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Geological Map

of Khan Tengri Massif

Explanatory Note

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1. Main geological setting of Central Tien Shan

The modern pattern of the Central Tien Shan was generated in the Late Oligocene-Pleistocene time. It includes serial parallel latitudinal strike ranges pided by basins. In major intermontane basins (Issyk-Kul, Naryn, Atbashy with lengths upto 250-380 km, widths upto 40-80 km) the surface of Paleozoic bedrocks is immersed to a depth of 3-4 km below than sea level. They are filled by Cenozoic deposits up to 4-5 km of thickness. The western boundary of the Central Tien Shan is the Talas-Fergana Fault, the eastern boundary is traced along the Chan-Tengri Peak meridian where all the mountain range system unites into the unified plexus of mountains. In the western part of the East (Chinese) Tien Shan the Halyk-Too Range adjoins to this plexus of mountains (Fig. 1.1).

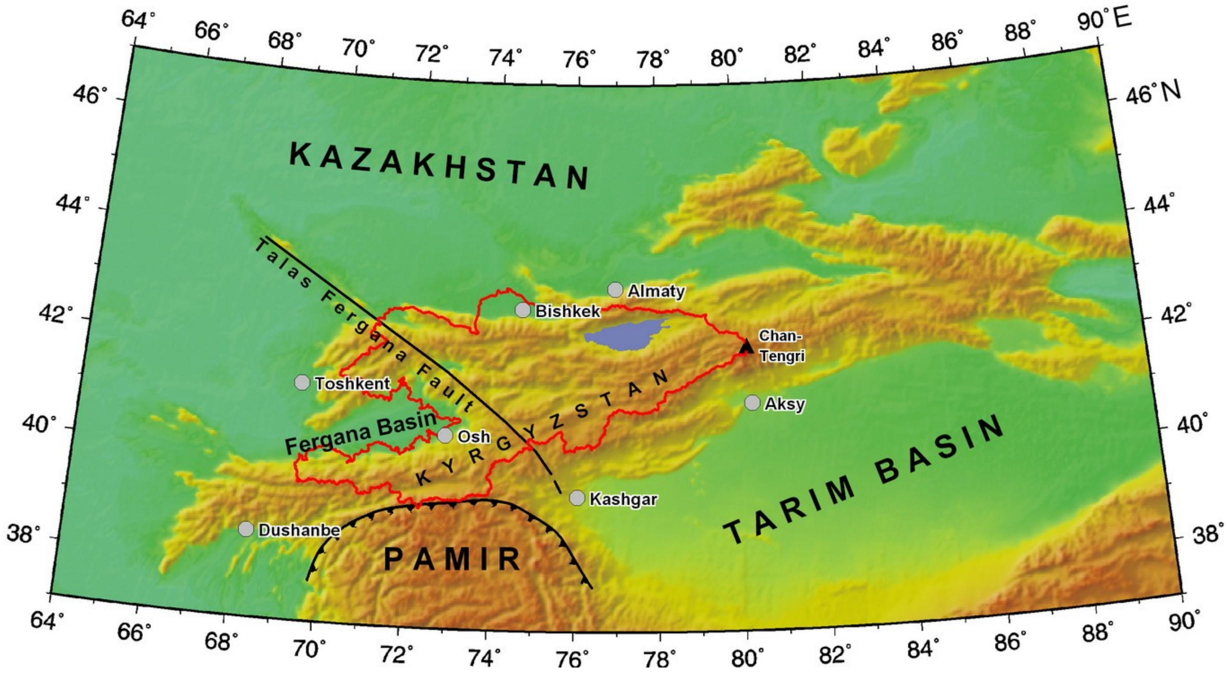

Fig. 1.1 Relief Map of the Central Asia

Tectonic zoning within the Central Tien Shan was caused by Paleozoic orogeny and is characterized by north-north-eastern strike. The Tarim and the Late Tien Shan represent continental massifs that surround from the south and the north the South Tien Shan Belt, which formed in the Middle Carboniferous as a result of close of the Turkestan Paleoocean (Fig. 1.2). The North Tien Shan tectonic zone (NTZ) and its counterparts in Kazakhstan are major units in the central part of the Ural-Mongol Belt.

The NTZ trends E-W parallel to the modern mountains for about 500 km in the North Kyrgyzstan and the South Kazakhstan; the eastward continuation of this zone into the Chinese Tien Shan is ambiguous (Mazarovich et al., 1995). In the west, the zone can be traced into the

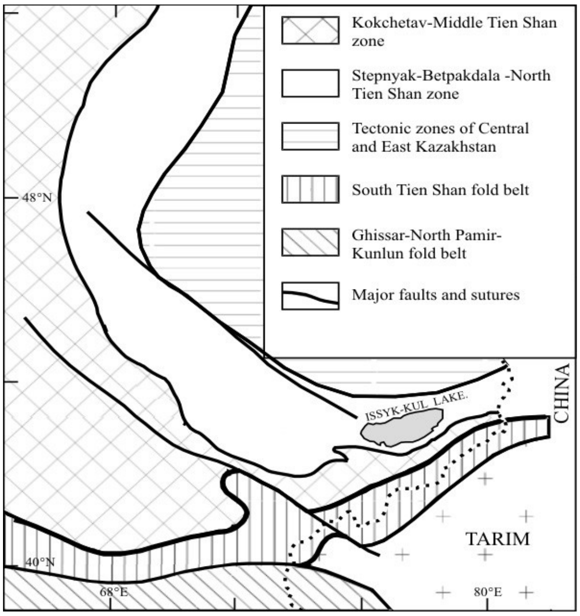

Fig. 1.2 Tectonic zoning within the Central Tien Shan

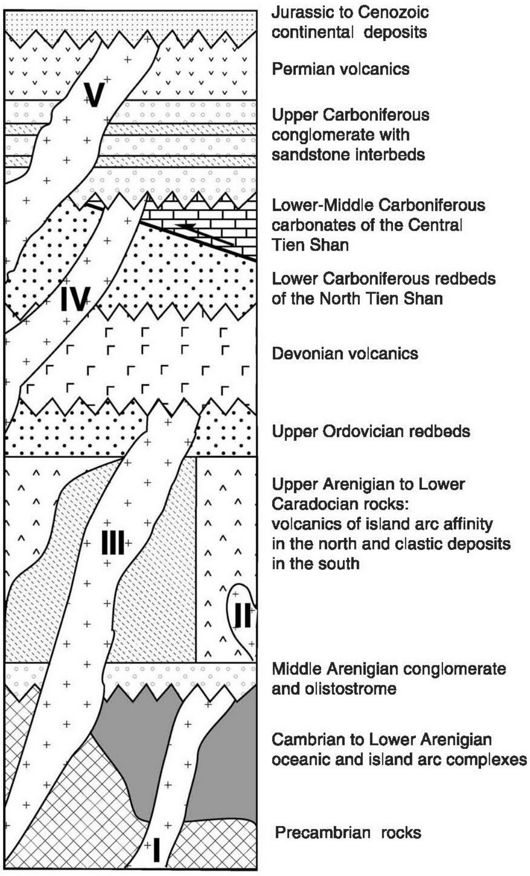

Fig. 1.3 Generalized geological column of the North Tien Shan [*]

Stepnyak-Betpakdala zone in Kazakhstan (Fig. 1.2). Despite lateral variation in structure and sections, the Stepnyak-Betpakdala zone and the NTZ are regarded as a single first-order tectonic unit about 2000 km in length (Nikitin, 1972; 1973). In the NTZ, shelf and continental slope complexes of Precambrian age outcrop as disrupted blocks and thrusts, and their original relationship is unclear. Cambrian to Lower Arenigian rocks include subduction-related volcanics, marginal sea, rift, and passive margin complexes which are regarded as the remnants of a basin with oceanic crust - the Terskey ocean or marginal sea (Mikolaichuk et al., 1997; Degtyarev and Mikolaichuk, 1998). The closure of this basin by the Early-Middle Arenigian boundary resulted in thrusting and deformation of all older complexes and some granite intrusions. Middle Arenigian conglomerate and olistostromes overlap the Cambrian-Early Arenigian complexes with a major angular unconformity (Fig. 1.3). A thick pile of differentiated volcanics of the Late Arenigian to the Early Caradocian age accumulated in the northern and central parts of the NTZ; this series is considered a counterpart of modern active continental margins (Lomize et al., 1997). Along the southern boundary of the NTZ, volcanics are replaced by terrigenous and volcanic-clastic rocks of the same age, which are locally intruded by relatively small bodies of acid to intermediate magmatic rocks and conformably covered by Upper Caradocian red sandstones containing siltstone and limestone interbeds. The Ordovician succession is intruded by numerous large granite bodies in the Late Ordovician and smaller granites in the Silurian (Mikolaichuk et al., 1997) . Due to the lack of Silurian rocks above the NTZ, the age of deformation here cannot be constrained better than Pre-Early Devonian. A major angular unconformity, however, is present at the Ordovician-Silurian boundary in the Stepnyak-Betpakdala zone of Kazakhstan (Nikitin, 1972; 1973), and it is likely that the NTZ was strongly deformed at about this time too. On a broader scale, geological data indicate that the Stepnyak-Betpakdala zone and the NTZ were welding to other major blocks of Kazakhstan during the Silurian (Mossakovsky et al., 1993).

Lower-Middle Devonian basic and acid subaerial volcanics in the North Tien Shan occur over a major unconformity with Lower Paleozoic rocks (Fig. 1.3).In the Late Devonian-Middle Carboniferous time a carbonate platform was existing in the southern part of the Middle Tien Shan (Fig. 2.2); the carbonate platform complex is laterally traced over 1000 km (Alexeiev et al., 2000). A deep basin filled by terrigenous rocks appeared between the carbonate platform and the NTZ in the Late Tournaisian. The northern part of the basin which onlaps the NTZ is filled by Upper Visean to Lower Bashkirian redbeds (Mikolaichuk et al., 1995).

The carbonate platform complex was thrusted onto the NTZ in the Middle Bashkirian time. The thrusts are sealed by Upper Carboniferous conglomerates with subordinate sandstone and siltstone, which in turn are overlain with erosional unconformity and basal conglomerate by Permian volcanics (Fig. 2.3). A prominent angular unconformity between Permian and Lower Jurassic rocks indicates strong deformation in the Lattermost Paleozoic and/or the Triassic. Finally, the entire Tien Shan was affected by Alpine tectonism. It should be stressed that the intensities of deformation events are laterally variable, and it is often difficult to evaluate the magnitudes of each deformation at a locality (Bazhenov et al., 2003).

