KYRGYZ REPUBLIC

Introduction

The Kyrgyz Republic or Kyrgyzstan (sometimes Kirgiz, Kyrghyz or Kyrghyzstan) is a mountainous country with an area of 198 500 km^2. It is situated in the heart of the Tien Shan Mountains. The highest peak (Pik Pobedy) reaches 7439 m. The Tien Shan Mountains are traditionally divided into the Western, Central and Eastern Tien Shan as well as the Northern and Southern Tien Shan. Kyrgyzstan occupies the main part of the Central Tien Shan and significant parts of the Western, Northern and Southern Tien Shan (Fig. 398).

The first geological map of the Western and Central Tien Shan at scale of 1:1 260 000 was published in 1884 (Romanovskiy and Mushketov, 1884). Regular geological mapping at scale of 1:500 000 began at the beginning of the 20th century; similar work at a scale of 1:200 000 began in the middle of the 20th century. At the present time there are 1:200 000 scale geological maps for all the territory of Kyrgyzstan and 1:50 000 scale maps for significant parts of it. Compiled geological maps have been published at scales of 1:500 000 and smaller (Geological Map, 1980, 1981).

Centers of geologic activity include the State Geological Survey, the Institutes of Geology and Seismology at the Academy of Sciences, and the Geology Department of the Polytechnic High School in Bishkek.

Rocks ranging in age from Archean to Cenozoic in Kyrgyzstan (Fig. 399) comprise two megacomplexes: the pre-Paleozoic to Paleozoic rocks and the Mesozoic to Cenozoic platform cover. The former originated in environments of pronounced tectonic activity, and contrast markedly with the latter.

Paleozoic and pre-Paleozoic

The Paleozoic structure of the Kyrgyzstan is complicated, and the stratigraphy is different in the various tectonic zones. The area is composed of a few Paleozoic island arcs. The Late Paleozoic Turkestan Suture separates the Northern Turkestan domain from the Southern Turkestan tectonic domain. Both are subdivided into tectonic zones (Fig. 400) bordered by the early Paleozoic Terskey Suture, strike-slip faults and thrust faults.

Northern Turkestan domain

Chatkal–Naryn Zone

The Chatkal–Naryn Zone is divided by the Talas–Fergana Fault into the Chatkal (Fig. 400, IA) and the Upper Naryn (Fig. 400, IB) areas. Both areas of the zone include Proterozoic basement, Vendian

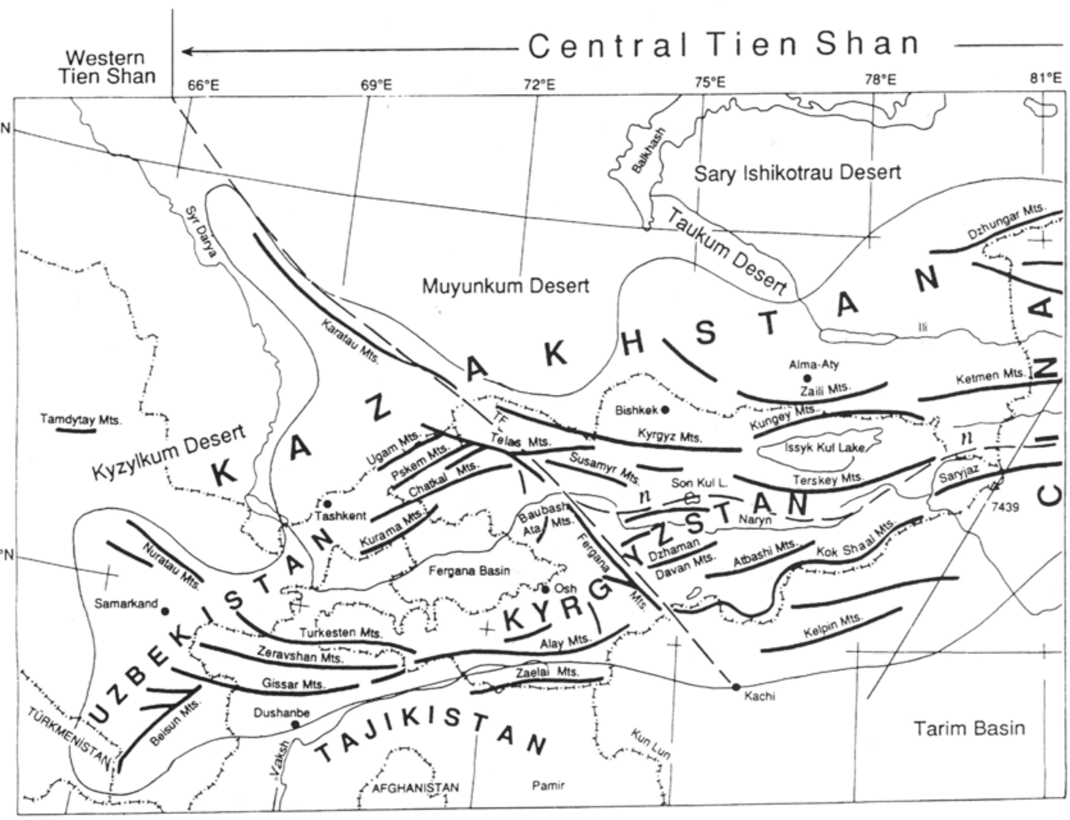

Fig. 398 Orography of the W part of Central Asia and the disposition of Kyrgyzstan. The Border of the Tien Shan Mountains is shown by a thin line. The Talas–Fergana Fault (TF) and faults of Nikolaev's Line are shown by dashed line. The Talas–Fergana Fault, which runs along the Fergana and the Karatau Ranges, marks the border between the Western and the Central Tien Shan. The NE-trending line between highest peak of the Tien Shan (Pic Pobedy, 7439 m) and the Ebinur Lake in China separates the Central and the Eastern Tien Shan. The Northern and Southern Tien Shan are divided by a system of faults, known as Nikolaev's Line (*n*), and shown as a dashed line through Son Kul Lake.

