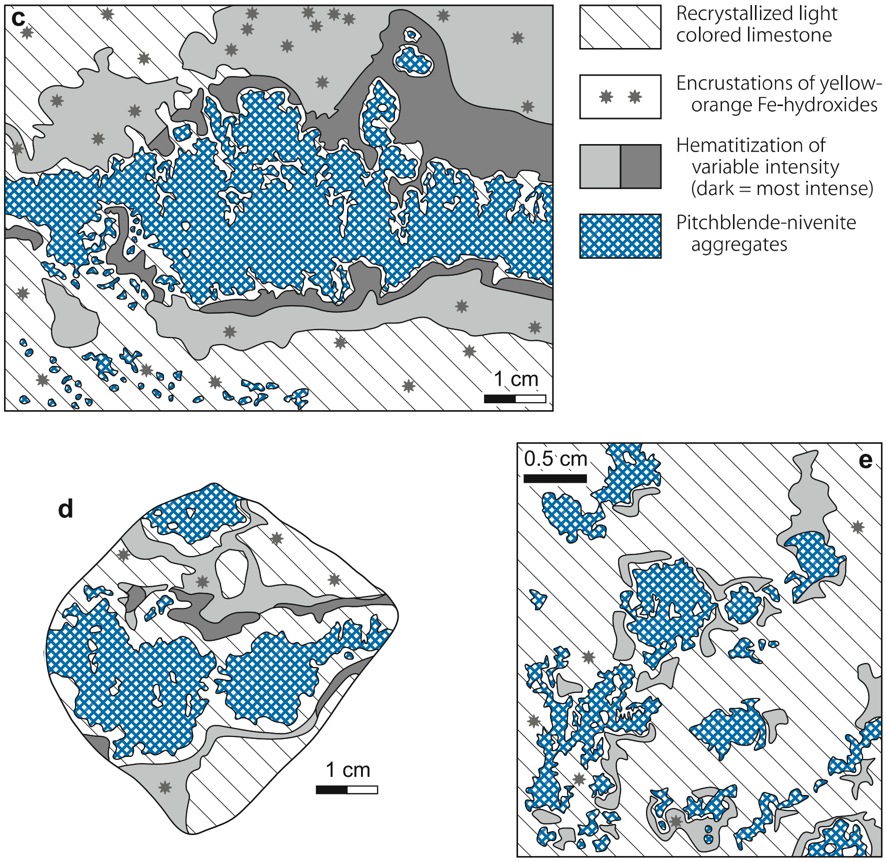


Fig. 7.6. (Continued)



direction. Besides a number of smaller ore zones, some ten major ore trends have been identified including the Bedre sector in the NW part of Mailuu-Suu deposit (Fig. 7.3).

The Bedre sector is almost 2 000 m long in an E-W direction along the major latitudinal fault from where it bulges for about 900 m to the NE (Fig. 7.4). Bedre includes several ore zones composed of discontinuous, lenticular and roll shaped ore bodies contained in the upper 3–3.5 m of the up to about 5 m thick carbonate unit (Figs. 7.5, 7.6). Three varieties of geological setting and ore body configuration are distinguished, fault associated, layered fracture associated and roll shaped types (roll in sense of a morphological term rather than a genetic).

Mottled black-pink mineralization occurs in the Bedre sector in a curved, about 200 m long and up to 20 m wide ribbon-like ore zone, the orientation and configuration of which is controlled by flexures of the strata and changes in attitude of shear planes. This zone is composed of small isolated or interconnected ore lenses, which occur adjacent to shears along which they can be traced in form of bands. Lenses are mostly positioned in the footwall of shears. The lenses are from less than 1 m to about 10 m long, a few centimeters to 0.5 m thick and locally more, and extend from a shear for 1–5 m into the wall rock. In zones of closely spaced shears, the ore lenses thicken appreciably and merge to columnar lodes of better grade ores. Due to the fracture controlled setting, this kind of mineralization is defined as *layered, fracture-associated type*.

Black pyrite-pitchblende-nivenite mineralization occurs in discontinuous lenses similar to those of the mottled black-pink ore and in crescent-shaped bodies. The ore lodes group to an irregular winding band, about 500 m long and up to 50 m wide, the position and configuration of which tends to be controlled by the major south fault, flexures of strata, and changes of the attitude of shears.

Large lenticular bodies (in the eastern part of the Bedre sector) are directly associated with the latitudinal fault along which they persist over a distance of approximately 200 m. They are referred to as *fault associated type*. Isolated small lenticular ore bodies are also present outside the black ore band. These lenses are associated with laminae of permeable, limonitic limestone near the top of the calcareous unit where they are bound to intersections of stylolites and shears.

Roll-type ore bodies are (multi-)crescent shaped in cross-section and typically occur in oxidized zones. Rolls are few meters to about 10 m wide perpendicular to the strike of strata, up to 3 m thick at their thickest compact section while tails are from several centimeters to approximately 1 m thick (Fig. 7.5). Internal structure and mineral distribution is in rolls similar to that of layered, fracture associated mineralization. The extended upper segment of rolls is developed along continuous stylolites in beds near the top of the carbonate unit while the lower part is in less permeable dolomitic, argillaceous shell beds and is poorly developed if not missing. Rolls commonly split up downdip, towards limonitic limestone. Enriched segments of black ore are often related to closely spaced shears. Contacts between massive black ore and limonitic and lighter colored, recrystallized rocks are sharp.

Potential Sources of Uranium

Felsic volcanics and perhaps granites of the Chatkal and Fergana ranges to the northwest and north, respectively, of the ore zone are presumably the most likely source of uranium and other elements contained in the bituminous limestone deposits.