[*] *Saw-toothed lines, angular unconformities; thick solid line, thrust between terrigenous rocks of the North Tien Shan in the north and carbonates of the Middle Tien Shan in the south. Cross-filling, granite intrusions of various age: I, Early Ordovician; II, Middle Ordovician; III, Late Ordovician and Early Silurian; IV, Middle Carboniferous; V, Permian. Note that this column is schematic, and there are minor lateral facies changes (modified after Bazhenov et al., 2003).*

2. North Tien-Shan Geological Province

2.1. Pre-Cambrian structural complex

2.1.1. Stratified formations

Sarytor Formation (R2sr). The formation was defined by Yu.V.Jukov, L.N.Mozolyev and V.M.Rozhanets in 1960 (Osmonbetov, Knauf, 1982). Its typical sections are located to the west of the research area on the southern slope of the Terskei Range near Ekurgenkol Lake area. The formation consists of biotite-amphibolic, garnet-biotite-amphibolic, micaceous schists, porphiroids, quartzites and micaceous marbles. It is about 2000 m thick (Mitrofanov, 1982). The Middle Riphean age of the formation's rocks metamorphism of 1100 Ma is based on U/Pb dating on zircons (Kiselyev et al., 1993).

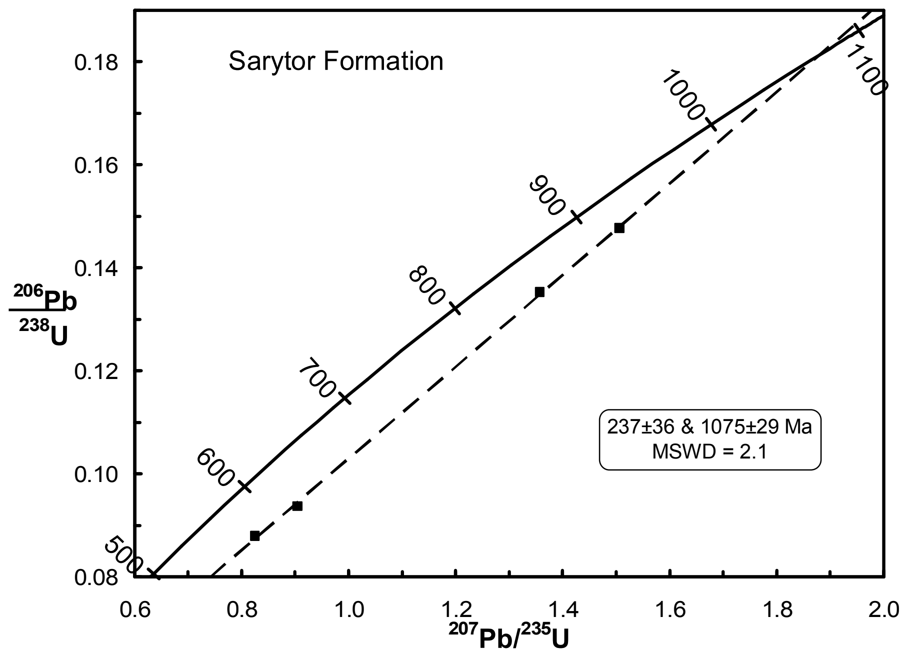

Fig. 2.1.1.1. U/Pb diagram with concordia for zircons composed of gneisses

In the investigated area, the Sarytor Formation is epidote-biotite-quartz schists, gneisses and marbles. They outcrop in the eastern part of area the (Ashurtor, Keksentas and Sauruksai rivers) occurring as a 2.5 km thick band. This formation is intruded by the Early and Late Ordovician granites. The formation has underwent alteration as observed in the formation section in the Keksentas river, where from the north to south there are: gneisses and schists (600-700 m), marbles (250-300 m), gneisses and schists (500-550 m). The Late Devonian and Early Permian granite massifs intruded the metamorphic rocks. The chemical content of gneisses is described by one sample (geochemistry catalogue). As it is shown on the SiO2 – Na2O+K2O (Le Maitre et al., 1989) diagram the gneisses point is located in the field of dacites and granodiorites. Gneisses age of 1075±29 Ma (Fig. 2.1.1.1) is based on the U/Pb dating on zircons (isotope age catalogue). The Middle Riphean age of gneisses is based on the received isochronous dating.

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Chonashu Formation (R_3?čn) was defined by T.A. Dodonova with co-authors (1968). A typical section stretchs from the right bank of the Ottuk River in the north-east direction to the Tyup River head waters adjacent to the north side of the "Nikolaev`s line" (the main structural lineament of the Tien-Shan) . Blocks of the Chonashu Formation have complicated tectonic relations with blocks of the Early Paleozoic ophiolites in the 5 km wide and 13 km long band. The information summarising the formation here was originally presented within the survey works (Grishenko, 1985). Three metamorphic rock associations are defined in the formation content. The first one is represented by the grey, greenish-grey thinly-bedded and by the massive amphibole-biotite gneisses. Gneisses are at least 500 m thick. The second association consists of dark grey, dark green massive amphibolites, thin-bedded gneisses and micro-micaceous schists occur rarely (460 m). The third association is composed of dark grey and black biotite feldspathized schists and rare gneisses. Schists with gneisses horizons are more than 480 m thick. Leucocratic and melanocratic gneisses of the Chonashu Formation outcrop eastward in the Chonjanalach head waters in the block of 1.6 km^2 and they are 870 m thick (Severinov, 1990).

Rocks of all three associations are exposed to the alkaline metasomatism which led to the feldspathization. The schist's feldspathization caused biotite-nepheline syenites and albite syenites to form. Gradual transitions from the nepheline and perthite syenites to the metamorphic rocks have previously been determined (Dodonova, 1972). The chemical content of the formation rocks is shown in the geochemistry catalogue. Location of the Chonashu formation rocks on SiO_2–(Na_2O+K_2O) diagram is shown in the Fig 2.1.1.2. Feldspathized schists on the Ottuk River left bank (Chonashu Stream) and metasomatic syenites in the Tyup river head had been dated by U/Pb method on zircons (isotope age catalogue, # 1273, 1305, 21750). Isochronous zircons age is dated by 680±25 Ma (Fig. 2.1.1.3). The Late Riphean age of the Chonashu formation metamorphism and alkaline metasomatism is based on these data.

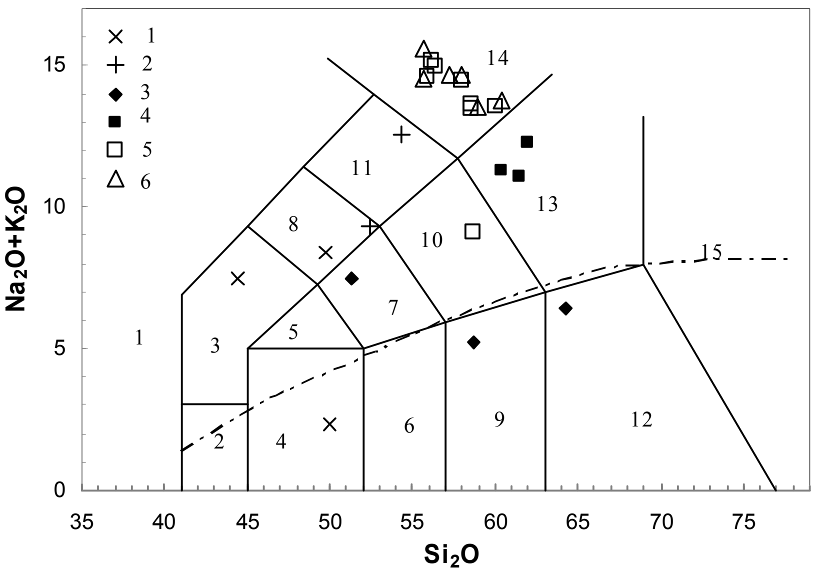

Fig. 2.1.1.2. Rocks of the Chonashu Formation on the SiO_2 – (Na_2O+K_2O) diagram. Fields (Le Maitre et al., 1989): 1- foidites and foidolites; 2- picrites and peridotite gabbros; 3- tephrites-basanites and felspathoid gabbros; 4 – basalts and gabbros; 5 – trachybasalts and sub-alkaline gabbros; 6 – andesibasalts and gabbrodiorites; 7 – trachyandesibasalts and monzodiorites; 8 – main feldspathoid rocks; 9 – andesites and quartz diorites; 10 – trachyandesites and monzonites; 11 – melanocratic phonolites and feldspathoid syenites; 12 – dacites and granodiorites; 13 – trachyte, trachydacites and syenites, quartz monzonites; 14 – phonolites and feldspahoid syenites; 15 – rhyolites and granites. Dotted line – the lower border of the sub-alkaline rocks spread after (Bogatikov et al., 1981). Legend: 1 – amphibolites; 2 – feldspathized schists; 3 – metasomatites; 4 – syenites; 5 – nepheline syenites; 6 – mariupolites

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2.2. Cambrian – Middle Ordovician structural complex

2.2.1. Stratified formations

< (Double click to view the stratigraphical columns)

Accretionary complex (acV?-Ꞓ1). We have combined into one complex the fragments of deformed and divided parts of the oceanic crust, siliceous and terrigenous-volcanogenic deposits. The complex formations are outcropped in the tectonic blocks within the narrow band which stretches to the north from the Nikolaev's line from the west to the east through the whole area. The complex is composed of basalts, gabbros, norites, pyroxenites, peridotites, serpentinites and siliceous-slate, terrigenous-volcanogenic and rare carbonate deposits. They are metamorphized to a various degree; rarely till the actinolite shales and amphibolites. The complex dislocating, imbricate structure, and dynamometamorphism degree in general grows eastward. The complex single parts are represented by the weakly deformed massive and pillow lavas of pyroxene-plagioclase and plagioclase basalts which are 800 m thick (Severinov, 1989). A significant amount of serpentinite or serpentinized ultrabasites lenses occurs around thrusts or nappes. In the Turuk River this complex consists of thrust sheets of marmorized limestone of 150 m thick and a thrust sheet of 450 m thick in which island-arc deposits have been described as: lithic tuffs of basic and medium structure, tuffstones and tuff-siltstones with lenses of the calc-siliceous rocks, conglomerates with fine pebble of acid effusives, marbles and cherts (Mitrofanova et al., 1986). Gabbros, gabbro-norites, pyroxenites and occasionally peridotites form the independent massifs in the Ottuk River, the Kichiburkut and Chonburkut headstreams (Grishenko, 1985).

The complex chemical composition of these rocks is described in the geochemistry catalogue. The figurative points of the Accretionary complex rocks are shown in Fig. 2.2.1.1. and Fig. 2.2.1.2., SiO_2 – (Na_2O+K_2O) and AFM diagrams. Basalts of the Accretionary complex mostly belong to the low temperate, potassic tholeiites of the sodium alkalinity type. TiO_2 is within 0.32 – 1.29%, the medium content is equal to 0.68±0.31%. Low ratios of K_2O/TiO_2 (0.50±0.23) and $Al_2O_3/(Fe_2O_3+FeO+MgO)$ (0.84±0.22) are typical for basalts. As it is shown on the discriminant diagrams (Pearce, 1976; Mironov, Kotlyar, 1991) the basalt points are located in the fields of tholeiites of island arcs and oceanic basalts. Basalt point with TiO_2 = 1.20 % (sample F120-87) content on the Cr – Ti (Sharaskin et al., 1980), Y – Cr (Pearce, 1982), Zr – Zr/Y (Pearce, Norry, 1979), Zr-Ti-Y и Zr-Ti-Sr (Pearce, Cann, 1973) diagnostic diagrams is in the tholeiites fields of island arcs and basalts of mid-ocean ridges.