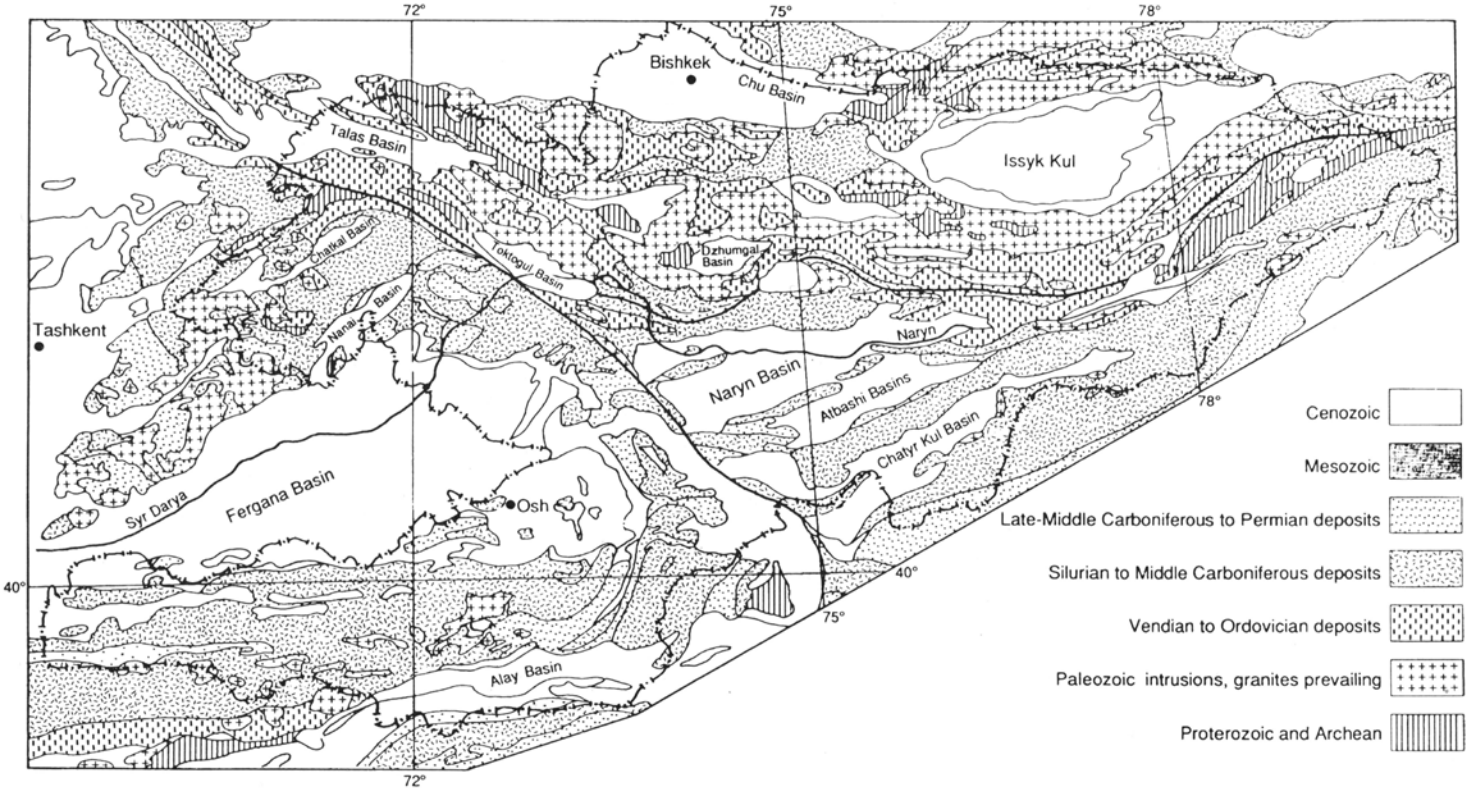

Fig. 399 Simplified geological map of Kyrgyzstan.

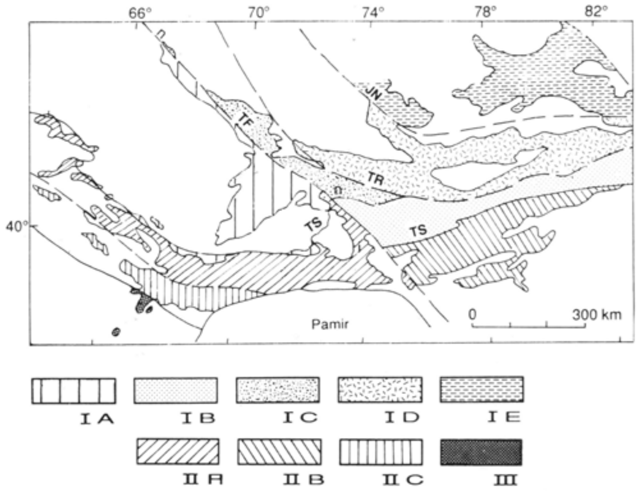

Fig. 400 Tectonic zonation of the W and central Tien Shan. I, Northern Turkestan domain: IA, IB, Chatkal–Naryn Zone separated by the Talas–Fergana Fault into the Chatkal (IA) and the Upper Naryn (IB) areas; IC, Talas zone; ID, Issyk Kul Zone; IE, North Ili Zone. II, Southern Turkestan domain: IIA, IIB, Alay–Tarim Zone separated by the Talas–Fergana fault on the Alay (IIA) and the Tarim (IIB) areas; IIC, Gissar Zone. III, Kara Kum domain: Baisun Zone. TF, Talas–Fergana Fault; n, Nikolaev's Line; JN Jalair–Naiman Fault; TR, Terskey Suture; TS, Turkestan Suture.

passive margin and rift sediments, Early Paleozoic passive margin sediments, the Ordovician to Silurian Sandalash magmatic arc and accretionary complex, and the Carboniferous Kurama magmatic arc and accretionary complex. The late Paleozoic Turkestan Suture defines the S border of the Chatkal–Naryn Zone, and the faults of the Nikolaev's line defines its N border.

Rocks of the Sandalash magmatic arc are distributed in the Chatkal system of ranges (Fig. 401). The Chatkal and the North Chatkal formations are composed of basaltic–andesitic flows, tuffs, volcanic breccias and cherts (up to 1000 m thick) with intercalations of sandstones, mudstones and chert. Chatkal rocks contain Ordovician radiolarians and overlie clastic rocks with Middle Ordovician graptolites (Ahmedjanov, Abdullaev and Borisov, 1979; Osmonbetov, Knauf and Korolev, 1982). Silurian rocks, up to 1000 m thick, have no stratigraphic contact with Ordovician deposits; they include andesites, dacites and sometimes basalts with intercalations of tuffs, conglomerates, sandstones and mudstones. There are Llandoverian corals in the lower part of the sequence (Osmonbetov, Knauf and Korolev, 1982). These deposits are unconformably overlain by sediments with Givetian fossils. Pelites and sandstones with Cambrian and Ordovician fossils and Silurian turbidities with graptolites are present in a thrust complex, which may represent an accretionary wedge of the Sandalash magmatic arc.

The basement of the Sandalash Arc in the Chatkal system of ranges includes gneisses and crystalline schists of unknown age and granites with a K–Ar age of 820–915 Ma (Osmonbetov, Knauf and Korolev, 1982).

Rocks of the Kurama magmatic arc are widely distributed in the Chatkal ranges (Fig. 402). The E prolongation of the magmatic belt displaced by the Talas–Fergana dextral strike-slip fault is situated in the Upper Naryn area and further eastward. The W prolongation of the belt may be recognized under a cover of Mesozoic–Cenozoic