Ore Controls and Recognition Criteria

Significant ore controlling parameters or recognition criteria of the major deposits in the region, include:

Host Environment

- Folded calcareous marine sediments sandwiched between continental redbed facies of Tertiary age located adjacent to a crystalline basement containing felsic volcanics
- Intense deformation of ore-hosting strata by faults, fractures, shears
- Flexures of strata and shears tend to play a significant role in ore localization
- Host rocks consist of a 4–5 m thick sequence of an upper bituminous/petroliferous, stylolitic and organic limestone, and a lower dolomitic, argillaceous limestone horizon; the upper, more permeable horizon is the preferential ore host

Alteration

- Several stages of oxidation and reduction
- Pre-ore alteration is reflected by limonitization, recoloring (green, grey), leaching, argillization/hydromicazation, and bleaching associated with lateral hematitization, and pyritization
- Ore-related alteration includes early hematitization and later pyritization
- Post-ore alteration is reflected by bitumenization and late, supergene oxidation

Mineralization

- Two varieties of mineral assemblages: older mottled black-pink hematite-pitchblende-nivenite practically free of pyrite, and massive black pyrite-pitchblende-nivenite
- Irregular distribution of U minerals in stylolites, sutures, microfissures (which also contain greenish hydromuscovite, and colored and black solid bitumens), interstices between carbonate grains, on walls of leached-out voids, pores, oolite grains, and fragments of fossils
- Solid bitumens often cement minute fragments of pitchblende and nivenite
- Primary control of position and configuration of ore bodies and ore zones by faults, fractures, flexures of strata, and changes of the attitude of shears
- Geological setting and configuration of mineralization is of three types: lenticular fault associated, lenticular layered fracture associated, and roll shaped

Metallogenetic Concepts

Metallogenetic considerations favor an exogenic-epigenetic origin of the uraniferous bituminous limestone deposits. The principal ore-forming stage was during the Miocene. Potential uranium sources are presumably felsic volcanics, which are abundant in the adjacent Karamazar region.

Roslyi (1975) proposes the following processes and sequence of events for the formation of ore: Mineralization was preceded by several alteration events of alternating oxidation and reduction processes:

Pre-ore alteration stages include (1) an early oxidation stage with replacement of ferrous iron minerals by goethite and hydrogoethite forming the yellow limonitized limestone facies. This was followed by (2) a reducing stage reflected by leaching, hydromicazation and bleaching of limonitic limestone, which was succeeded by recrystallization. These alteration effects were accompanied by weak pyritization, removal of iron and its redeposition as hematite-hydrohematite at the margins of alteration zones. Subsequently, (3) a late oxidation stage evolved as indicated by replacement of newly formed pyrite by Fe-hydroxides. Oxygenated waters, which caused the alteration of stages (1) and (3) presumably entered the calcareous unit from the north, i.e. from the outcrop of the crystalline basement.

Mineralization stages include (4) the introduction of U, Fe, V, Pb, and Cr as a base for the deposition of a hematite-pitchblende-nivenite assemblage (mottled black-pink ore, practically free of pyrite). The assemblage was superimposed on the lighter colored recrystallized and limonitized limestone affected by late stage (3) oxidation. Invading solutions probably migrated from south to north and generated intensive hematitization in front of the developing pitchblende-nivenite mineralization. U minerals are surrounded by hematite halos but separated from them by reduction fringes and repulsion of iron, which suggests that hematitization preceded crystallization of the U minerals. A second, supposedly transitional mineralizing event generated (5) a pyrite-pitchblende-nivenite assemblage (black ore) by introduction of Fe, V, Mo, As, Ni, Co, Pb, Cr, and S. Deposition occurred in a band bordering pyritized limestone and overprinted all types of previously altered rocks as well as the mottled black-pink ore. Transitional varieties between stage (4) and (5) ore suggest a gradational evolution without a hiatus between the two ore stages.

Post-ore stages (associated with block faulting during Pliocene-Quaternary) include (6) bitumenization of limestone as a result of oil infiltration along faults as reflected by insoluble solid bitumens that developed in a narrow zone separating black roll-shaped ore bodies from limonitic lithologies. Since these bitumens have the identical chemical and physical properties and the superimposed character as those found in mineralized, pyritized and oxidized zones, it is postulated that bitumenization postdates all epigenetic alteration and mineralization events. This is supported by the fact that no older inclusions of hydrocarbons have been observed. As such, oil infiltration and associated bitumenization is not considered essential in the ore-formation but probably caused the discontinuation of the ore forming process. At the same token, the bituminous facies may have acted as a geochemical barrier preventing the dissolution of the U mineralization. (7) A late ingress of viscous petroleum (maltha) formed a narrow maltha belt semi-parallel to a major fault. The position of this belt is considered to be a result of fault-water pressure. The migration of maltha is indicated to be recent by abundant maltha seepages from young fissures. (8) Current surface-related oxidation is documented by yellow Fe-hydroxides and U-V micas in near-surface fractures in limestone spreading northwestward from the eroded crest of a domal uplift in the southeast.

7.1.0.2 Other Deposits in the Northeastern Fergana Region of Kyrgyzstan

Maylisay (or Maili-Sai) is situated 20 km ESE of the town of Tash-Kumyr, W Kyrgyzstan. Uranium was known before World War II but it was only in 1945 that a minable deposit was established. Mining took place from 1955 to 1960 and produced a few hundred tonnes U. Mineralization was hosted in fractured, organic-oolitic sandstone, dolomite, dolomitic clay and marl of Oligocene-Paleocene age. Ore grades were less than 0.1% U (IAEA 1995).

Shakaptar (or Shakoptar) (Kassan-Varzykskoye ore field), a deposit of similar geological setting and size as Maylisay, is located near the settlement of Sumsar, about 40 km NW of the Uzbek town of Namangan in the Fergana Valley. It was discovered in 1946. Mining lasted from 1950 to 1958 and produced a few hundred tonnes U.

Charkasar was discovered in 1955/1956 at the southern margin of the Chatkal Range, some 50 km WNW of the Uzbek town of Namangan. This vein-stockwork-type deposit is related to Permian felsic volcanics. Charkasar was mined by underground methods in the late 1950s. Production was on the order of a few hundred tonnes U. Ore averaged <0.1% U.