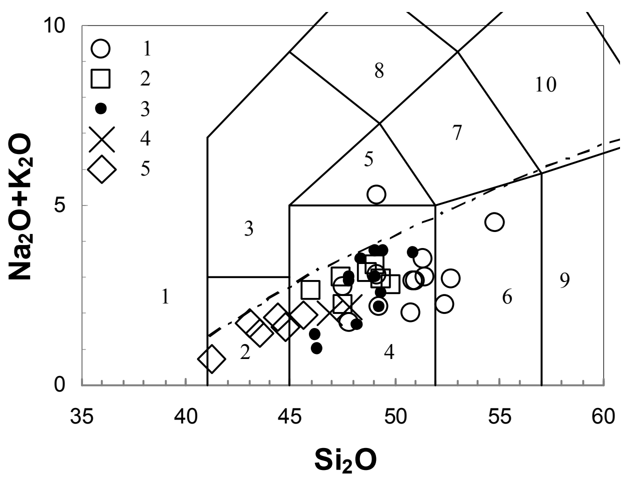

Fig. 2.2.1.1. Rocks of Accretionary complex on the SiO_2 – (Na_2O+K_2O) diagram

Field numbers (Le Maitre et al., 1989): 1- foidites and foidolites; 2- picrites and peridotite gabbros; 3- tephrites-basanites and felspathoid gabbros; 4 – basalts and gabbros; 5 – trachybasalts and sub-alkaline gabbros; 6 – andesibasalts and gabbrodiorites; 7 – trachyandesibasalts and monzodiorites. Dotted line – the lower border of the sub-alkaline rocks spread after (Bogatikov et al., 1981). Legend: 1 – basalts; 2- diabases; 3 – gabbros; 4 – norites, troctolites; 5 – peridotites, pyroxenites

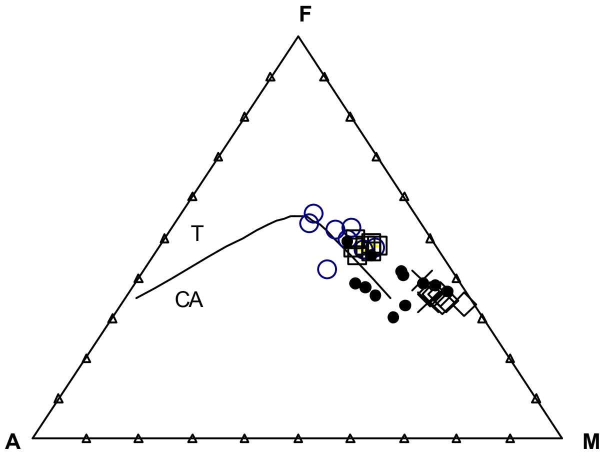

Fig. 2.2.1.2. Rocks of Accretionary complex on the AFM diagram with the line dividing tholeiite and calc-alkaline rock series (according to Irvin and Baragar, 1971). For symbols see legend in Fig. 2.2.1.1.

The Accretionary complex is intruded by diorites of the Central Turuk Formation with isochrone age 532±12 Ma (isotope age catalogue). Tuff-conglomerates contain chert fragments with sponge spicules and radiolarians of the Lower Paleozoic (fauna catalogue, site 298). Basalts in the Chinese Tien-Shan of 516.3±7,4 Ma (Qian et al., in print) to the east of the research area, obviously represent this Accretionary complex too.

Compiler : F.Kh. Apayarov

Ashuairyk section type

Jolkolot Formation (Ꞓ2?dk) is defined by Korolev V.G. (1954). The name is comes from the Jolkolot valley in the Chon Jalanach headwaters, where the stratotype section is located. The formation is traced in the top part of northern slope of the Terskei Range from the west to the east of the studied territory. The formation bottom to 450 m thickness consists of rust-brown, grey-green, green medium and fine-grained quartz arkoses, siltstones and chlorite shales. There are interbeds of conglomerates, gritstones with a pebble of marbles and acid effusives. Limestone olistolithes occur rarely. The formation top to 380 m thick consists of speckled (lilac, brown, green) polimict sandstones and siltstones with rare gritstone lenses and thin limestone interbeds. The cleavage in the formation is intense and has therefore erased petrographic rock differences, leaving only slates (Grishenko, 1985, Severinov, 1990). The Jolkolot formation bottom is not outcropped and a Middle Cambrian age is expected, on the basis of lithologic similarities with the Ovva formation of the Kyrgyz Range (Apayarov, 2007).

Compiler: M.D. Ghes

Ashuairyk Formation (Ɛ3?aš) is defined by Korolev V.G. (1954). The name is taken from the Ashuairyk River which is the left tributary of the Chon Janalach River. This formation , lies stratigraphically over the Jolkolot Formation, and together are found along the Turuk River (Severinov, 1990). The bottom part of the Asuiaryk formation which is 270 - 660 m thick consists of the alteration of dark grey, greenish-grey, calcareous shales, black graphitic shales with interbeds of calcarenites, dolomites and marble limestones. Layers are 2 - 5 m thick, sometimes increase to 30 m. In the middle part of the formation there are light grey, cream-yellow, dark grey massive and thin-bedded (0.5-1cm) marble limestones and dolomites among which there are limited occurrences of sericite shales. Carbonate deposits are 200-400 m thick. The formation tops (to 300 m) are similar to its bottom part by the section content and structure. A typical feature is the presence of graphitic shales. Full thickness of Ashuairyk formation is 770 - 1360 m (Grishenko, 1985, Severinov, 1990). The Late Cambrian age of Ashuairyk formation is accepted conditionally, on the basis of the lithologic similarities with Bayankol formation from Jergalan section type, Chener formation of the Kyrgyz Range (Apayarov, 2007) and Toraygyr formation of the Kungei Range (Mikolaichuk, 1998).

Compiler: M.D. Ghes

Turgenaksu section type

Turgenaksu Formation (Ɛ-O 1 tr) is defined by V.N.Krivolutskaja and V.G.Korolev (1960). Its stratotype is described in the eastern part of the Terskei Range in the Turgenaksu. It stretches from here as a narrow strip and separate fragments limited by faults through all reviewed territory and out to the east. The main part of the formation contains flows of grey and black-green greenstone changed pillow-lavas and lava –breccias of aphyric and porphyry basalts. Variolite and andesite flows are rarer. The formation up-section often consists of thin interbeds of litho- and perlitic tuffs of basalts, tuffites, lava-breccias, siliceous shales and marmorized limestones among the effusives. Visible formation thickness reaches 1200 m. In the studied area chemical composition is defined only in 1 sample (geochemistry catalogue).

According to the geochemical data from adjacent territories, analyzed by diagrams FeO/MgO-TiO_2, TiO_2-K_2O, the rocks belong to the island-arc series (Ghes, 2003). The Cambrian – Early Ordovician age of Turgenaksu formation is based on the chert interbeds occurence among pillow-lavas of Entactinininae gen. et sp. indet (fauna catalogue, site 3) radiolarians fossils and facial transitions to the Tashtambektor formation more reliably described by the Cambrian and Ordovician fauna. Inanigutta sp. indet (Mitrafanova, Vasilyev, 1986) sponge spicules have been actually found in cherts among the Tashtambektor formation tuffs (Chernyshuk et al., 1989).

Compiler: M.D. Ghes

Tashtambektor Formation (Є$_3$–O$_1$tš). The formation stratotype section is described along the Tashtambektor River, found 4 km in from the west of the studied territory (Krivolutskaja, Korolev, 1960), where it stratigraphically overlies the Turgenaksu effusives. Everywhere the Tashtambektor formation consists of andesite and rarer basalt tuffs which facially are replaced by grey - green, green, lilac or vinous volcano-terigenic rocks (tuff siltstones, tuff sandstones, and tuff gritstones), interbedded by sericite, and chlorite shales, siliceous shales and jaspers. The layers thickness usually does not exceed 20-40 cm. On the Turuk River it is possible to see how the described deposits facially replace Turgenaksu formation basalts. The formation minimum thickness within the studied territory does not exceed 490-525 m, whereas in the stratotype area of pyroclastic and volcano-terrigenic deposits the formation is to 1100 1300 m thick (Krivolutskaja, Korolev, 1960). The mentioned authors described at the Tashtambektor formation an upper parts horizon of polymict inequipebbled conglomerates from 60 to 400 m thick. Zaharov I.L. (1988) suggested that based on the formation structure, this horizon was an independent stratigraphic unit of the Early Ordovician age, an interpretation which we completely agree with. Similar correlations are observed to the west from the investigated territory (Karajorgo Range). Kichidolon conglomerates overlies the Cambrian – early Ordovician iseland-arc complex and forms the bottom of an Ordovician flysch section (Mikolaichuk et al., 1997). Around the Chakyrkorum Pass, Chernyshuk V.P. (1989) collected conodonts which have been used to infer the Late Cambrian and Early Ordovician age of the described sediments (fauna catalogue, site 4,5).

Compilers M.D. Ghes, A.V. Mikolaichuk

Ashutor Formation (O$_{1-2}$aš). The section mentioned above on the Tashtambektor River is stratigraphically replaced by the Ashutor formation (Krivolutsky, Korolev, 1960). The formation named after the Ashutor Pass between the Tyup and Chon Janalach rivers where described sediments are widely spread. Within the studied territory the section on the left bank of the Kokkiyanynsu River (Zubtsov, 1972; Chernyshuk et al., 1989, section 232) is best, due to its availability and stratigraphical completeness. The basal horizon consists of inequipebbled conglomerates 200-250 m thick. There are basalts, cherts and jaspers of Turgenaksu Formation, biotite - muscovite schists, green shales, granodiorites, and quartzite pebbles. The layer of dark grey, green-grey fine-grained polymict sandstones and siltstones of massive structure or with hardly shown bedding lies conformably on the conglomerates. They are composed of 20-70 m thick layers, with alternate parts in the section (10-20 m) consisting of limestones and siliceous siltstones. Thickness of layers in the upper parts is equal to 2 -5 cm, and on the weathering surfaces the rocks get a ribbed shape which is a typical feature of this formation. The carbonate-terrigenic deposits on the Kokkiyanynsu River are 950 1000 m thick.

To the east, along the Chon Janalach River there is no basal horizon of conglomerates and the 750m thick carbonate-terrigenic "ribbed" layer conformably lies on tuff gritstones of the Tashtambektor formation. Described sediments are in overturned bedding. Polimict conglomerates known by the region researchers as the Chon Janalach's lies above stratigraphically. V.G. Korolev (1954), the first to describe that stratigraphic unit, defined them as the Late Ordovician ones. In the course of survey works (Severinov, 1990) it is established that there is a normal stratigraphic relation among the sandstones and conglomerates. This fact is confirmed by our observation. Transition to conglomerates occurs gradually, through «pudding» gritstones. Hence, we consider Chon Janalach conglomerates as the upper element of Ashutor formation. These are dark green well sorted and rounded conglomerates, from fine-pebbled to coarse-grained, with rare lenses, and gritstone/sandstone interbeds (to 0.5 m). Pebbles consist of basalts, andesites, tuffs, cherts, jaspers and limestones. Occasionally there are gabbro-diorites, rhyolites, granites and gneisses. The conglomerates are 500-600 m thick. Total Ashutor Formation thickness varies between 1000 and 1350 m. In the formation, brachiopods and conodonts have been collected and shown the sediments to be of an Early Ordovician age (fauna catalogue, site 1, 7, 69).