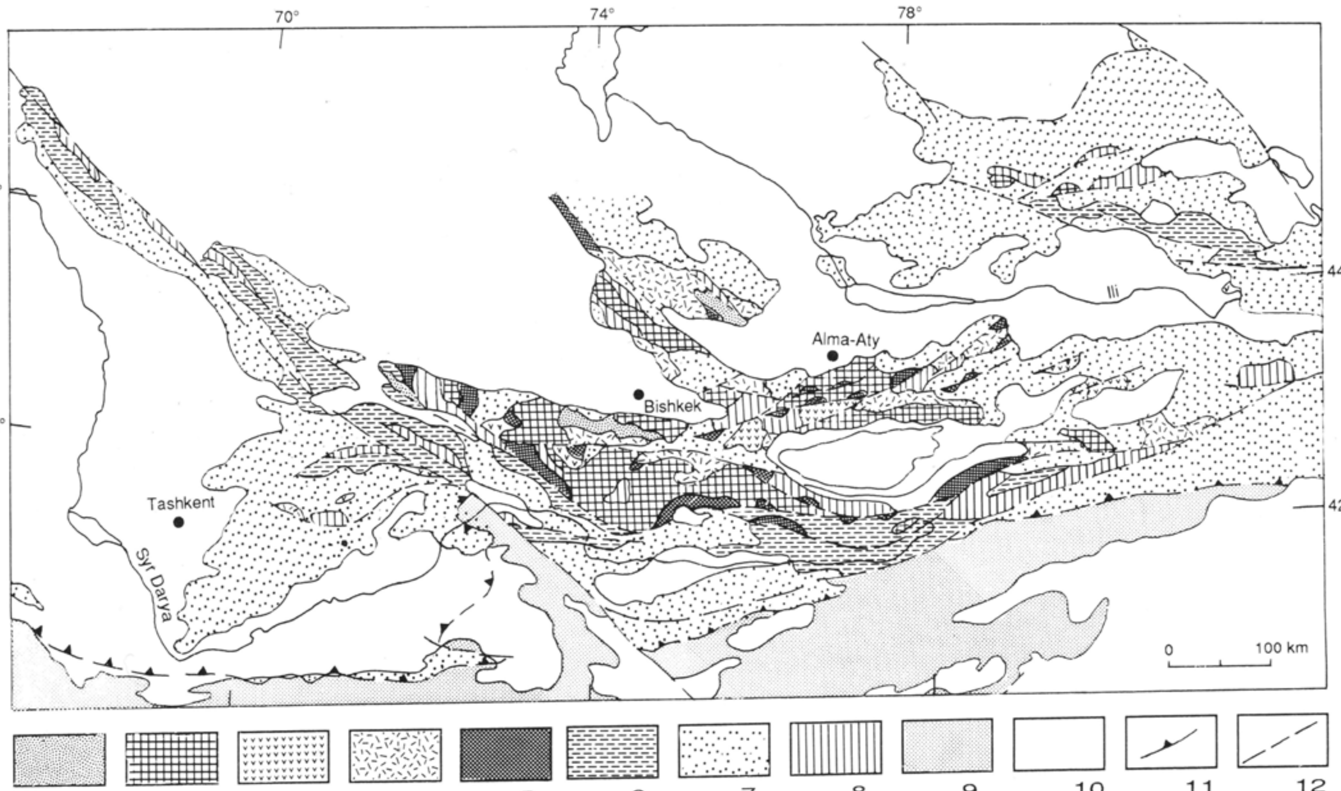

Fig. 401 Early Paleozoic in the Northern Turkestan domain. 1, Late Ordovician to Silurian molasse; 2. Middle and Late Ordovician granites; 3. Cambrian to Middle Ordovician volcanic rocks of the Kungey magmatic arc; 4, Cambrian to Middle Ordovician turbidities; 5, Vendian to Middle Ordovician ophiolites; 6, Vendian to Ordovician passive margin and rift sediments. 7, Middle and Late Paleozoic in the Northern Turkestan domain; 8. Proterozoic in the Northern Turkestan domain; 9. Southern Turkestan domain; 10 Mesozoic and Cenozoic; 11, thrust faults on the S border of the Northern Turkestan domain; 12, other faults.

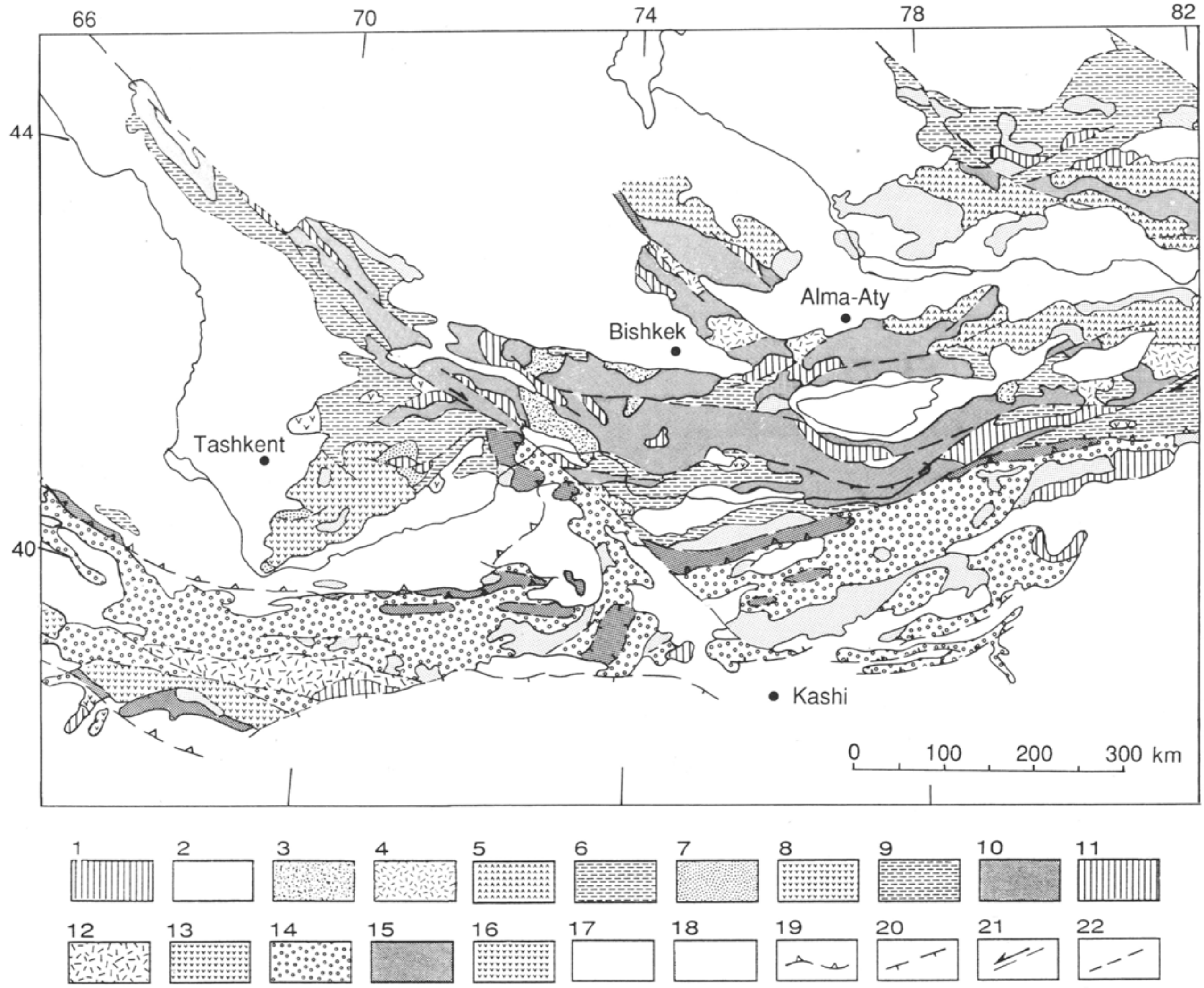

Fig. 402 Middle Paleozoic of the W and central Tien Shan. Northern Turkestan domain: 1, Proterozoic; 2, Vendian and Early Paleozoic; 3–6, Northern Tien Shan magmatic arc: 3, Early–Middle Devonian magmatic rocks; 4, Middle Devonian to Early Carboniferous magmatic rocks; 5, Middle Devonian to Late Carboniferous magmatic rocks; 6, Silurian to Carboniferous sedimentary rocks; 7–9, Sandalash and Kurama magmatic arcs: 7, Silurian to Early Devonian magmatic rocks of the Sandalash Arc; 8, Middle and Late Carboniferous magmatic rocks of the Kurama Arc; 9, Middle Devonian to Early Carboniferous sedimentary rocks. Turkestan suture: 10, Cambrian to Early Carboniferous ophiolites, green and blue schists, accretionary complex with ophiolites. Southern Turkestan and Kara Kum domains: 11, Precambrian; 12, Early Paleozoic volcanic rocks of the Yagnob Arc; 13, Early–Middle Carboniferous volcanic rocks of the Gissar Arc; 14, Early and Middle Paleozoic sedimentary rocks; 15, Southern Gissar Suture: Carboniferous ophiolites; 16, Early–Middle Carboniferous volcanic rocks of the Kugitang Arc. 17, Cenozoic and Mesozoic; 18, Late Carboniferous and Permian; 19, sutures; 20, thrust faults and strike-slip faults. 22, other faults.

deposits by magnetic anomalies, and a number of rare outcrops, and drillholes that extend along the Turkestan Suture in the Kyzylkum Desert and beneath the Aral Sea to the Ural Mountains. Magmatic rocks of the Kurama Arc date from the late Early Carboniferous to the Permian.