7.2 Tyuya-Muyun District, Southwestern Kyrgyzstan

The Tyuya-Muyun uranium district is in Osh Province, about 2 km to the west of the 250 m deep Tange gorge of the north-flowing Aravan river in the semiarid northern Alai range of the southern Tien Shan mountains. Osh is the nearest town. It is 25 km to the NE at the margin of the eastern Fergana Valley.

Uranium was discovered at Tyuya-Muyun (meaning two camel humps) in 1902. The site inherited its name from the nearby Tyuya-Muyun pass. Subsequent exploration identified a number of scattered, small U deposits.

Mining in the region dates back to ancient times with copper recovery possibly as early as the Bronze age. U mining began at Tyuya-Muyun by the Fhergana Co. in 1908 when vanadium-uranium ore was recovered from karst caverns in Carboniferous limestone. By 1913 about 1 000 t of ore had been recovered. 750 t thereof with a grade of 0.97% U_3O_8, 3.36% V_2O_5, and 3.72% Cu were shipped for radium extraction to St. Petersburg and yielded 2.39 g Ra. Discontinuous mining went on over several decades. In 1926, a second mining period was started in order to provide ore for radium production (together with ore from Taboshar), the first radium produced by the Soviet Union, but water inflow at the mine disrupted the activities. Reportedly, 526 t of hand-sorted ore were shipped to a special plant in Leninabad (now Khodzent) for radium recovery. The final exploitation period lasted from 1947 for a short time. Exploration for additional U deposits continued until 1954 but without success. The final period included the opening of a tunnel almost two kilometers long from the Aravan river banks to the Tyuya-Muyun lode under the hypothesis forwarded by Fersman (1927) that additional mineralized solution pipes or karst caverns may occur in the given geological environment but none of either was intercepted.

By 1922, resources were estimated at about 5 000 t of ore but exploration during 1924 through 1934 had discovered additional deposits enlarging the resource base. Selectively mined ore contained up to 3% V_2O_5 and 1% U.

Sources of information. Bain 1950; Chervinsky 1925; Fersman 1927, 1930; Fersman and Shcherbakov 1925; Heinrich 1958; Kazansky 1970, pers. commun. 1998, 2002; Kirikov 1929; Nenadkevich 1917; Pavlenko 1933; Shcherbakov 1924, 1937, 1941; Shimkin 1949; Smirnov 1947.

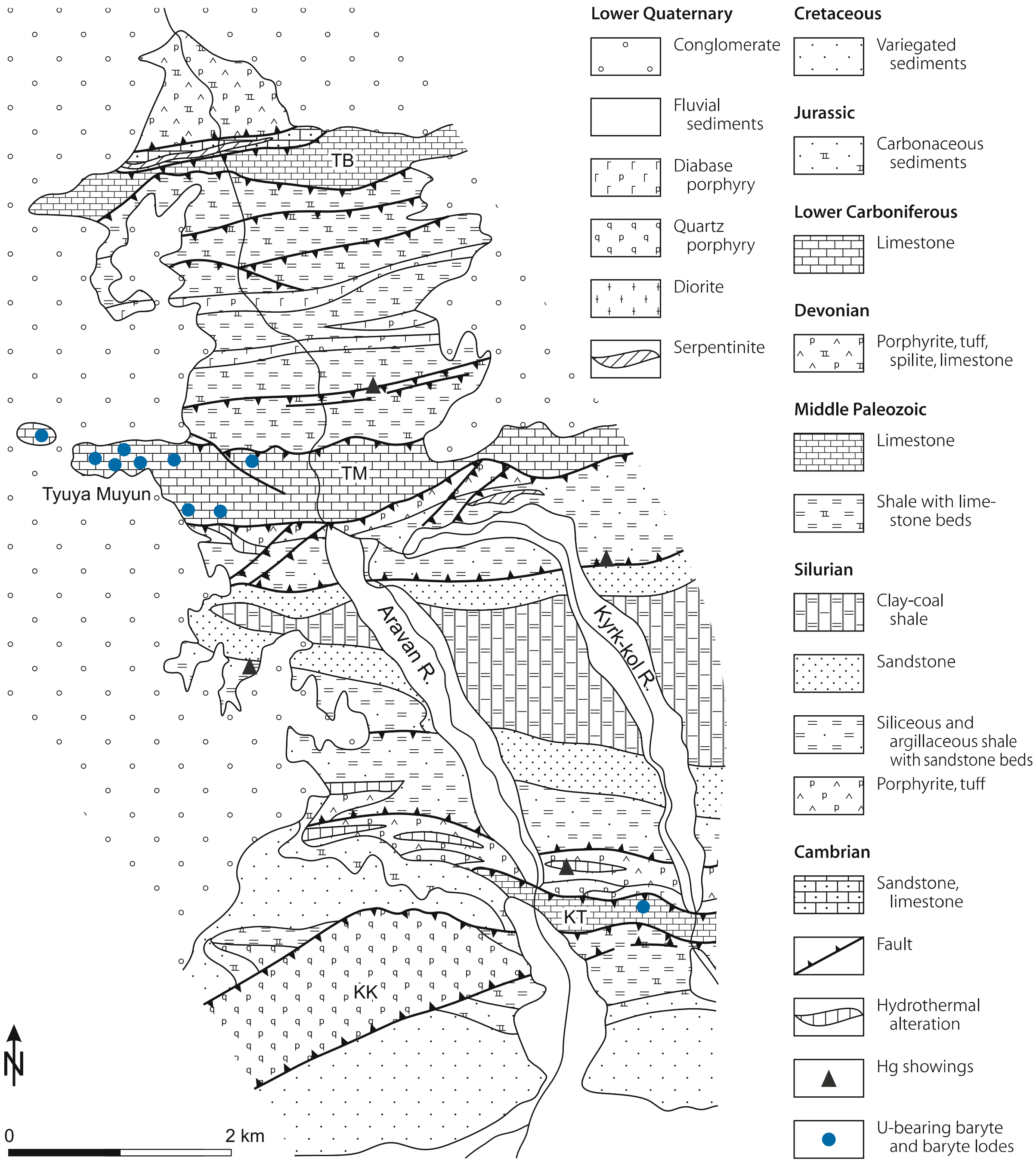
Regional Geology and Alteration

The sublatitudally trending Precambrian-Paleozoic Alai range of the western Tien Shan mountains marks the regional geology of the Tyuya-Muyun uranium district. This range forms the southern rim of the intermontane Fergana Valley, a downfaulted basin, 300 km long in an E-W direction and up to 150 km wide, filled with Mesozoic-Paleogene marine sediments and Neogene-Quaternary coarse-grained clastics.