Compiler: A.V. Mikolaichuk

Jergalan section type

These stratigraphic unit sediments are spread to the north from the Turgenaksu section. Initially they were described as a part of the Jergalan zone (Zubtsov, 1972), characterised by absence of volcanogenic sediments. Though the section formations were defined and described in the seventies (Zubtsov, 1972; Gutermakher, 1978; Esmintsev, 1999), however their stratigraphic order within one section is established here for the first time.

Koichi Formation / (Ɛ2 kč) is found in a north-east part within the studied area with the stratotype on the Koychi stream, a right tributary to the Ulkenkokpak River (Gutermakher, 1978). The formation consists of thin-bedded light grey arkosic and quartz-rich sandstones with the limited interbeds of siltstones and single layers of marmorized limestones of 5-7 m thick. Formation on the Koychi Stream is 980 m thick. Carbonaceous limestones of Bayankol formation overlay conformably above. The section is difficult of access. Koychi formation outcrops in the another area have undergone intensive hornfelsing and the initial rock structure is hardly identifiable. Therefore we offer the Bayankol River left bank outcropped section 600 m to the north from border of studied territory as **neostratotype**. In this section bottom grey-green thin-bedded siltstones prevail, upper parts consists of light-grey quartz-rich and arkosic sandstones with the some interbeds and gritstone lenses. The formation is not less than 1000 m thick. Cambrian radiolarian have previously been found (Gutermakher, 1978) among the formation sandstones (fauna catalogue, site 100), however there are no siliceous types among formation sediments and gathering was impossible to repeat. The Middle Cambrian is more likely accepted on the basis of lithologic similarities with Ovva formation of the Kyrgyz Range (Apayarov, 2007).

Compiler: A.V. Mikolaichuk

Bayankol Formation (Ɛ3 bn) was described for the first time by Rakhman B.I. (1964), although the stratotype site is not specified. As the **hypostratotype** for future research, we suggest the section of the Bayankol Formation on the Bayankol River's left bank, to the north of the border of the studied territory. Marmorized thick-stratified limestones of Bayankol formation lie conformably on Koichi quartz-rich sandstones, dipping in southern under a angle of 20-40°. The Bayankol formation's apparent thickness in this section is 800-900 m.

The section of the Bayankol Formation on the Baimensai river was described in detail by A.N.Esmintsev (1999). At the apparent bottom there are graphitic shales, siltstones which alternate with thinly-bedded marmorized limestones to 3 m (105 m) thick. They are overlain by a horizon of light grey dolomite limestones of massive structure but with thin-bedded and breccia structures in the outcrop (310 m). Then siltstones, graphitic shales and limestones (35 m) are found, which in turn overlain by dolomite limestones with siltstone and arkosic sandstones interlayers (25 m). The measured thickness along this section is 475 m. The formation's upper part (>250 m thickness) outcrops along the Kokchukur-west stream, which is located in the Tuyukkokpak River headwaters (Gutermakher, 1978; section 30). The formation consists there of thin-bedded limestones, clayey limestones, marls with the minor interbeds and lenses of arkosic sandstone and siltstone (3-20 cm), which is then replaced conformably by motley Kokchukur formation sediments.

According to A.N.Esmintsev's data (1999) microfossils and acritarches are found (fauna catalogue, site 82,83, 84) with a wide Vendian-Cambrian age range. As the Early and Middle Ordovician sediments lie stratigraphically above we have limited the Bayankol formation age as the Late Cambrian. According to the section structure and microorganic complex the sediments described above are very similar to Toraygyr formation of the Kungei Range (Mikolaichuk, 1998).

Compiler: A.V. Mikolaichuk

Kokchukur Formation (O_1kk) first described in the Kokchukur-west Stream (Gutermakher, 1978; section 30) where it conformably overlay the Bayankol formation. The formation outcrops are traced from the right bank of the Turuk River in the west to the Tuyukasha River mouth in the east. The formation section available for observation is outcropped in Ulkenkokpak towards the Kokpak Pass. Kokchukur formation is enough uniform and can be easily recognized in the field. It is represented by lilac, brown or green-grey shales and siltstones interbedded in the section (0,4-2м) with light - green or white quartz-rich and arkosic fine-grained sandstones. In sandstones and siltstones crossbedding can be often observed, and there total thickness is 350 - 600 m. There are no organic fossils among the motley sediments. We assume the Early Ordovician age by location in the section below the Sulusai Formation described by a rich complex of the Early-Middle Ordovician.

Compiler: A.V. Mikolaichuk

Sulusai Formation ($O_{1-2}sl$) is described for the first time by B.I. Rakhman (1964), the stratotype site is not specified. Gutermakher M.M. (1978) accepted as the stratotype area the Sulysai – Ulkenkokpak interfluve, and thus the formation bottom is not defined. The described formation field coincides with the Kokchukur formation extention. In the Karakol River headwaters multicoloured sediments of the Kokchukur formation are conformably overlaped by grey-green fine-grained sandstones and siltstones which we accept for the Sulusai formation bottom. They are about 150 m thick and up-section are overlain by syngenetic breccias consisting of angular fragments of lilac and green coloured thin-bedded siltstones. In the top part of the breccia horizon there are some granitoid pebbles, although angular siltstone fragments account for 80 % of clasts. This horizon is 450 m thick. Conformably overlying this there is a 50 m layer of white or cream-yellow fine-medium-grained arkosic sandstones which can be traced to the Kokchukur – Ulkenkokpak interfluve (Gutermakher, 1978).

The formation's medium part consists of graded-layered polymict sandstones and sometimes there are grindstones in the rhythm bottom. Rhythm-layers reach 60 – 90 cm. They are interbedded with black limy siltstones, siliceous shales and cherts which usually do not exceed 10-20 cm, but there are also meters interbeds. This section part is 750 m thick (Gutermakher, 1978; section 19). Further up-section this is overlain by 635 m thick sequence of carbonate deposits (Gutermakher, 1978; section 31). That reef body consisting of light grey, usually marmorized limestones interbedded by graphitic shales and siltstones or by black carbonaceous limestones of 10-40 m thickness. The top part of the Sulusai formation consists of graded polymict sandstones and is not less than 365 m thick. Total formation is 2400 m thickness.

The numerous algae, bryozoans and radiolarians describe the host rocks as the Ordovician. The Early and Middle Ordovician formation age is based on gathering of Arenigian conodonts and graptolites of the Early Ordovician (fauna catalogue, site 2, 85 89, 242, 249).

Compiler: A.V. Mikolaichuk

2.2.2. Intrusive formations

Central Turuk Formation (qδƐ₁ct). We defined it in the framework of Mintor formation (Osmonbetov, Knauf, 1982). The formation spreads in the Turuk River and in the watershed area of the Terskei Range and it is represented by three massifs. The Central Turuk massif (1.5 km^2) is located in the Turuk River. All the formation massifs are composed of greenish-grey medium-grained amphibolic quartz diorites. Rocks consist of andesine (60-70%), hornblende (10-25%) and quartz (7-15%). Potassium feldspar and chloritized biotite occur rarely (to 5%). The rock composition can change to melanocratic tonalities and granodiorites.

Petrochemistry. Quartz diorites chemical composition is defined by 5 samples (see geochemistry catalogue). SiO_2 content is within 61.0 – 62.5%; Na_2O+K_2O content varies within 5.54 – 6.96%. According to the petrochemical diagrams the quartz diorites are the medium-K (K_2O = 1.14-2.42 %) rocks and belong to the calcareous-alkaline group with potassic – sodium alkalinity type (K_2O/Na_2O = 0.26-0.63).

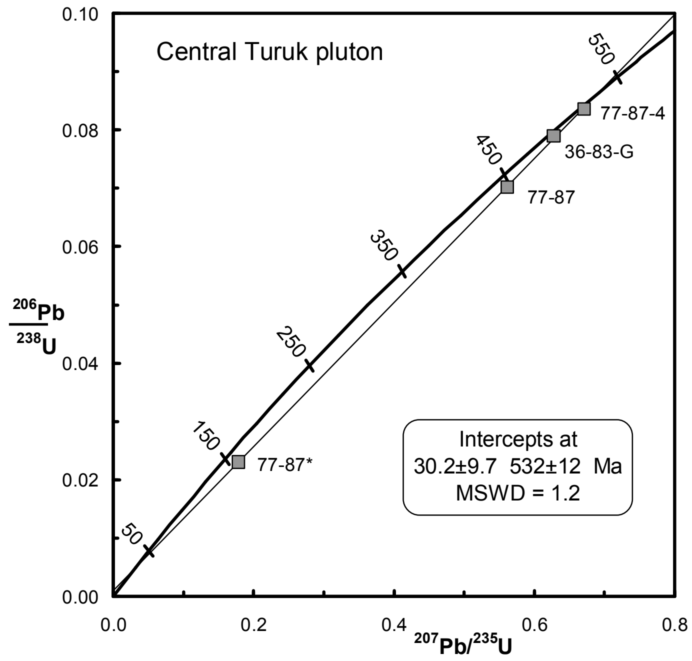

Fig. 2.2.2.1 Diagram with concordia for zircons from quartz diorites of the Central Turuk massif

Age. Central Turuk massif quartz diorites intruded rocks of Vendian (?) – Early Cambrian Accretionary formation. Isochron plotted according to four zircon samples of quartz diorites (isotope age catalogue) defined their Early Cambrian age of 532±12 Ma (Fig. 2.2.2.1).

Compiler : F.Kh. Apayarov

Almalysai Formation (O_2a). The formation typical Almalysai massif is located at the western end of the Kyrgyz Range where it had been first defined under the name of "Almaly" and was briefly described by T.A. Dodonova (Dodonova, Goretskaya, 1972). The formation rocks within the researched area are spread in the Jergalan and Tyup Rivers valleys. They take about 64 km^2 and form Sharkratma and Jergalan massifs. The formation consists of two phases. The first phase **($q\delta_1O_2a$)** is represented by greenish-grey, dark grey medium-grained biotite-amphibolic diorites and quartz diorites. Gabbrodiorites occur quite rarely. Dark-colored minerals' content can amount to 35%. Potassium feldspar often occurs in endocontacts of intrusives. The second phase **($\delta\gamma_2O_2a$)** consists of grey medium-grained amphibole-biotite granodiorites which are alternated by granites and rarely by quartz monzonites. Dark-colored minerals content in rocks is less than 15%.