In the Chatkal area, there was no magmatic activity during Givetian, Late Devonian, Tournaisian or Visean times. Red-colored clastic deposits and thick organogenic limestones were formed at that time. The first Carboniferous volcanic rocks are found in the upper part of the Uya Formation along with foraminifera, goniatites and brachiopods of Serpukhovian–Bashkirian (middle Carboniferous) age. Rocks include trachybasalts, trachyandesites, trachytes, ignimbrites, tuffs and tuffaceous sandstones intercalated with sandstones. They are possibly of the same age as some small intrusions and sills of monzonites, syenite-diorites and syenites which have yielded a radiogenic K–Ar age of 321–327 Ma (Tulyaganov *et al.*, 1984).

The Minbulak Formation (up to 3000 m thick) consists of lavas, ignimbrites and tuffs ranging in composition from trachybasalt to trachyliparite and liparite. These unfossiliferous rocks lie unconformably on the Uya Formation and are intruded by granites, having a radiogenic K–Ar age of 310–334 Ma. Intrusions and dikes of gabbro, diorite, granodiorite and granosyenite are associated with the volcanic rocks of this formation.

The Akchin Formation (up to 1500 m thick), composed of trachyandesites, andesites, trachyandesite-dacites, trachyandesite-basalts, trachytes, basalts, ignimbrites and tuffs, lies unconformably on the Minbulak Formation. The formation includes Middle Carboniferous plants and spores and volcanic rocks dated with K–Ar at 281–328 Ma (Tulyaganov *et al.*, 1984).

The Nadak Formation (1500 m thick) lies unconformably on the Akchin Formation with conglomerates at the base of the section, which also includes andesites, trachyandesites, trachyandesite-dacites, andesite-dacites, liparites, ignimbrites and tuffs. Middle–Late Carboniferous plants have been found and dated by K–Ar to be 273–305 Ma (Afonichev and Vlasov, 1984). Large plutons of adamellites, granodiorites and leucocratic granites intrude the Nadak Formation. The granitoid rocks have yielded radiogenic K–Ar ages between 292 and 323 Ma. Pebbles of these rocks are known in Early Permian (Sakmarian) conglomerates (Tulyaganov *et al.*, 1984).

In the Upper Naryn area no Middle Paleozoic lavas are known. In the Dzhaman–Davan Range there are tuff sandstones and tuff conglomerates among clastic deposits of Bashkirian (?) age. Near the W margin of the Naryn area in the Fergana Range, there is a long narrow massif of granites and granodiorites penetrating Late Devonian and Bashkirian (?) sediments and having a K–Ar age between 290 and 350 Ma (Osmonbetov, Knauf and Korolev, 1982; Afonichev and Vlasov, 1984). Smaller granitic massifs having possibly the same age are distributed eastward from the Fergana Range.

Talas Zone

The Talas Zone (Fig. 400, IC) includes Proterozoic basement, Vendian passive margin and rift valleys sediments, Early Paleozoic passive margin sediments and granites of Silurian or Devonian age. The W part of the Early Paleozoic Terskey Suture is its NE border.

Issyk Kul Zone

The Issyk Kul Zone (Fig. 400, ID) is made up of Proterozoic basement, Cambrian to Ordovician rocks including the Kungey magmatic arc and accretionary complex, and Devonian to Carboniferous rocks including the Northern Tien Shan magmatic arc and accretionary complex. The Early Paleozoic Terskey Suture forms the S border of the zone and the Jalair–Naiman strike-slip fault makes its N border.

The basement of the Kungey magmatic arc is made up of gneisses and crystalline schists. Zircons with a Pb–U radiometric age of greater than 2000 Ma are found in the E and W parts of the Kyrgyz Range. Granites with a Pb isochron age of 1100 Ma have been intruded into sediments with Riphean stromatolites in the Kyrgyz Range (Mitrofanov, 1982; Osmonbetov, Knauf and Korolev, 1982).

The Early Paleozoic island arc volcanics of the Kungey Arc are distributed throughout the Kungey and Kyrgyz Mountains (Fig. 401) and are characterized by andesites and tuffs intercalated in thick, mainly clastic deposits containing Middle and Late Cambrian fossils. Such volcanics are common in the Ordovician and have a calc-alkaline composition. In the W part of the Kyrgyz Mountains, the Keptash and Utmek formations are composed of andesites, dacites, basalts and tuffs totaling 2500 m thick. There are intercalations of mudstones and limestones with brachiopods, cephalopods and trilobites of latest Early Ordovician to Middle Ordovician age. The volcanic rocks were intruded by granites with a radiogenic K–Ar age of 450 Ma.

In E part of the Kyrgyz Mountains, the Oktorkoy Formation (1600 m thick) is composed of andesites and tuffs with chert, mudstone, sandstone and limestone intercalations. Trilobites, brachiopods and foraminifera of Middle Ordovician age have been found in the formation (Osmonbetov, Knauf and Korolev, 1982). In the Kungey Mountains, the Ordovician island arc volcanics reach 4 km thick, and have yielded Middle Ordovician corals and brachiopods (Afonichev and Vlasov, 1984).

Middle Ordovician and Late Ordovician to Silurian granites, granodiorites and diorites are widely distributed in the Northern Tien Shan (Fig. 401). The age of the intrusions is based on the relationships of sedimentary formations and radiogenic age determinations. Studies of rare earth and other trace elements show that Middle Ordovician intrusives have a volcanic arc origin, and the Late Ordovician granites are of collision type (Ghes and Bakirov, 1993). Turbidities and clastic sediments of the accretionary complex are distributed all over the Northern Tien Shan (Fig. 401).

The Northern Tien Shan arc embraces all the Northern Tien Shan (Fig. 402). Magmatic activity began here in the Silurian or Early Devonian and continued to the Permian.

In the Kyrgyz Range, the Barkol formation of volcanic rocks lies unconformably on Middle Ordovician deposits, and is in turn overlain by early–middle Devonian volcanic rocks. The lower part of the Barkol Formation (600 m thick) includes andesites with intercalations of dacites, andesite-basalts, tuffs, clay and siliceous slates. The middle part of the section (450 m thick) includes tuffaceous conglomerates, andesite-basalts, dacites and tuffs. The upper part of the formation (350 m thick) is built by ignimbrites of andesitic and basaltic composition. There are no fossils in the Barkol Formation, but it may be of Silurian or Early Devonian age.

The Almerek Formation lies disconformably on the Barkol Formation and is composed of liparites, dacites and tuffs up to 800 m thick. The formation is also found in the Terskey Range where it exceeds 1500 m in thickness. In the Kastek Mountains the volcanics of the Almerek Formation contain coarse clastic deposits with Early-Middle Devonian plant remnants and spores of Givetian age (Osmonbetov, Knauf and Korolev, 1982).

The Aral volcanic formation (1200 m) lies unconformably over the above-mentioned clastic deposits and other older formations. In the Kyrgyz Range, the formation is composed of basalts, andesite-basalts, andesites with intercalations of tuffs and conglomerates. In the Susamyr Range, trachybasalts are widely distributed. Plant remnants from the Aral formation are possibly of Devonian age (Osmonbetov, Knauf and Korolev, 1982).