The ore-hosting Aravan river area in the northern part of the Alai range is composed of folded Lower Carboniferous limestone and Silurian carbonaceous graptolite-bearing black shales and quartzose schists. Volcanic breccias and tuffs are interstratified. Fold axes trend sublatitudally (Figs. 7.7, 7.8). Dikes of keratophyre, sills of diabase, and numerous baryte veins, up to 1.5 m thick, cut the sedimentary-volcanic suite. Baryte veins persist to a depth of at least 500 m. The black shales contain up to 500 ppm U and 1 000 ppm V (Fersman 1927).

Fig. 7.7.

Northern Alai range/Tien Shan mountains, generalized geological map of the Tyuya-Muyun mining district in the Aravan river area (after Kazansky 1970) (Lower Carboniferous Limestone ridges: TB Taylibeltash, TM Tyuya-Muyun; KK Kyzyl-Kungey, KT Karatash)

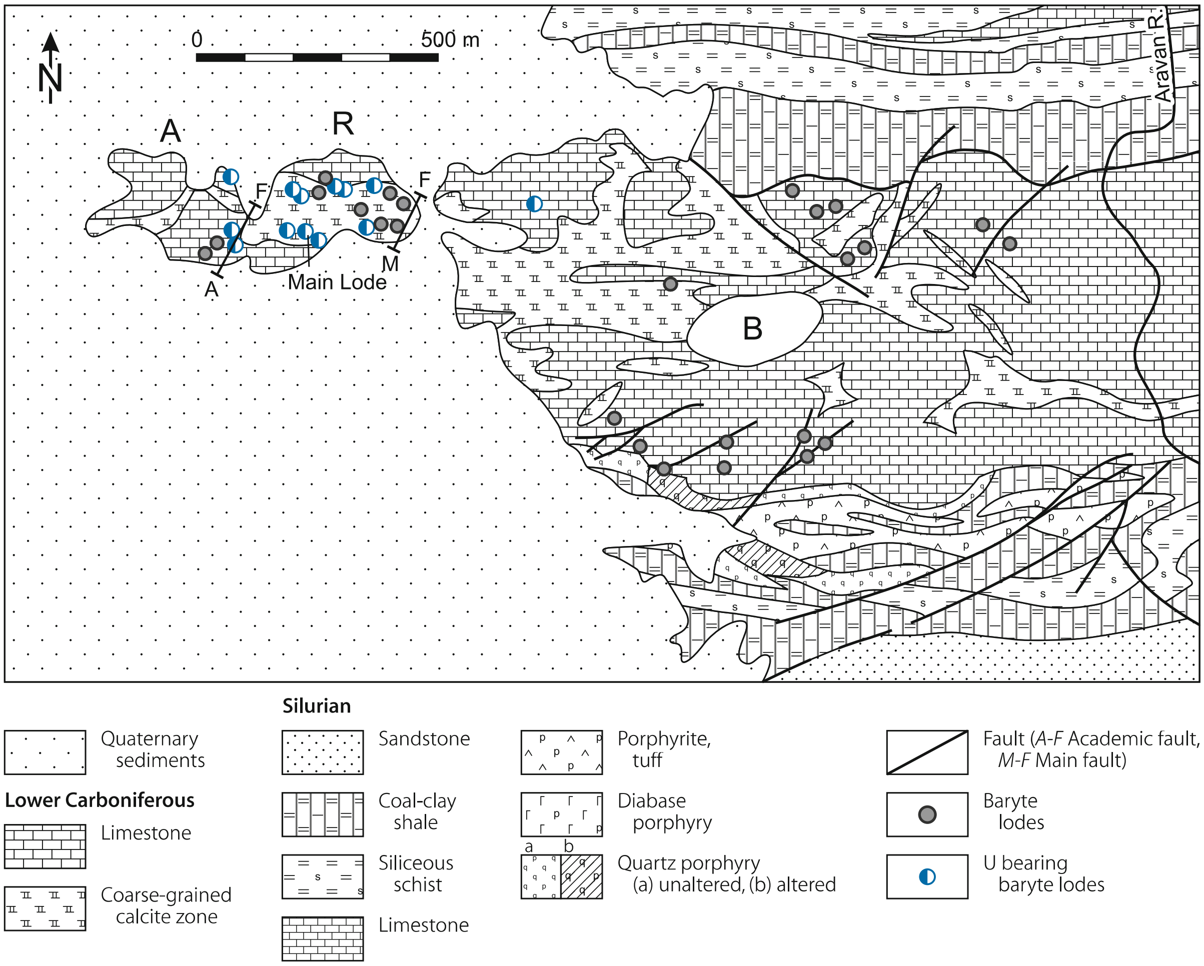


A fractured and locally brecciated, coarse-grained, pinkish or brownish violet limestone veined by calcite is the host rock. Limestone beds strike about E-W and dip from medium steep to near vertical. Extensive karst-related solution channels and pipelike caverns occur in the limestone (Fig. 7.9). Cavities are partly filled with radial aggregates, stalagmites, and crusts of calcite. Caverns contain stalagmitic onyx in form of pipes and wall coatings. The onyx is banded and is composed of laminae of calcite, baryte, and, locally, U minerals. Mg metasomatism has dolomitized the limestone around mineralized structures.