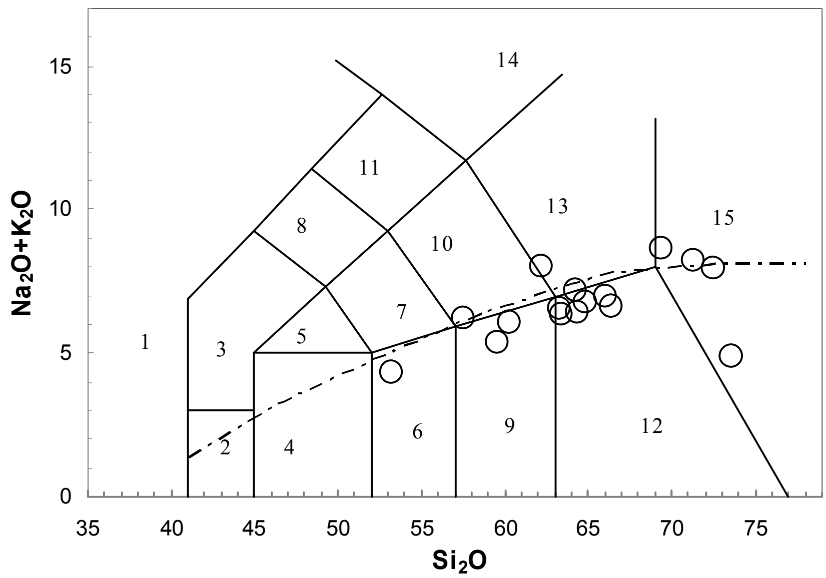

Fig. 2.2.2.2. The Almalysai formation rocks location on the TAS diagram.
Fields according to (Middlemost, 1994): 1 - 1- foidolites; 2- peridotite gabbros; 3- felspathoid gabbros; 4 – gabbros; 5 – monzogabbros; 6 – gabbroic diorites; 7 – monzodiorites; 8 – feldspathoid monzodiorites; 9 – diorites; 10 – monzonites; 11 – feldspathoid monzosyenites; 12 – granodiorites; 13 – syenites, quartz monzonites; 14 – feldspahoid syenites; 15 – granites. Dotted line – the lower border of sub-alkaline rocks spreading after (Bogatikov et al., 1981).

Petrochemistry. The rock formation's chemical composition is defined by 16 samples (geochemistry catalogue). Rocks mainly belong to the calcareous-alkaline group (Fig. 2.2.2.2) with potassic-sodium alkalinity type (K_2O/Na_2O = 0.75-2.07). The rocks have high-K values (on the SiO_2 - K_2O diagram (Le Maitre et al., 1989)), with points located above the line dividing medium-K and high-K rocks.

Age. Rocks of the Almalysai formation intrude the Early-Middle Ordovician sediments of the Ashutor formation, and are themselves subsequently intruded by Susamyr formation granites of the Late Ordovician – Early Silurian. The rocks from the formation have been dated by 4 K/Ar и 5 U/Pb (isotope age catalogue). Only one U/Pb dating on zircons (451 Ma) from 9 others meet the age determined according to the geological data, indicating significant disturbances of minerals isotope systems in the formation by younger thermal process. U/Pb dating on zircons of 459±2 Ma is assumed to be the age of the Almalysai typical massif granodiorites (Apayarov et al., 2008).

Compiler : F.Kh. Apayarov

2.3. Late Ordovician – Silurian structural complex

2.3.1. Intrusive formations

Suusamyr Formation (O_3-S_1s). The formation is composed of large batholiths stretched latitudinal in the North Tien-Shan on 600 km distance (Osmonbetov, Knauf, 1982). Within the research area, the formation granitoids are spread across the Jergalan, Tyup, Chon Janalach and Karkara Rivers' valleys. They have an area of nearly 100 km^2 and form several large massifs and bodies (West Jergalan, Kichine Janalach and Karkara) as well as numerous minor ones. There are two phases in the formation content. The first phase (**$\delta\gamma_1O_3$-S_1s**) is the main one and represented by medium- macrocrystalline porphyry-like biotite and amphibole-biotite granodiorites, granites and macrocrystalline inequigranular biotite granites. The second phase (**γ_2O_3-S_1s**) is much more limited and formed small stocks, dyke-like bodies and veins of fine-medium-grained granites of leucocratic appearance.

***Petrochemistry*. The** granitoid's chemical composition is defined by 23 samples (geochemistry catalogue). Rocks mainly belong to the calcareous-alkaline group (Fig. 2.3.2.1) with potassic-sodium alkalinity type (K_2O/Na_2O = 0.83-2.35) and high-K (K_2O=3.60-5.30). Granitoids are mainly perlitic-alumina ones, with points lying within the typical *I*-type and *S*-type granite ranges although they can be described as having a higher alkaline content compared with them (Fig. 2.3.2.2)

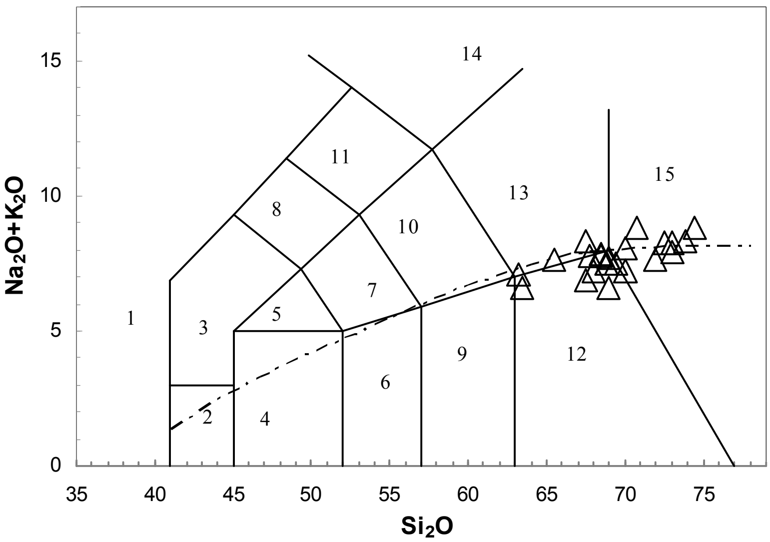

Fig.2.3.2.1. Position of Suusamyr formation rocks on the TAS diagram

Name of fields see at the Fig. 2.2.2.2

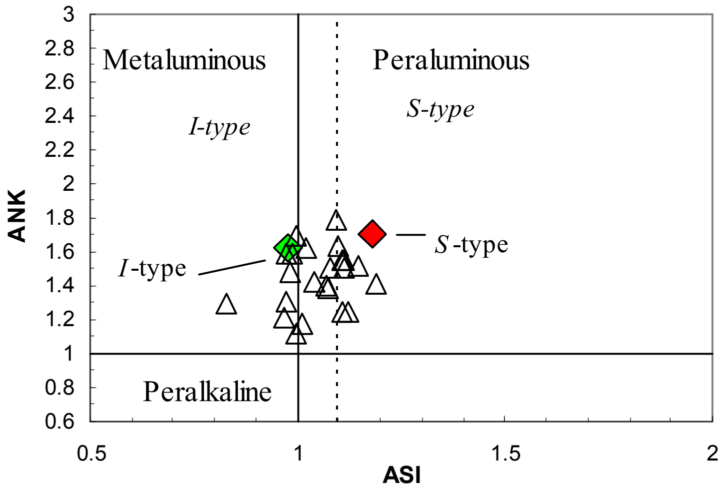

Fig.2.3.2.2. Granitoids of Suusamyr formation on the ASI-ANK diagram with *I*-type and *S*-type granitoid fields

ASI = $Al_2O_3/(CaO+Na_2O+K_2O)$ mol.; ANK = $Al_2O_3/(Na_2O+K_2O)$ mol. Rhombuses indicate medium *I*-type and *S*-type granite contents (Whalen et al., 1987).

Age. Granitoids of Suusamyr formation intrude the Early-Middle Ordovician Ashutor formation sediments and Middle Ordovician granitoids of Almalysai formation. They themselves were latter intruded by Early-Middle Devonian leucogranites of Almaly formation. There are six isotope granitoids datings within the research area (isotope age catalogue). Five K/Ar datings defined the age within 247 – 431 Ma. Only one of them on amphibole (432 Ma) corresponds the geological inferred granite age. Younger biotite datings indicate argon loss from the system within secondary processes. U/Pb dating on zircons from granite sample (isotope age catalogue) gave sharply discordant values for various isotope correlations and have not revealed its age. The Late Ordovician – Early Silurian of Suusamyr formation granites is defined by U/Pb dating on zircons to the west from the research area in the Jumgal, Karajorgo and its other typical massifs (Mikolaichuk et al., 1997; Kiselev, 1999; Apayarov et al., 2003).

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Aktash Formation (O_3-S_1a). The Late Ordovician – Early Silurian intrusive rocks within Kazakhstan are traditionally unified into the Aktash formation (Gutermakher, 1978; Esmntsev, 1989). Aktash formation rocks are spread in the north-east part of investigated area. The outcrop area comes to more than 200^2 km there. Three phases are defined within the formation. The first phase (**$\mu\delta_1O_3$-S_1a**) provides the least volume to the formation, and consists of dark-grey, grey medium- macrocrystalline, as well as rarer porphyry-like melanocratic monzodiorites and monzonites. Monzodiorites contain small (< 1 m) gabbroid xenoliths

(Gutermakher, 1978). Rocks of this first phase form the south and north-west parts of the Igliksai massif, which stretches eastward from the Iglik headwater to the Izbushka headwater (15 km). We have also related to the first phase, the sub-alkaline gabbroids within the large (< 1.5 km) xenolith found among the granitoids of the third phase at the Keksentas River right bank, north of the Alaaigyr River mouth. Rocks of the second phase (**$\gamma\delta_2O_3$-S_1a**) consist of grey, light-grey medium- macrocrystalline biotite-hornblende quartz diorites, quartz monzonites, granodiortes with large (to 5-7 mm) grains of hornblende and biotite. They form massifs, mainly at the western parts of the formation development, in the Tekes, Ortokokpak and Ulkenkokpak Rivers' valleys. The third phase (**γ_3O_3-S_1a**) is the main one within the formation. Medium- macrocrystalline porphyry-like biotite granites prevail, while granodiorites are limited in their extent. These Granitoids form the large (more than 120 km^2) Baimensai massif, which is divided into two parts by a massif of the Early Devonian quartz monzonites and granosyenites, and the Igliksai massif located in the Bayankol River valley.