The Taldysu Formation lies discomformably on the Aral Formation and older rocks. The formation is built by liparites and ignimbrites of liparitic and dacitic composition with intercalations of tuffs. There are trachyliparites and trachytes in some sections. The thickness of the formation is usually 300 to 600 m and exceeds 1500 m in some places. Middle Devonian plant remnants have been found in the formation in the Zaili Range (Osmonbetov, Knauf and Korolev, 1982).

In association with Devonian volcanic rocks there are small bodies of diorites, granodiorites and (rare) granosyenites and syenites. Also, the Kumyshtag granitic massif in the Talas Range may be of Devonian age (Osmonbetov, Knauf and Korolev, 1982).

In the Kyrgyz Range and to the S of it, volcanic activity stopped in the Middle Devonian and a red-colored rhythmical formation of conglomerates, sandstones and mudstones lies unconformably on the volcanic deposits. In these clastic sediments, over 2000 m thick, Middle–Late Devonian fish have been found in the lower part and Famennian–Tournaisian plant remnants and foraminifera in the upper part (Burtman, 1964; Osmonbetov, Knauf and Korolev, 1982). The Visean and Serpukhovian sections include red-colored clastic deposits with intercalations of limestones. In E part of the Kyrgyz Range these sections include tuffs and tuffaceous sandstones, which were deposited in Middle and Late Carboniferous time.

Northeast of the Kyrgyz Range, volcanic rocks of Devonian and Early Carboniferous age are intruded by granodiorites, granites and quartz diorites with a radiogenic K–Ar age of 320 Ma (Afonichev and Vlasov, 1984).

Southern Turkestan domain

Alay–Tarim Zone

The Alay–Tarim Zone is divided by the Talas–Fergana strike-slip fault into the Alay (Fig. 400, IIA) and the Tarim (IIB) areas. The zone exhibits Proterozoic basement overlain by Vendian to Middle Carboniferous passive margin sediments.

Late Paleozoic magmatic rocks

The Late Carboniferous–Permian volcanism is a prolongation of volcanic activity in Middle Paleozoic magmatic arcs, but the distribution of the Late Paleozoic magmatic intrusives is relatively uniform throughout the territory of the Tien Shan.

Chatkal–Naryn Zone

In the Chatkal area volcanic deposits lie unconformably on Middle–Late Carboniferous rocks. In the SW part of the area, volcanic deposits reach a few kilometers thick and contain Early Permian foraminifera of Asselian and Sakmarian age (Tulyaganov *et al.*, 1984). Rocks of Asselian age include liparites and liparite-dacites (50%), trachyliparites and trachytes. Sakmarian rocks include trachyandesites (40%), trachybasalts, andesites, andesite-basalts and trachytes. The upper part of the Paleozoic stratigraphic sequence of the Chatkal area include tuffs and lavas of trachyliparite, liparite and trachyte composition. The formation is more than 1000 m thick and contains plant remnants of the Late Permian–Early Triassic age. Syenites, alkali and leucocratic granites with radiogenic K–Ar ages of 250–300 Ma (Tulyaganov *et al.*, 1984) intrude the volcanic rocks.

In the Upper Naryn area, late Paleozoic volcanic rocks S of Son Kul Lake include andesites, dacites and tuffs with Permian plant remnants. Farther to the S in the Dzhaman Davan Mountains, ignimbrites and tuffs interfinger with clastic sediments and limestones in which Early Permian foraminifera have been found. Granites, granosyenites and granodiorites with radiogenic K–Ar ages of 280–300 Ma are distributed in the area (Osmonbetov, Knauf and Korolev, 1982).

Issyk Kul Zone

Late Paleozoic volcanic rocks are distributed in the Kyrgyz and Kungey Mountains. In the E part of the Kyrgyz Mountains volcanic rocks lie uncomformably on Middle–Late Carboniferous clastic sediments. Rocks include andesites, trachyandesites, dacites, basalts and tuffs with slates, sandstones and mudstones; the latter have yielded Permian spores (Osmonbetov, Knauf and Korolev, 1982). Deposits are over 1500 m thick. Intrusive rocks are mainly granosyenites, syenites and leucocratic granites with radiometric K–Ar ages of 260–315 Ma (Afonichev and Vlasov, 1984).

Alay–Tarim Zone

No Late Paleozoic volcanic rocks are known in the Alay–Tarim Zone. Widespread Late Paleozoic intrusive rocks are the youngest Paleozoic rocks of the zone. Dominant rocks are granites having a two-mica composition, and syenites, adamellites and granodiorites.

Main Paleozoic sutures and faults

Talas–Fergana Fault

The Talas–Fergana Fault is one of the great strike-slip faults of Asia (Fig. 400). Dextral strike-slip movements occurred in the Late Permian and Cenozoic (Burtman, 1964, 1980). Measured strike-slip separation aggregates 180 km, and horizontal folds (oroclines) are present on both ends of the fault. The total magnitude including strike-slip displacement and orocline bending reached 250 km.

Nikolaev's Line

Nikolaev's Line (Fig. 398, Fig. 400) is a structure composed of Late Paleozoic faults of different types which were described by V.A. Nikolaev (1933). The N part of the Talas–Fergana Fault forms its W terminus. The Son Kul system of thrusts and the Sarydjaz left-lateral strike-slip fault form the E prolongation of Nikolaev's Line.

Terskey Suture

The W part of the Early Paleozoic Terskey Suture is the border between the Talas and the Issyk Kul tectonic zones (Fig. 400). The suture joins Nikolaev's Line near Son Kul Lake. To the E, the suture follows Nikolaev's Line and is situated northward of it in some places.

Early Paleozoic ophiolites are distributed in nappes along the Terskey Suture in the W Kyrgyz Mountains, the Susamyr Mountains and the Terskey Mountains. Rocks include serpentinized ultramafics, cumulative gabbro-troctolites and gabbro-norites, sheeted dikes, tholeiitic basalts and tuffs with intercalations of cherts and limestones. Cambrian–Early Ordovician radiolarians and conodonts were found in cherts. Geochemical studies indicate MORB compositions for the ophiolites and suggest, therefore, a marginal basin origin (Ghes and Bakirov, 1993). Thus the Terskey Suture may have originated in Late Ordovician as result of closure of a Terskey back-arc basin.

Turkestan Suture

The Late Paleozoic Turkestan Suture (Fig. 401, 402) extends along the Tien Shan and its W prolongation beneath the Cenozoic sedimentary cover to the Urals (Burtman, 1980). The suture consists of a thrust–nappe stack of ophiolites which were emplaced along the margin of the Southern Turkestan domain. Green- and blueschists are thrust on top of the ophiolites.

A few hundred outcrops of ophiolitic rocks are known along the Turkestan Suture. In the Alay Mountains there are dunites, harzburgites and pyroxenites overlain by ophiolite breccia and pillow-lavas with intercalations of cherts. Radiolarians, conodonts and other fossils from sedimentary interlayers are of Early Ordovician to Late Devonian–Early Carboniferous age. The breccia includes blocks of komatiite with interbedded carbonate containing early Cambrian archeocyathids and trilobites (Bakirov and Burtman, 1984).

Petrochemical data show that the volcanics of the Alay Mountains belong to mid-oceanic ridge basalts, oceanic island tholeiites and oceanic island alkali basalts (Kariakin, Kurenkov and Aristov, 1993). Tholeiitic basalts distributed in the Turkestan Suture in the Central Tien Shan are of mid-ocean ridge type (Khristov and Mikolaychuk, 1983).