Principal Characteristics of Mineralization

Tyuyamunite is the principal U mineral. Associated minerals include Cu- and Ca-vanadates (volborthite var. uzbekite, calciovolborthite var. tangeite, turanite), vanadium-bearing clays,

Fig. 7.8.
Tuya-Muyun District, generalized geological map of the western Tyuya-Muyun ridge showing the distribution of baryte and uranium- baryte lodes. U lodes are essentially restricted to the Radium-Academic hills while baryte lodes occur beyond this center (after Kazansky 1970). ***A*** **Academic Hill,** ***B*** **Baryte Hill,** ***R*** **Radium Hill**



chrysocolla, malachite, goethite, baryte, calcite, and quartz. The baryte is radioactive. Some Ra-bearing carbonate is found. The ore texture is fine-grained and massive, banded, brecciated, or vuggy.

Ore occurs in karst caverns and fissure veins (to some extent in a similar geological setting and mode as the karst-type U-V deposits in the Pryor Mountains, Montana-Wyoming). Caverns contain ore minerals as crusts on the walls, and as concentric encrustations or geodes in a depth interval from near surface to the paleowater level and below. Mineralized geodes are up to several meters in diameter and consist commonly of a core of coarse-grained calcite that is overgrown first by yellow and then by pink baryte. A next layer consists of quartz with disseminated tyuyamunite containing 0.6–4% U_3O_8 plus 1–7% V_2O_5. The outer shell consists of acicular calcite.

U mineralized fissures range in thickness and length from few centimeters to 1.5 m and more. They encompass 1–3 mm thick bands and up to 5 mm thick lenses of fine-scaled tyuyamunite and/or disseminations of tyuyamunite with Cu-vanadates.

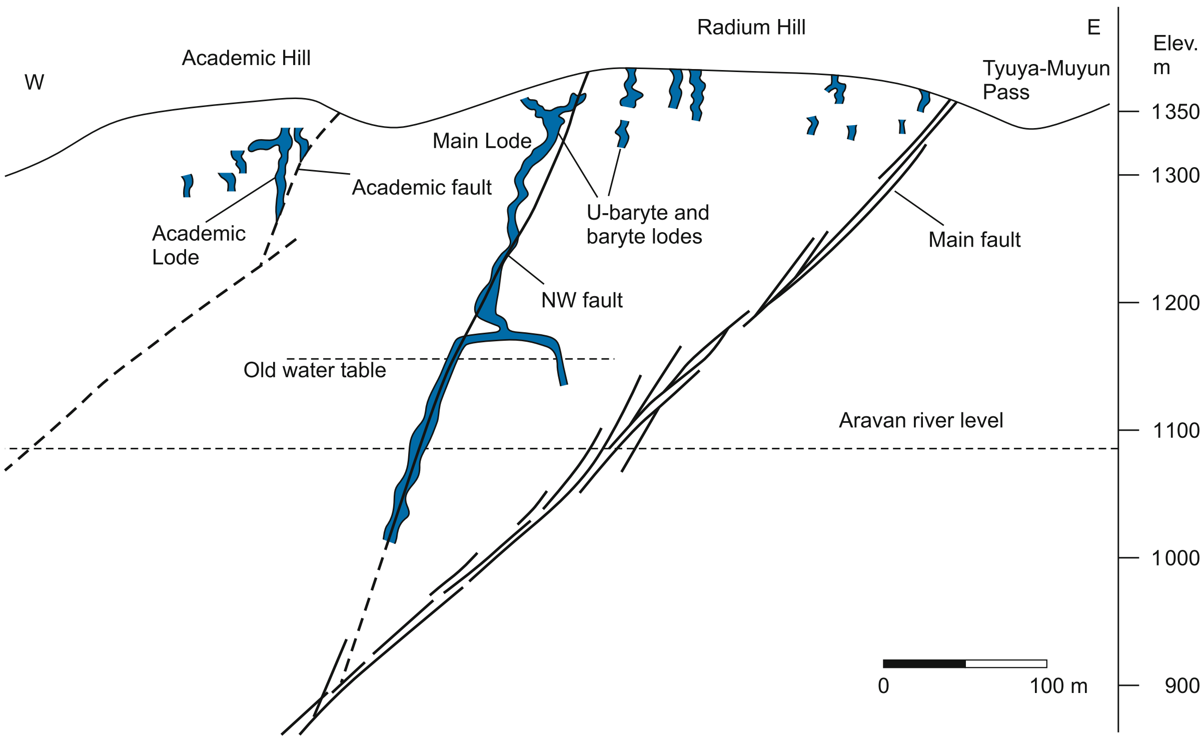
At least 13 uraniferous and about 30 U-barren baryte lodes or veins were found. The former, including the Tyuya Muyun deposit, are grouped in the western part of the district most of them in strips paralleling the E-W strike of the sediments. Baryte veins occur for up to 1 500 m beyond this center (Fig. 7.8).

7.2.0.1 Tyuya-Muyun Deposit

The Tyuya Muyun deposit proper is located on the western flank of Radium Hill and consists of the *Main Lode*. A similar but smaller deposit, the *Academic Lode*, occurs 150 meters to the west of the Main Lode (Fig. 7.9).

Reserves remained unpublished. Aleksandrov (1922) reported for the then known Main Lode ore reserves of 5 000 t.

Fig. 7.9.
Tuya-Muyun deposit, schematic latitudinal projection of mineralized karst structures and faults (after Kazansky 1970)



Mining grades were variable ranging from 0.5 to 4% U averaging 1.4% U, 1.5–7% (av. 3.8%) V_2O_5, 1.5–7 (av. 3.0%) CuO, 1.5–5% (av. 3.6%) $(Al, Fe)_2O_3$, 0–20% (av. 2.7%) $BaSO_4$, 0.5–5% SiO_2, 37–49% (av. 46.6%) CaO, 28–39% (av. 35.7%) CO_2 (Heinrich 1958).

Kazansky (1970) provides a comprehensive account on the exploration history, geology, and mineralogy of the Tyuya Muyun deposit. A summary is given below.