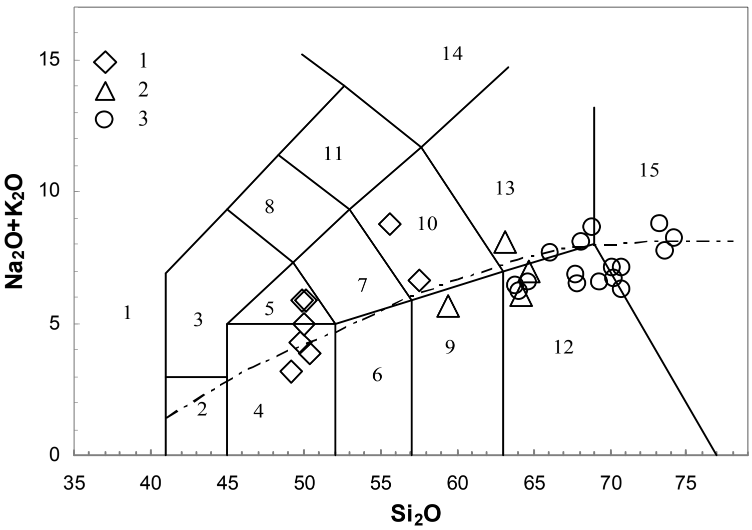


Fig. 2.3.2.3. Position of the Aktash formation rocks at the TAS diagram

Figurative points of the first (1), second (2) and third (3) phases Aktash Formation. Fields' names see at the Fig. 2.2.2.2

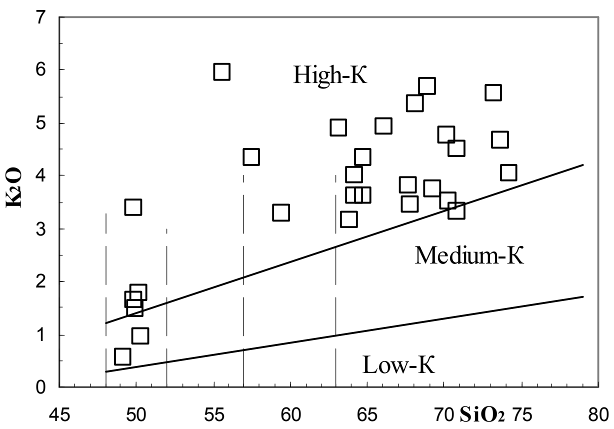


Fig.2.3.2.4. Correlation of SiO_2 and K_2O in the Aktash formation rocks

Separating lines according (Le Maitre et al., 1989). Granitoids are mainly perlitic-alumina ones and correspond to the S-type granites according to their content (Fig. 2.3.2.5).

Petrochemistry. The formation's chemical composition is defined by 28 samples (geochemistry catalogue). Rocks mainly belong to the sub-alkaline and calcareous-alkaline groups (Fig. 2.3.2.3) with potassic-sodium alkalinity type (K_2O/Na_2O = 0.23-2.35). The rocks have a high-K content (Fig. 2.3.2.4). Sub-alkaline gabbroids form a separate group on the diagram plots ((Fig. 2.3.2.3 and Fig. 2.3.2.4) and are described by high MgO (2.33-8.95 %), CaO (5.98-9.12 %) and P_2O_5 (0.05-0.61 %, at the average content of 0.31 %). Petrochemically they obviously differ from the Accretionary Complex gabbroids.

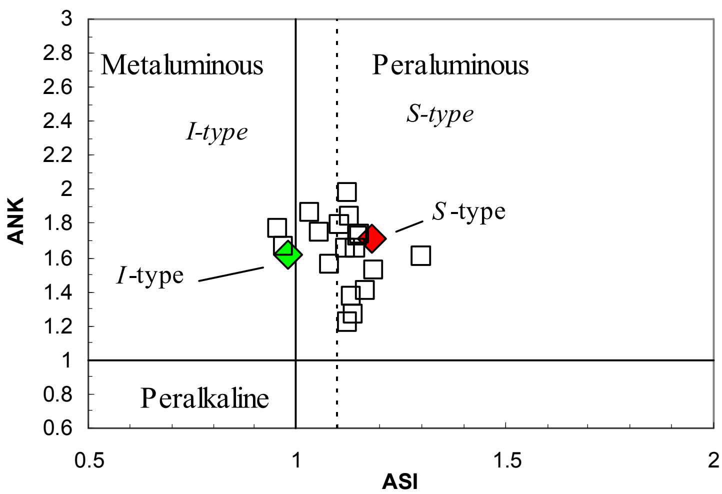


Fig.2.3.2.5. Aktash formation granitoids at the ASI – ANK diagram with *I*-type and *S*-type granitoids' fields.

ASI = $Al_2O_3/(CaO+Na_2O+K_2O)$ mole.; ANK = $Al_2O_3/(Na_2O+K_2O)$ mole. Rhombuses indicate medium contents of *I*-type and *S*-type granites (Whalen et al., 1987).

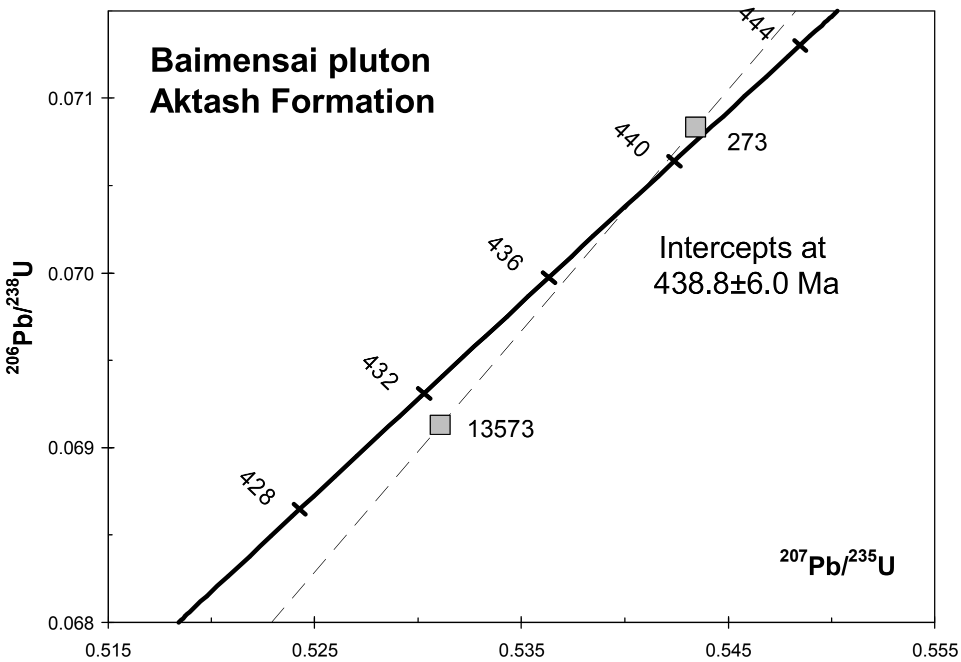


Fig. 2.3.2.6. Diagram with concordia for zircons from the Aktash formation granites

Age. Monzodiorites and granitoids of the Aktash formation are in intrusive contacts with the Early – Middle Ordovician sediments of the Sulusu formation, and have in turn been intruded themselves by the Early Devonian intrusions of the Saurusai formation. The granites age within the research area had been defined in 6 samples (isotope age catalogue). Three K/Ar biotite and amphibole datings of 285-400 Ma obviously represent an alteration effect. U/Pb dating on zircons of two granite samples (isotope age catalogue) gave similar values on different isotope correlations (438, 441, 441 and 441, 433, 431 Ma) and approved the defined Late Ordovician- Early Silurian formation age (Fig. 2.3.2.6).

Compiler : F.Kh. Apayarov

3. Middle Tien-Shan Geological Province

3.1. Pre-Sinian structural complex

3.1.1. Stratified formations

Kuilyu Formation (aAR-PR₁kl). Metamorphic rocks at the structural base of the Middle Tien-Shan sections were grouped under the name of Kuilyu Formation (P.A.Gryushe, 1940, cited in Korolyev, 1972). Typical sections are located in the Saryjaz River valley and the Kuilyu River mouth. These rocks also occur in the eastern part of the Saryjaz headwaters, in the source areas of its left tributaries, and in headwaters of the Keksentas and Ashutor Rivers. The unit comprises voluminous metabasites, metapelites, and migmatites, whereas carbonates and quartzites occur in subordinate quantities. The original rocks were metamorphosed to the amphibolite-facies and then became partly diaphtorized (Bakirov, 1984). The following sequence (from structural bottom to top) has been defined in typical sections on the right bank along the Kuilyu River (Grishenko, 1985):

1. Biotite and amphibole-biotite gneiss with amphibolite and schists interbeds – 700 m.
2. Amphibole-biotite and biotite-amphibole, quartz-biotite schist, amphibolite, gneisses and migmatites – 900 m.
3. Micaceous marble, quartzite, schist and amphibolite interbeds – 500 m.
4. Marble, schist and amphibolite interbeds – 350 m.
   The formation is at least 2500 m thick

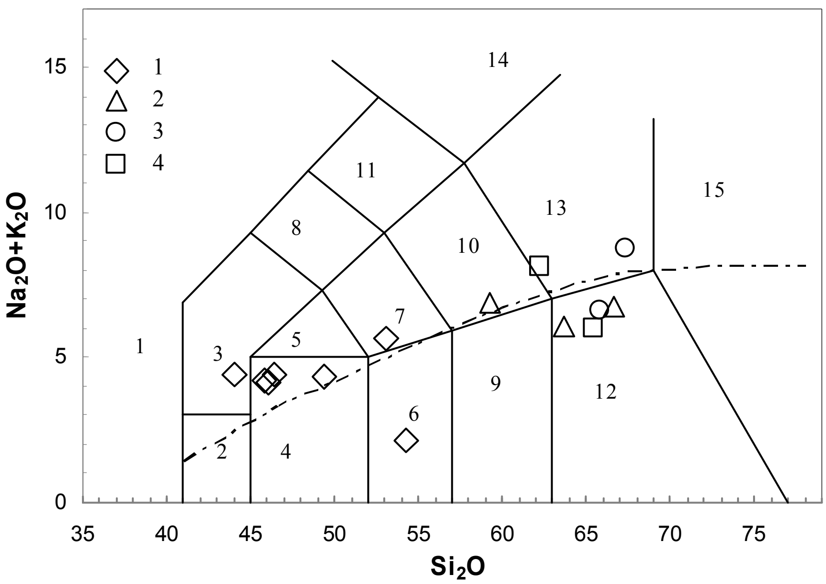


Fig. 3.1.1.1. Location of samples of the Kuilyu Formation in the TAS diagram.

1 – amphibolite; 2 – gneiss; 3 – migmatite; 4 – biotite-amphibole schist.

Petrochemistry. The chemical composition is characterized by 14 samples (geochemistry catalogue).

Analytical points for amphibolites in the TAS diagram (Fig. 3.1.1.1) are located in the gabbro (basalt) and gabbro-diorite (basaltic andesite) fields, and migmatite analyses are in the fields of granodiorite and quartz monzonite. The chemical compositions of gneisses, migmatites and biotite-amphibole schists are generally similar. A slight spread in values of K_2O/Na_2O (0.42-0.65) is typical for the amphibolites.