Paleozoic tectonic evolution

The Precambrian history of the area is not very clear. The Northern Turkestan domain probably formed along the margin of the Proterozoic Baltica–Siberia continent (Sengör, Natal'in and Burtman, 1993). The Tarim Block probably belonged to Gondwanaland, based on Cambro-Ordovician biogeographic evidence (Burrett, Long and Stait, 1990). There are no paleomagnetic data for the Precambrian and the Lower Paleozoic of the Tien Shan Mountains. If this reconstruction is correct, the Turkestan ocean would have been one of main branches of the ancient Paleopacific Ocean.

The Paleozoic of the Tien Shan is composed of a few island arcs. The main tectonic events occurred in the Late Ordovician and in the Late Paleozoic.

From Vendian time on, the Northern Turkestan domain was probably a part of the Kipchak island arc system situated between the East European and the Siberian continents (Sengör, Natal'in and Burtman, 1993). The Terskey back-arc basin, which originated in the Vendian as rift basin, separated the two branches of the arc system – a passive margin in the Talas and the Chatkal–Naryn tectonic zones and an active margin with the Kungey magmatic arc in the Issyk Kul tectonic zone.

In the Ordovician three island arcs were active, which later were incorporated into the Tien Shan tectonic collage. Amalgamation occurred by subduction of the Terskey oceanic crust under the Kungey Arc, subduction of the Turkestan oceanic crust under the Sandalash Arc and subduction of the Paleotethys oceanic crust under the Yagnob Arc (Fig. 403).

In middle Ordovician time, the Terskey Basin closed and the composite Kyrgyz Block formed which was then deformed in the Middle–Late Ordovician. Coarse-grained upper Ordovician molasse sediments lie unconformably on volcanic rocks and subduction-related granites. Late Ordovician collisional granites are widely distributed N of and probably also S of the Terskey Suture.

In late Ordovician–Silurian time the Turkestan oceanic crust was subducted under the Sandalash magmatic arc, which was situated on the S margin of the Kyrgyz Block. In early Devonian time magmatic activity moved northward to the Northern Tien Shan. This magmatic activity may be connected with the subduction of remnants of the Turkestan oceanic crust (Fig. 403). There is no evidence of subduction under the S margin of the Kyrgyz Block from the Early Devonian to the Serpukhovian.

There are no good data concerning magmatic activity in the Southern Turkestan domain from Silurian to early Carboniferous time. Sedimentation took place in continental seas and on a N passive margin of the Tarim–Alay Block. The S border of the Tarim–Alay Block may be of transform origin.

In early Carboniferous time the second epoch of pronounced magmatic activity began (Fig. 403). Spreading in the Turkestan Ocean probably ceased after Devonian time. The Turkestan Ocean probably began to close in the Serpukhovian, when subduction under the Kyrgyz Block resumed. Early–Middle Carboniferous subduction-related magmatism is known in all zones of the North Turkestan domain except the Talas Zone.

Collision of the Tarim–Alay continent and the Kyrgyz Block began in late Moscovian (late Carboniferous) time, marked by the emplacement of large nappes containing ophiolites and passive margin sediments over the Tarim–Alay Block (Burtman, 1973, 1975, 1976; Fig. 404).

In late Carboniferous–Permian time magmatic activity was present throughout the Tien Shan. Collisional magmatic rocks dominate, but are mixed with subduction-related magmatic rocks in some places. Widespread deformation of the Tien Shan took place (Fig. 405) and coarse-grained molasse sediments were deposited in separate basins.

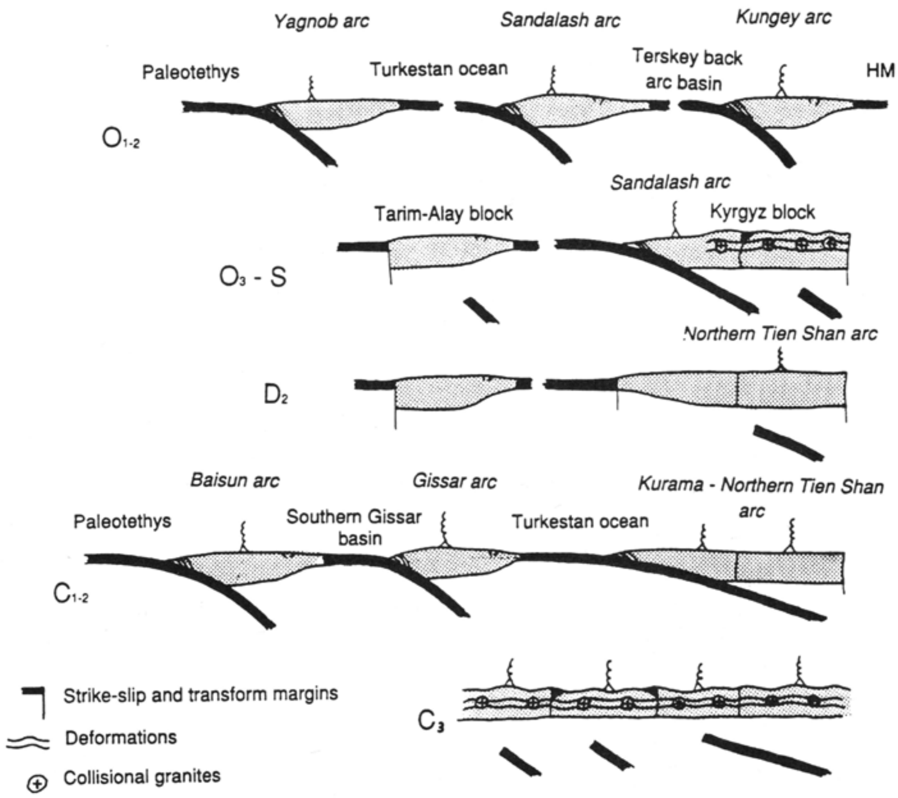

Fig. 403 Geodynamic cross-sections across the Tien Shan. Oceanic crust is dark, continental crust is light; passive and active margins and magmatic arcs are shown. HM, Hanty Mansi back-arc basin.