Geology and Mineralization

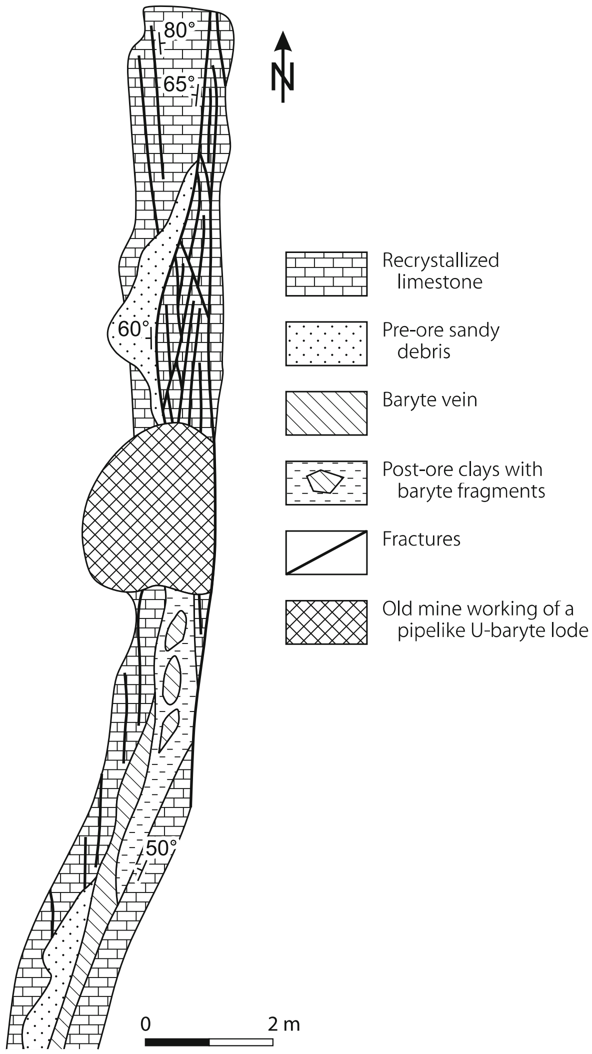
The Main Lode is a steep plunging mineralized solution pipe with some bifurcating subhorizontal channels hosted by Lower Carboniferous recrystallized limestone. A repeatedly reactivated, NW-SE-striking and 65–85° SW inclined fault/fracture system controls the pipe setting. The fault system coincides with a vein of coarse-grained calcite and defines the setting of pre-ore and post-ore karst structures (Figs. 7.9, 7.11a,b). At a depth of some 400 m, the Main Lode is intersected by the NNE-SSW-trending and medium steep westerly dipping Main Fault that is filled by pre-ore, karst-related pebble and sandstone debris, baryte veins, and post-ore clay. Similar characteristics are found in the mineralized Academic fault (Fig. 7.10).

The Main Lode has a diameter of few to over 10 m and persists to at least 280 m below surface. The groundwater table is at a depth of 180 m below surface from which the Main Lode continues for at least 100 m without any major change in orientation, size- and mineral filling. The Main Lode is largest at the lower levels except for the so-called "Academic Cave" at a higher level. At the lowest explored level, the Main Lode has a diameter of 6–10 m and plunges westerly at 70°. In centripetal direction, the lode is composed of seven concentric layers: starting with columnar calcite, followed by "ore marble", pink foliaceous baryte, hematite with quartz and calcite, tan and honey colored baryte, tan plumose baryte, and finally columnar calcite. The interior is an open cavity. The peripheral band overgrows recrystallized limestone and thin laminae of karst-derived marl (Fig. 7.11c).

"Ore marble" (referred to as onyx by Fersman) consists, both above and below the groundwater table, of medium-grained calcite with finely dispersed colloform tyuyamunite, tangeite, alaite, hematite, and traces of malachite, chalcocite, chrysocolla, covellite, and pyrite. No U-oxides such as pitchblende have been encountered.

At higher levels up to the present-day surface, the Main Lode maintains the same concentric-zonal structure and mineral composition except that at depth the baryte and calcite layers are six to eight times thicker while the thickness of "ore marble" remains practically stable.

Fig. 7.10.
Tuya-Muyun District, planview of a fraction of the Academic fault (after Kazansky 1970)



Metallogenetic Aspects

A variety of metallogenetic hypotheses have been forwarded for the development of karst openings such as those forming the Tyuya Muyun solution pipe and therein-contained mineralization.

Karst forming processes must have occurred in pre-Jurassic time, perhaps starting as early as in the Paleozoic. Ore formation is thought to have evolved by a combination of weak hydrothermal and supergene solutions leaching uranium and other ore forming elements from the Silurian black shales, which are exposed in the Alai Range. These shales contain up to 500 ppm U and 1 000 ppm V (Fersman 1927).

Chervinsky (1925) considers an origin of the Tyuya-Muyun deposit by postvolcanic solutions and a secondary, presumably still active process for the formation of the uranyl minerals. He argues that the baryte veins with their dolomitized wall rocks can only be hydrothermal and that the karst-hosted mineralization probably represents a supergene redistribution of material derived from the oxidized baryte veins. On-going mineralization up to Recent is supported by tyuyamunite found on human bones, which remained in the Tyuya-Muyun Mine for several years during the Bolshevik revolution.

Shimkin (1949) suggests an ore forming sequence starting with vein-type ore deposition from low temperature solutions related to the Hercynian Orogeny. Faulting occurred during the Alpine Orogeny. Karst developed in post-Eocene time and was associated with partial destruction of veins, reworking and reconcentration of the ores.

Kazansky (1970) presents the following concept at the end of final investigations of the Tyuya Muyun deposit. Pre-karst meridional faults offered and prepared the environment for karst development resulting in pipe and channel structures. Regional studies suggest two probable periods of pre-ore karst development: the Upper Carboniferous and the Upper Permian-Triassic.

Open cavities were subsequently and selectively occupied by baryte or U-V-bearing baryte phases as reflected by zonal distribution of ore bearing and ore-free baryte lodes within the Tyuya-Muyun limestone ridge. The presence of equal modes of karst structures and ore infillings continuing from far above to deep below the present-day groundwater table rules out a Quaternary age of ore formation as suggested by Chervinsky (1925). Chervinsky's observations rather suggest a redistribution of the ore forming elements in recent times.