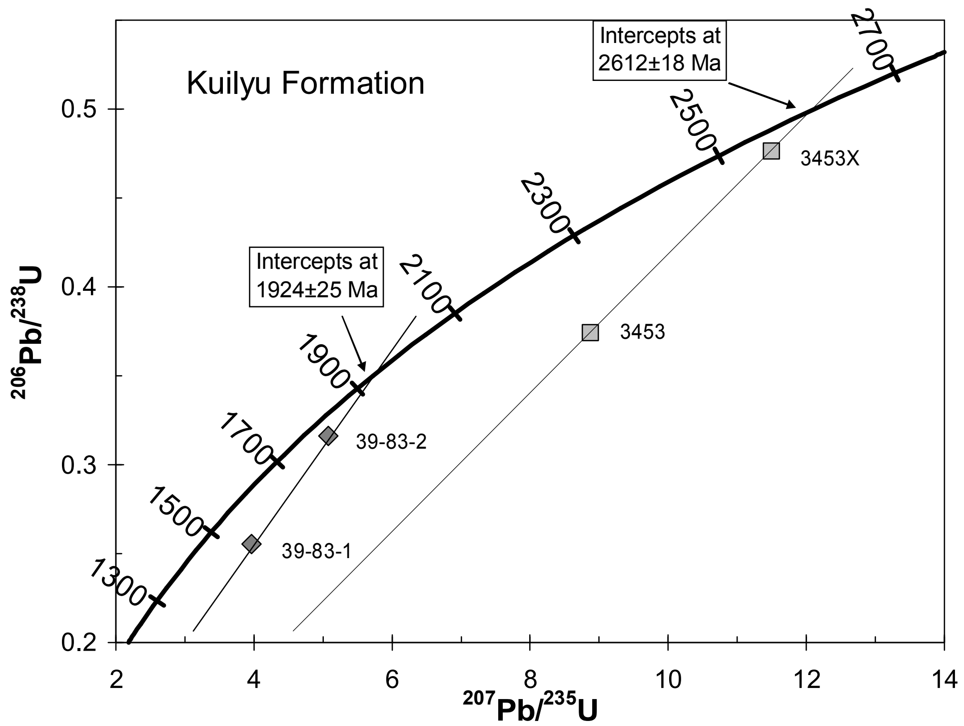


Fig. 3.1.1.2. Concordia diagram for multigrain zircon analyses of Kuilyu Formation metamorphic rocks.

Age. The age of the formation is defined by 6 samples of different composition (isotopic age catalogue). The oldest age was obtained for biotite-amphibole schists and amphibolites in the lower part of the formation. Multigrain zircon dating of 2 samples of biotite-amphibole schist (plagioclase – 74.0 %, amphibole – 7.3 %, biotite – 5.7 %, epidote – 3.4 % and accessory minerals – 1.4 %) carried out in two separate laboratories, yielded variably discordant results, and a discordia line defined by these analyses yields a Neoarchaean Concordia intercept age of 2612±18 Ma (Fig. 3.1.1.2). The dated zircons are morphologically similar to zircons of ampibolite- to granulite-facies metamorphic rocks (Kiselev et al., 1993). A hornblende K/Ar age of 2431±200 Ma was obtained for an amphibolite (amphibole – 66.5 %, plagioclase – 27.2 %, quartz – 1.8 %, ore minerals – 2.7 % and accessory minerals – 1.8 %).

Zircons from migmatized gneisses were dated as Palaeoproterozoic. Two discordant multigrain analyses define a discordia line with an upper Concordia intercept age of 1924±25 Ma (Fig. 3.1.1.2). Late Riphean biotite and hornblende K/Ar ages for gneisses and amphibolites reflect the emplacement age of granitoids of the Saryjaz Pluton (see 3.1.2).

The oldest amphiboles and zircons within Kyrgyzstan are found in the Kuilyu Formation metamorphic rocks. They register an early stage of metamorphism in the Neoarchaean. Migmatization occurred at ca. 1900-1950 Ma. The younger age limit for the Kuilyu formation is defined by intrusive late Riphean granites of the Saryjaz Pluton (Kiselev et al., 1993). On the basis of all these data we define the Kuilyu formation as Neoarchean to Palaeoproterozoic in age.

Compiler: F.Kh. Apayarov

3.1.2. Intrusive formations

Saryjaz Formation (R_3s). Defined by T.A. Dodonova in 1967 (Dodonova, 1974), this granitoid pluton occurs in the western part of the area in the Saryjaz River valley. It forms two large massifs, Saryjaz and Ottuk, and several small bodies with a total area of about 200 km^2. The main pluton is overlain by Quaternary sediments. We define two granitoid phases within the pluton. The first phase ($\gamma\delta_1R_3s$) is represented by medium- to coarse-grained, and more rarely porphyry-like, hornblende-biotite granodiorites, biotite granodiorites and granites. Gneissic textures are shown in several locations. Saryjaz Massif intrusive contacts and small bodies within the Kuilyu formation metamorphic assemblage contain hornblende-biotite quartz monzodiorites, and some granites contain gabbroic xenoliths (Grishenko, 1985). The second phase (γ_2R_3s) is volumetrically smaller (no more than 10% of the entire pluton) and is composed of fine-grained, aplite-like granites and leucogranites. They form bodies up to 7 km^2 in size and numerous veins and dykes in granitoids of the first phase.

Petrochemistry. The chemical composition is defined by 25 samples (geochemistry catalogue). Granitoids of the Saryjaz and Ottuk massifs are petrochemically diverse (Fig. 3.1.2.1, 3.1.2.2, 3.1.2.3). The Saryjaz massif rocks belong to the sub-alkaline group, whereas the Ottuk massif granitoids belong to calc-alkaline group. Na_2O usually exceeds K_2O ($K_2O/Na_2O \leq 1.13$) in the Saryjaz massif, whereas in the Ottuk massif K_2O contents are higher than Na_2O (K_2O/Na_2O nearly always higher than 1.1).

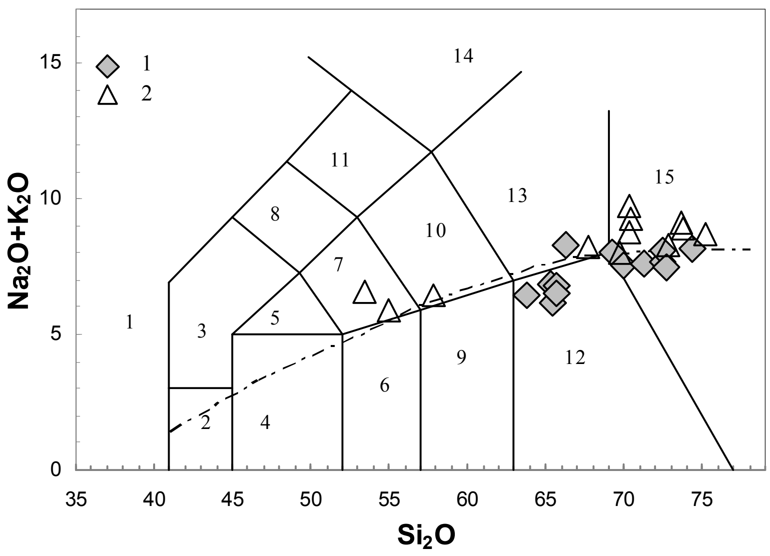


Fig. 3.1.2.1. Location of Saryjaz Pluton rocks in the TAS diagram. Name of fields see Fig. 2.2.2.2.

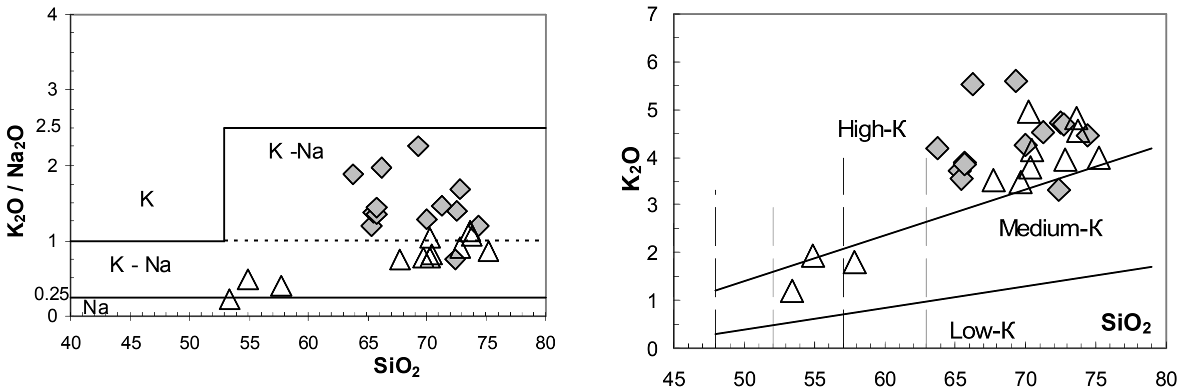


Fig.3.1.2.2. Alkalinity type (K_2O/Na_2O) and K_2O-content in Saryjaz Pluton rocks
For symbols see legend in Fig. 3.1.2.1

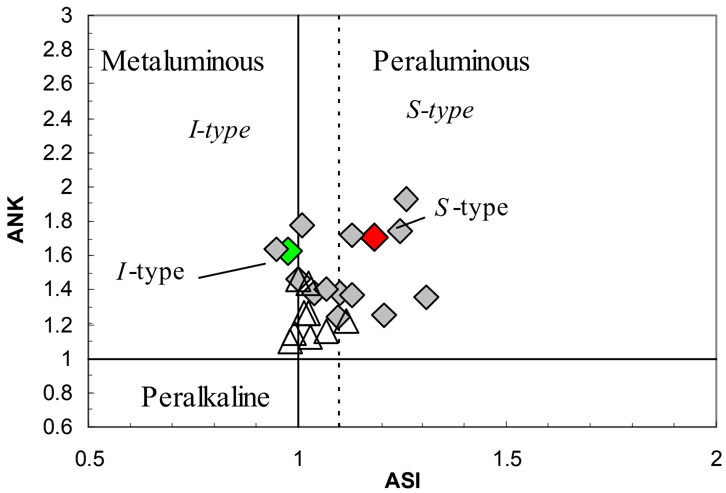


Fig. 3.1.2.3. Saryjaz granitoids in the ASI/ANK diagram with *I*-type and *S*-type granitoid fields. ASI = $Al_2O_3/(CaO+Na_2O+K_2O)$ mole; ANK = $Al_2O_3/(Na_2O+K_2O)$ mole.
Green and red rhombs indicate medium contents of *I*-type and *S*-type granites (Whalen et al., 1987). See the legend in Fig. 3.1.2.1

Age. Saryjaz Pluton granitoids intrude the Archaean to Palaeoproterozoic Kuilyu formation, whereas late Riphean toVendian arkoses of the Kichi Taldysu formation and conglomerates of the late Ordovician Tez formation rest on the pluton. The pluton age is defined by 8 samples of different composition (K/Ar and U/Pb methods, see isotopic age catalogue) and two granite samples from the Ottuk massif (Sm/Nd method). Sm/Nd dating defined an age of 420 Ma (Konopelko et al., 2007). Six K/Ar ages for hornblende and chloritized biotite (646-950 Ma) and four multigrain U-Pb zircon ages (827-1390 Ma) define a Precambrian age for the Saryjaz granitoids. Zircons from Ottuk massif granite samples appear to be older than zircons of the Taldysu massif granites. This may probably be explained by the presence of xenocrystic cores in zircons of the Ottuk massif granites (Kiselev et al., 1993).

In the west of the research area the Saryjaz Pluton is overlain by felsic volcanic rocks of the Bolshoi Naryn formation (Osmonbetov, Knauf, 1982). Multigrain U-Pb zircon dating defined the age of these volcanics as 800-825 Ma, and the underlying granite zircons yielded an age of 830±25 Ma (Kiselev et al., 1993). Thus, relying on the geological and geochronological data, we assume a late Riphean age for the Saryjaz Pluton.