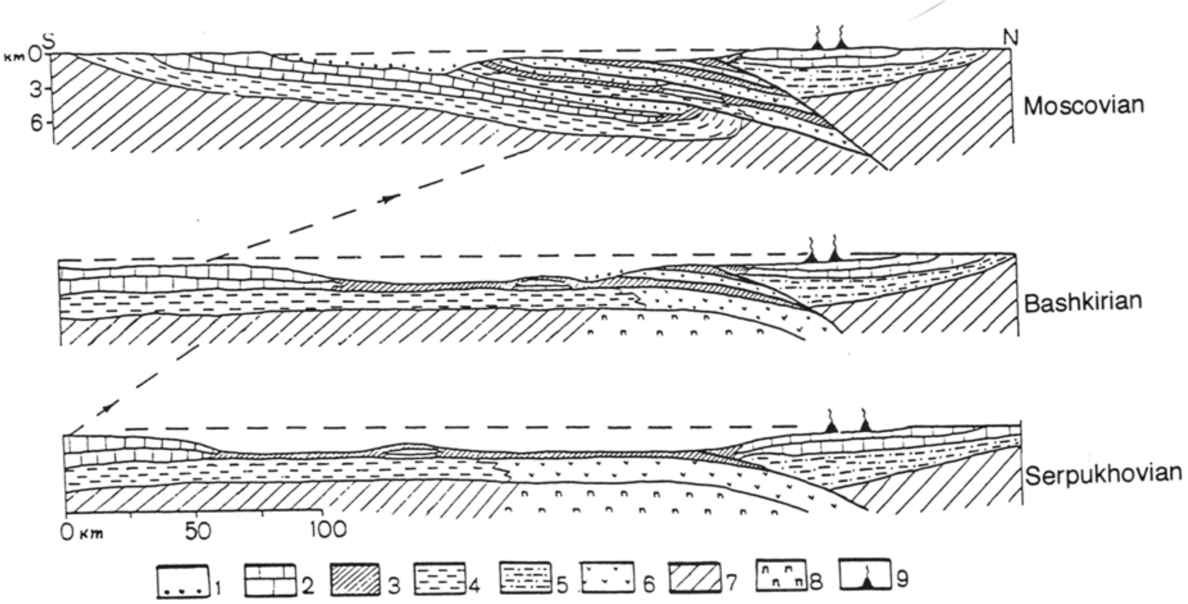

Fig. 404 Schematic diagram of the closure of the Turkestan Ocean (after Bakirov and Burtman, 1984): cross-sections across the Western Tien Shan for the Serpukhovian, Bashkirian and Moskovian. The Chatkal area is to the right and the Alay area is to the left. 1, Bashkirian and Moscovian flysch and olistostrome deposits; 2, Devonian to Bashkirian shallow-water deposits; 3, Devonian to Bashkirian deep-sea deposits; 4, Cambrian to Devonian terrigenous deposits; 5, Cambrian to Devonian terrigenous and volcanogenic deposits; 6, Cambrian to Devonian oceanic basalts; 7, continental basement; 8, oceanic basement; 9, island arc volcanism.

Strike-slip displacements along the Talas–Fergana and certain other faults took place in the Late Permian (Burtman 1964, 1976, 1980). These movements were the last Paleozoic tectonic events in the Western and Central Tien Shan.

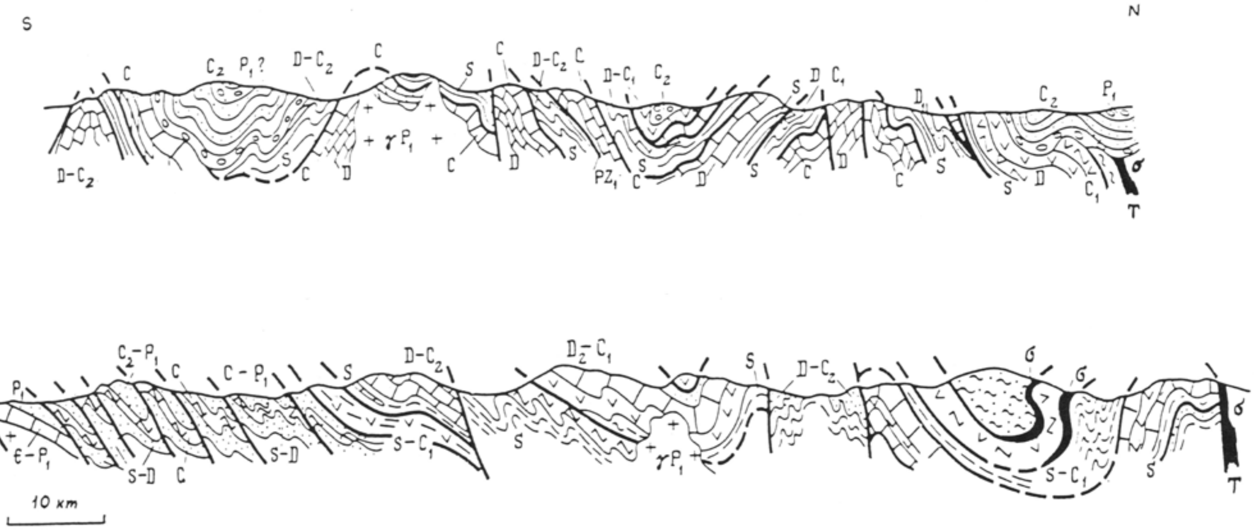

Fig. 405 Cross-sections across the Southern Turkestan domain (after Porshnyakov, 1983). Compiled cross-sections across the Alay Mountains (upper diagram) and the Kok Shaal Mountains (lower diagram). T, Turkestan Suture. The symbols are after the *Geological Time Scale* of W.B. Harland *et al.*, 1989: D_2, Middle Devonian; C_1, Lower Carboniferous, etc.

Mesozoic and Cenozoic

The Mesozoic and Cenozoic history of the Kyrgyzstan area can be divided into three main stages: (1) Triassic and Jurassic, (2) Cretaceous to Early Pliocene and (3) Late Pliocene to Quaternary time.

Triassic and Jurassic

A series of depressions developed in late Triassic and Jurassic time, and coal-bearing sediments accumulated in the depressions. The largest of these depressions, the East Fergana pull-apart basin, is aligned along the Talas–Fergana Fault (Burtman, 1964, 1980). Sediments deposited in the W and central parts of the basin are well exposed. Deltaic and nearshore facies with layers of coal characterize the W periphery and deeper water facies are found in the central part of the basin. The thickness increases from nil along the W periphery to 4–5 km in the central part of the basin. Sediments contain remnants of Rhaetian–early Jurassic and middle Jurassic plants, and late Jurassic spores and pollen have been found in the upper part of the sequence (Osmonbetov, Knauf and Korotev, 1982). The rocks have been folded.

Cretaceous to Early Pliocene

In Early Cretaceous time a broad intercontinental shallow-water basin formed, and sediments with both fresh and salt water fauna were deposited to the W of the Talas–Fergana Fault in the Fergana and Alay depressions and the Alay Range. Alluvial deposits mark the peripheries of the lake. The thickness of early Cretaceous deposits exceeds 500 m. At the beginning of late Cretaceous time the lake was transformed into a shallow intracontinental sea. During late Cretaceous, Paleocene and Eocene times, marine and lagoonal deposits accumulated. Maximum transgressions occurred in Campanian and Middle Eocene times. In Late Paleogene time the sea began to retreat. This regression occurred after the collision of the Indian Plate with the Eurasian Plate at roughly 50 Ma. In Oligocene time environments changed from marine to lagoonal and continental. The thickness of the Cretaceous, Paleocene and Eocene sequence exceeds 2000 m in the Fergana Basin.

East of the Fergana Range, Cretaceous and Paleocene sediments are absent. There, continental sediments began to accumulate in Eocene time. Clay, siltstone and sandstone with interbedded layers of limestone, marl, gypsum and conglomerate accumulated in isolated or interconnected basins through the Central Tien Shan in Oligocene and Miocene time. These deposits contain freshwater fauna and mammal bones (Osmonbetov, Knauf and Korolev, 1982). The thickness of these deposits vary from several tens of meters in some basins to several kilometers in others. The greatest thickness of Oligocene–Miocene sediments (more then 4000 m) accumulated in the Fergana, Naryn and Atbashi Basins (Fig. 399). The appearance of coarse-grained facies including conglomerates on the peripheries of lake-filled basins attests to the presence of mountains which probably reached several hundred meters. The warping of the crust in the Tien Shan in the Oligocene–Miocene can be seen as an 'echo' of the collision of India with Eurasia. The tectonic conditions in the Early Pliocene were similar to those described above.

Cretaceous and Paleogene folds are unknown in the Tien Shan. Angular unconformities on the basement and within the sedimentary formation of probably Miocene age were described in the mountains to the S of the Fergana Basin (Shcherba, 1990).