Both, the ore bearing and barren baryte lodes were formed from ascending thermal solutions in ancient karst openings below the groundwater table. The origin of these solutions remains obscure, however.

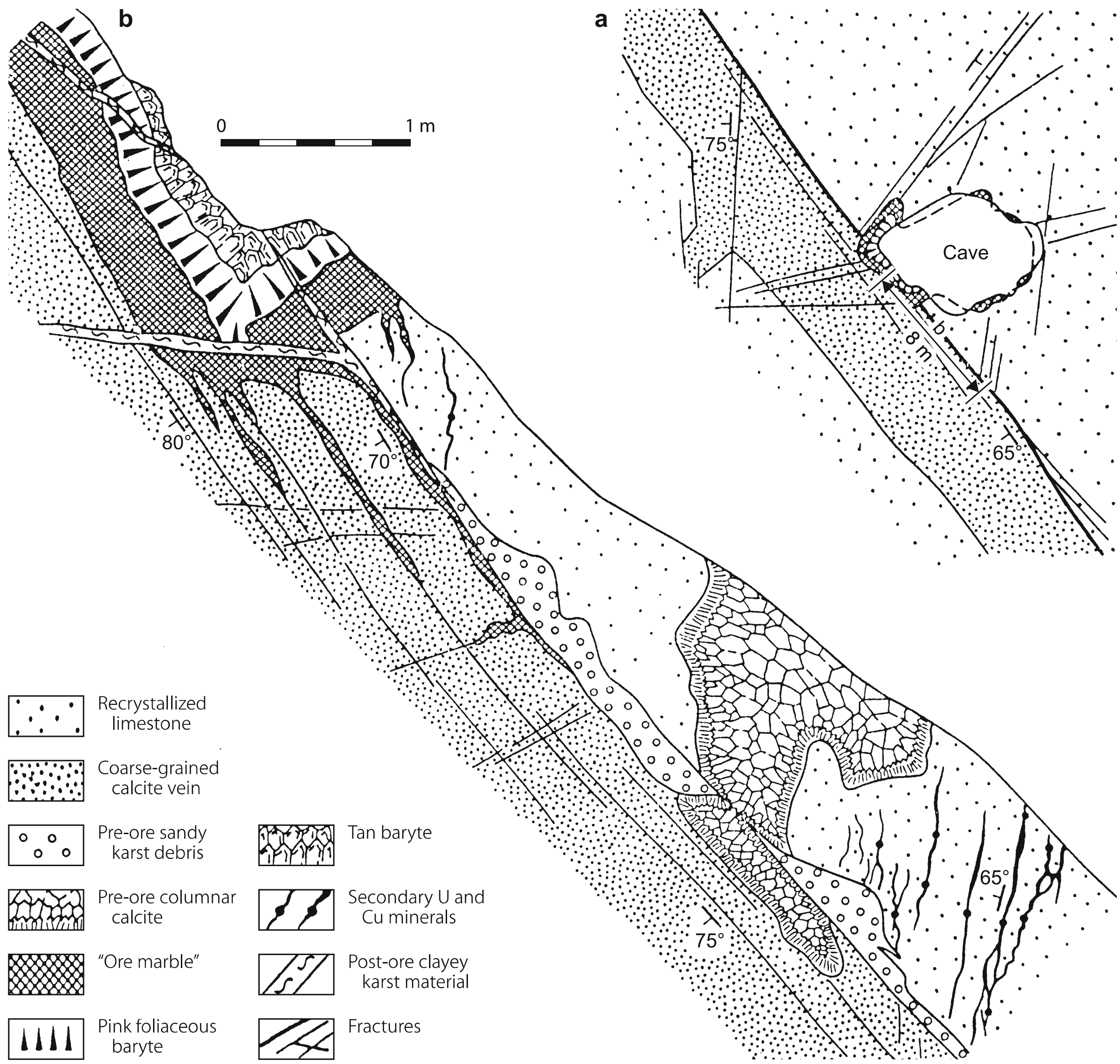
7.3 Jurassic Coal Basins in Central and Eastern-Central Kyrgyzstan

A number of small intermontane coal-bearing basins in the Tien Shan mountains of central and eastern Kyrgyzstan contain uraniferous lignite seams that were mined for uranium. Reported localities include the *Min-Kush*, *Sogut-Issyk-Kul*, and *Naryn* Basins (Fig. 7.1).

Sources of information. Kislyakov and Shchetochkin 2000; and others.

The *Min-Kush Basin* is a narrow coal basin, 8–9 km long, in the central part of the northern Tien Shan mountains, central Kyrgyzstan. Uranium was discovered in lignite in a Jurassic coal-sandstone sequence near the town of Naryn during exploration for coal in the 1950s. Several uraniferous lignite deposits, referred to as Kavak group of U-coal deposits, are reported: *Agulak, Kashka-Suu, Sarykamysh, Sasyktash, Turakavak (also known as Min-Kush),* and *Tuyuk-Suu (= Dzhilskoye)*. Each of them contained between 1 500 and 5 000 t U. Ore grade (in ash?)

Fig. 7.11a,b.
Tuya-Muyun deposit, a schematic and b detailed plan of the structure of the Main Lode at the Fersman cave level (after Kazansky 1970)



was 0.1–0.3% U (IAEA 1995). Uranium production was associated with the extraction of lignite by strip-mining and lasted from 1955 to 1960 (Turakavak). Tuyuk-Suu reportedly produced 2 626 t U. Mill concentrate was transported by truck to the processing plant at Kara Balta, 200 km to the north.