Late Pliocene to Quaternary

In the Late Pliocene there was a sharp activation of tectonic movement. Pliocene–Quaternary deposits of continental provenance accumulated in intermontane basins. Thick formation of conglomerates containing bones of Late Pliocene vertebrates (Lukina *et al.*, 1985) unconformably overlie older deposits. At the end of the Pliocene there also occurred a change in the climate toward colder and more arid conditions leading to Pleistocene glaciation. The Cenozoic folded structure and contemporary relief of the Tien Shan developed in Pliocene–Quaternary time. Folds are expressed in Mesozoic and Cenozoic rocks in basins and by warping of Cenozoic denudation surfaces preserved on ridges. Asymmetric anticlines, with one or both sides bounded by reverse or thrust faults, comprise the majority of ridges. The vergence of folding and thrusting commonly is towards large basins, including both the internal Fergana and Issyk Kul Basins and the external Chu, Ili and Tarim Basins (Sadybakasov, 1990).

Paleomagnetic study shows that in the Cenozoic the block including the Fergana Basin and the Alay Range was rotated counterclockwise relative to the Central Tien Shan (Bazhenov *et al.*, 1993). The Talas–Fergana Fault formed the E border of the rotated block and a strike-slip displacement along the fault with a rate of 1–2 cm y^{-1} accompanied the rotation of the Fergana–Alay Block (Burtman, Scobelev and Sulerzhitsky, 1987; Trifonov, 1993).

Kyrgyzstan is an area of high seismic activity. There were 11 earthquakes with magnitude greater than 6 since 1865 and two of these had a magnitude greater than 8. The Kyrgyz and Kungey Ranges and the E Fergana region are areas of highest seismicity (Djanuzakov *et al.*, 1977).

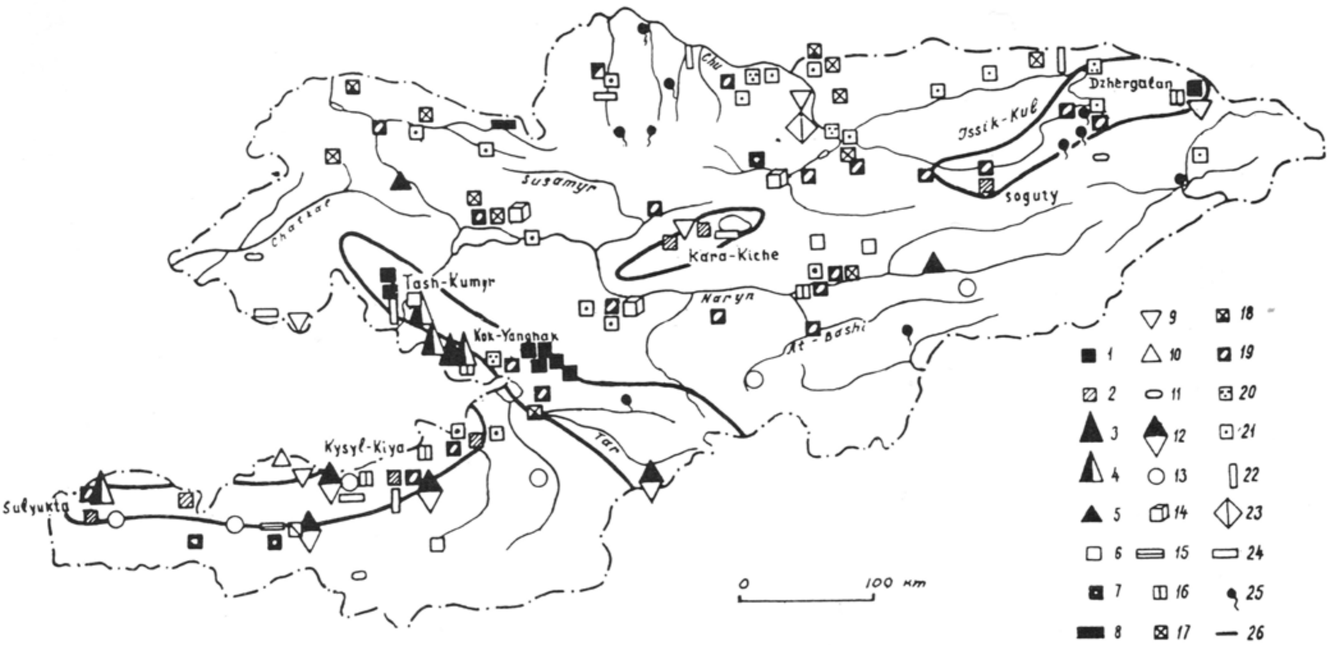

Fig. 406 Mineral resources of Kyryzstan (after Bakirov and Burtman, 1984). 1, hard coal; 2, brown coal; 3, oil; 4, oil and gas; 5, iron ores; 6, tungsten ores; 7, aluminum ores; 8, copper ores; 9, lead ores; 10, zinc ores; 11, tin ores; 12, antimony ores; 13, mercury ores; 14, common salt; 15, fluorite; 16, gypsum; 17–24, Building materials: 17, limestones; 18, facing stones; 19, brick clays; 20, building sands; 21, sand with gravel; 22, cement raw material; 23, basalts; 24, expanded clay aggregates; 25, mineral water springs; 26, coal-bearing basins.

Resources

Kyrgyzstan is rich in resources with mercury, antimony, gold and tin being of the greatest importance (Fig. 406). Their description is based on the article, published by A.D. Dzhumagulov, F.T. Kashirin and K.O. Osmonbetov in the guide-book for the excursion of 27th International Geological Congress (Bakirov and Burtman, 1984).

Metallic deposits

Mercury and antimony deposits (the Khaydarkan, Chauvay, Kadamzhai and others) are of quartz–fluorite–antimonite–cinnabar (jasperoid), magnesian–carbonate–cinnabar (listvenite), carbonate cinnabar and quartz–dickite–cinnabar types. Jasperoid type deposits include mercury, antimony and mercury–antimony deposits located near the contact between Carboniferous limestones and overlying nappes of Silurian shales and Devonian sandstones. Listvenite-type deposits are present in mélange with serpentine.

Gold ores are of contact-metasomatic (skarn) and hydrothermal types. Gold ore bodies form veins, lenses and stockwork. In some of the valleys placer gold deposits are also present.

Tin ores include pegmatite, cassiterite–quartz, skarn, cassiterite–silicate and cassiterite–sulfide types. Most significant deposits are situated in the contact zones of granites.

Iron ores occur in the Proterozoic slates. There are also minor deposits of U, W, Mo, Bi, Va, Pb, Zn, Al, Ag, Sr, Ge and other elements in Kyrgyzstan.

Oil and gas

The Fergana Basin is the only basin where commercial deposits have been discovered and exploited. Productive levels occur in Jurassic, Cretaceous, Paleogene and Neogene sediments. Cretaceous and Paleogene deposits are in sandstones, although some Paleogene ones are also in limestones. The oil of Jurassic, Cretaceous and Paleogene deposits is light and low sulfur. Gas from Jurassic and Cretaceous levels is dry with 72–75% methane.

Coal

There are four coal-bearing basins in Kyrgyzstan (Fig. 406): from SW to NE, the South Fergana Basin with the Sulyukta, Kyzyl Kiya and other deposits; the Uzgen Basin with the Tashkumyr, Kok Yangak and other deposits; the Kavak Basin with the Kara Kiche and other deposits; and the Southern Issyk Kul Basin with the Soguty, Dzhergalan and other deposits. Coal-bearing sediments are late Triassic–early Jurassic in age, and were formed under continental conditions. The thickness of coal-bearing sediments ranges from 200 to 700 m in the Kavak Basin, and up to 5000 m in the Uzgen Basin. About 30% of geological reserves are brown coals and about 70% hard coals. The number of commercial coal seams ranges from two in the Southern Issyk Kul Basin to 15 in the Uzgen and Kavak Basins. Most seams of hard coal are less than 3.5 m thick whereas seams of brown coal are thicker, reaching 40 m or more in the Kavak Basin.

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