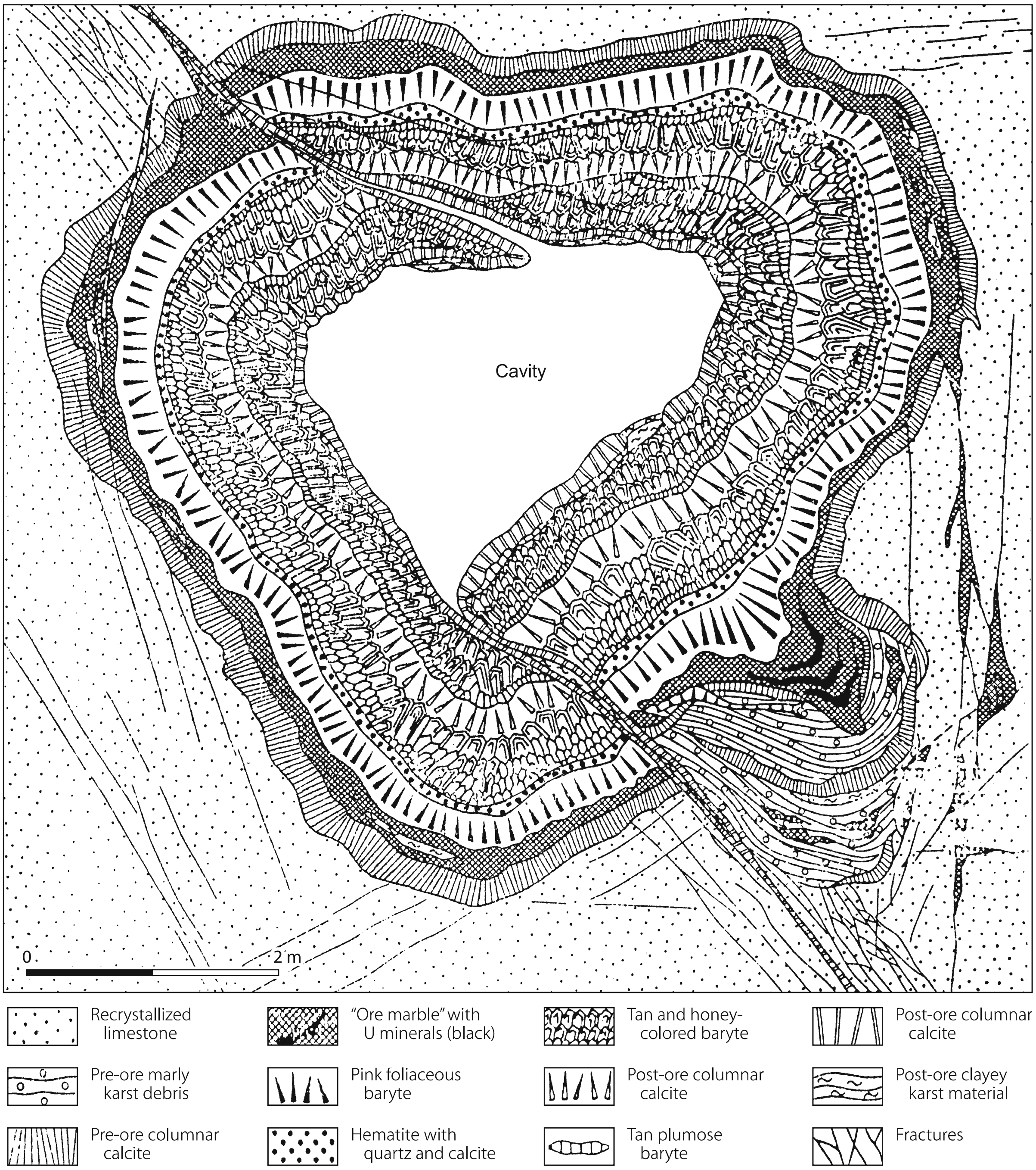
The *Sogut-Issyk-Kul Basin* in east-central Kyrgyzstan contains uraniferous lignite, which was mined by underground methods at *Dzhilskoye* (= *Tuyuk-Suu*) (discovered 1947) near Kadzhi-Say on the south shore of Lake Issyk-Kul from 1948 to 1966. Dzhilskoye was one of the earliest Soviet uranium mining sites. A special plant, N8, was locally built to process the uraniferous lignite; it was closed in 1956 for subeconomic reasons.

7.4 Other Uranium Occurrences in Kyrgyzstan

At *Almalyk* in the Fergana Valley region, Carboniferous limestone hosts veins with Cu, Fe, Mn, Ni, and radioactive minerals in a baryte-calcite gangue grading up to 3% U_3O_8, and veins with galena, sphalerite, cerussite, wulfenite, chrocoite, turanite and usbekite in a baryte gangue (Komischau 1927).

Some U was said to have been produced from yttrium and REE ore mines at the eastern end of the *Chu* (or Tshu) valley, and from *Kyzyl-Dhzar* (U + Au) and *Sumsar*. Silurian uraniferous black shale containing about 100 ppm U is reported from the *Alai Range* in SW Kyrgyzstan (Bain 1950).

Fig. 7.11c.
Tuya-Muyun deposit, horizontal section of the Main Lode below the groundwater table illustrating the sequential deposition and mineralogical composition of the pipe lode. The diameter of the lode varies between 6 and 10 m (after Kazansky 1970)



References and Further Reading for Chapter 7 · Kyrgyzstan

For details of publications see Bibliography.

Aleksandrov 1922; Bain 1950; Boitsov 1999, and pers. commun.; Chervinsky 1925; Fersman 1927, 1930; Fersman and Shcherbakov (1925); Häusser et al. 1997; Heinrich 1958; IAEA 1995; Karimov et al. 1996; Kazansky 1970, and pers. commun. 1998, 2002; Kazansky and Laverov 1977; Kislyakov and Shchetochkin 2000; Kirikov 1929; Kohl 1954; Komischau 1927; Laverov et al. 1992a–c; Mashkovtzev and Naumov 1999; Melnikov et al. 1996; Minerals Yearbook 1946, 1949; Nenadkevich 1912; Pavlenko 1933; OECD-NEA/IAEA 1993, 1995, 2001; Roslyi 1975; Savchenko et al. 2003; Shcherbakov 1924, 1937, 1941; Shchetochkin and Kislyakov 1993; Shimkin 1949, 1953; Smirnov 1947; Thoste 1999; Venatovsky 1993.