Compiler: F.Kh. Apayarov

3.2. Sinian - Middle Ordovician structural complex

3.2.1. Stratified formations

< (Double click to view the stratigraphical columns)

Ishym-Naryn Section type

This lithostratigraphic unit combines a variety of Vendian to early Palaeozoic rocks that can be traced for 2800 km from the Ulutau Mountains in the northwest to the Kuruktakh Range in the eastern (Chinese) Tien-Shan (Zubtsov, 1972a; Korolev, Maksumova et al. 1984) and is known from the literature as the Ishym-Naryn zone. According to modern geodynamic interpretations the Ishym-Naryn section comprises a rift complex consisting of Vendian diamictites and alkaline volcanic rocks and predominantly siliceous deposits of early Palaeozoic age (Degtyarev, Ryazantsev, 2007).

Kichitaldysu Formation (R_3-Vkt) was defined in the middle section of the Saryjaz River at the confluence of the Chon Taldysu and Kichi Taldysu Rivers (Zubtsov, 1972) where it rests on an erosional contact with the Saryjaz granites. The basal horizon of the formation is not thick and occurs at the bottom by unsorted arkoses, overlapped by light-grey, grey, and yellowish-grey thinly bedded arkosic sandstones (3-50 cm). Higher upsection, sandstones are interbedded with dark-grey siltstones and shales containing admixed carbonaceous material. The total thickness of the arkose is from 150 to 270 m (Zubtsov, 1972; Grishenko, 1985). Diamictites (up to 60 m thick) with a 2 metre thick dolomite layer at the bottom, rest on the arkoses. Angular and semi-rounded fragments of different sedimentary, igneous and metamorphic rocks are found in the diamictites (Zubtsov, 1972a). The upper part of the 620-700 m thick section is represented by trachybasalt, andesite, andesitic tuff and volcanoclastic rocks which contain sills of gabbro and gabbro-dolerite. Belonging to the subalkaline vulcanites group is confirmed by the 8 samples (geochemistry catalog). The section is varies along strike, lavas and sills on average comprise 30-45 % of its volume. Metamorphism and alteration in the volcanic rocks are insignificant within the greenstone-facies (Dodonova, 1974; Grishenko, 1985). The formation is 770-970 m thick.

The Saryjaz Pluton granites underlying the Kichitaldysu formation have a zircon age of 830±20 Ma (isotope age catalogue). E.I. Zubtsov (1966) reported Neoproterozoic blue-green algae from carbonaceous siltstones near the bottom of the Kichitaldysu formation (fauna catalogue, site 301). These data are probably not reliable since they are not mentioned in later publications. V.V. Kiselev (1991) includes the Kichitaldysu sediments into the Aktugai-Chychkan interregional horizon of quartz and arkosic sandstones (Chychkan formation) containing late Riphean microfossils and microphytolithes.

Compiler: A.V. Mikolaichuk

Jetymtau Formation (Vjt) was first described by Shultz in 1936 along the southern slope of the Jetymtau Rainge as the formation of "conglomerate- shales", the name was offered by Yu.V. Jukov (1960). A detailed formation description with the characteristic of its facial variability along strike had been done in the paper (Korolyev, Maksumova, 1984); however the location of stratotype section was not defined.

Jetymtau Formation rocks transgressively overlie different horizons of the Kichitaldysu Formation and locally more ancient sediments (Zubtsov, 1972a). The main occurrence is along the right bank of the Chon Taldysu River, where small outcrops are located in the headwaters of the Kichi Taldysu and Tez Rivers. The formation is divided into 3 parts in structure. Coarse diamictite beds (up to 60 m thick) and sand-siltstone sediments occur in the lower part. The middle part consists of greenish-grey and brownish-grey polymict, diversely grained, thinly bedded sandstones (15-20 cm) alternating with black and dark-grey siltstones (5-8 cm) and slates and shales. Diamictite prevails in the upper part. 70-80 % of the rocks are composed of matrix; with fragments of up to 0.5 cm in diameter are not rounded or sorted. Saryjaz granites prevail in the fragments, but limestone, sandstone, quartzite, basalt, vein quartz and shale and gneiss of the Kuilyu formation also occur. The apparent thickness of the formation varies between 780 and 1100 m (Zubtsov, 1969, 1972f; Grishenko, 1985).

A Vendian age for the Jetymtau sediments is based on micro-phytolites found in the western regions of the Tien-Shan. Dolomite fragments in the Airansu diamictites of the Jetymtau Ridge contain III and IV micro-phytolite complexes. The presence of *Asterosphaeroides radiosus* Z. Zhur., *Nubecularites uniformis* Z. Zhur.in the Uzunturuk River area is related to complex III, and *Volvatella zonalis Nar.*, *V.vadosa* Z. Zhur – belong to complex IV along the Airansu River, below the iron-ore horizons. IV complex micro-phytolites *Ambigolamellatus aff. Horridus* Z. Zhur., *Nubecularites abustus* Z. Zhur were found in Archaly diamictites of the Shortor-Egiztor watershed. Carbonate fragments in the Naryntau Ridge diamictite cotain *Ambigolamellatus horridus* Z. Zhur., *Volvatella* sp.» (Korolyev, Maksumova, 1984; p.112).

Compiler: A.V. Mikolaichuk

Jakbolot Formation (V jb) was defined by Yu.V. Jukov (1960) on the southern slope of the Jetymtau Ringe where it lies with a sharp but concordant contact with the rocks of the Jetymtau Formation. The sediment thickness is no more than 400 m. Its occurrence in the study area is limited to the Ottuk-Oljobai watershed. The formation is bounded by a fault in the north, and its basal layers are not exposed. Grey and green-grey sericite schist and well defined siltstone beds (30 m) are present at the bottom. Variegated (grey-green, cherry-red and brown) siltstones and shales contain 3-4 cm thick interbeds of clayey limestone (110 m) and alternate with them. There are green-grey calcareous shales and variegated (pink, white, yellow and green) marble in the upper part of the section. Synsedimentary landslide breccias named "bamboo leaf - like" limestones also occur in this horizon. Black, brown and lilac sericite shales and siltstones make up most of the upper section (90 m). The top of the formation consists of thinly laminated dolomite that contains limestone beds which are interbedded with calcareous siltstones and shales (up to 50 m). The occurrence of a carbonate member in the upper section is a typical feature of the Jakbolot Formation. Its observed thickness is 230-270 m (Adyshev et al., 1962; Zubtsov, 1969).

The upper part of the Jakbolot formation along the Kichi Oljobai River is represented by brown and lilac siltstones interbedded with grey leaf-like shales. These are followed by light-grey and cream-yellow calcareous siltstones with an eastward-decreasing thickness from 20 m to 3 m. Black cherts of the Shortor Group rest conformably on the siltstones. The Baikonur Formation diamictite (up to 30 m thick) occurs in the middle course of the Shylun River (a Saryjaz River tributary) (Adyshev et al., 1962; Korolyev and Maksumova, 1984). However, later mapping has not approved the previous observations (Grishenko, 1985).

Organic fossils are unknown from the Jakbolot formation sediments but have been found in the Baikonur diamictites which are a facies analog of the Jakbolot beds. Vendian micro-phytolites were only found in carbonate fragments along the Balasauskandyk River. According to a conclusion of B.Sh.Klinger they belong to the *Marcovella* (?) and *Vesicularites bothrydioformis (Krasnop.)* group (Korolyev and Maksumova, 1984; p.112).

Compiler: A.V. Mikolaichuk

Shortor Group (Ɛ-O1 šr) had been defined by V.G. Korolyev (1957) at the Jetym Range along the Shortor River valley. The stratigraphic sequence of the Group covers the entire Cambrian and Tremadocian, and has been defined by V.V. Shabalin (1964) who also described two type sections. The composition is homogenous at the Karator section and is represented by graphitic-siliceous and siliceous shales; the same rock types prevail in the Shortor section, but horizons of limestone and dolomitic limestone with interbeds and lenses of graphitic shales appear in the middle part of the section. Thus three formations can be defined in the group (Shabalin, 1964).

The Shortor group sediments were defined by A.D. Smirnov in 1949, in the valley of the Saryjaz River, but were re-defined as the Berkut Formation (Adyshev et al., 1962). The most complete and unaltered section is located along the Kichi Oljobai stream where the sediments rest conformably on variegated limy siltstones of the Jakbolot Formation.

Black and often iron-rich (haematitic) thin- to medium-bedded cherts alternate with black graphitic-siliceous and grey siliceous shales and lie in the lower part of the Shortor Group and define layers 8-30 m thick. The lower part is 500 m thick. The middle part is represented by grey, calcareous shales interbedded with thin- and medium-bedded black chert, black siliceous shales and horizons of dark-grey medium and thickly bedded pelitomorphic limestones and limestone breccias with brachiopods and trilobites (260 m). A horizon of debris sediments, up to 50 m thick, occurs in the upper part of carbonate deposits in the Adyrtor River headstream (at the watershed with the Achekta River). These are breccias and poorly rounded gritstones in which clastic material is represented by limestone, chert and arkosic beds, the latter of which occurs in small quantities. The upper section (390 m) is similar to the lower section and consists of black cherts and graphitic-siliceous shales. Dark grey, medium-bedded pelitomorphic limestones also occur, but rarely. The total Shortor Group thickness along the Kichi Oljobai stream reaches 1150 m but does not exceed 500 m in the southern sections on the Chon Taldysu River (Pomazkov, 1972; Chernushuk et al., 1989).

An early Cambrian age for the Group's lower part was substantiated by correlation with the Chatkal and Karatau Ranges where Cambrian sediments were documented palaeontologically. Numerous late Cambrian trilobites and early Ordovician brachiopods have been collected in the middle and upper parts of the section within the research area (fauna catalogue, site 184, 199-206).

Compilers: A.V. Mikolaichuk, Z.I. Chernjavskaja

Oljobai Formation (O_1ol) was defined by V.I. Knauf (1954) within the described area, and the name was proposed by V.G. Korolyev (quoted in Adyshev et al., 1962) on the Oljobai River, a left tributary of the Ottuk River. A stratotype section has not been defined. The above section is complicated by northeast striking faults along the Oljobai River valley; therefore we propose a different stratotype section in the Chon Oljobai headwaters. There we observed stratigraphic correlations with both the Shortor Group and the overlying Eastsaryjaz formation. The lower 150 metres of the Oljobai formation consist of grey chert and siliceous shale; the upper section (100 m) is represented by brown-red siliceous siltstone and shale with some interbeds of haematite-siliceous shale, jasper and bluish-green siliceous shale. Within the research area the thickness varies from 100 to 700 m (Chernyshuk et al., 1989). An Arenigian age is established by numerous conodonts (fauna catalogue, site 9, 12-13, 77-79).

Compiler: A.V. Mikolaichuk

Eastsaryjaz Formation (O_{1-2} es) was defined by V.G. Korolyev in 1956 (quoted in Adyshev et al., 1962) within the described area under the original name of Saryjaz formation. We changed the name as it has already been used for the late Riphean granitoids of this region. A stratotype section has not been defined by previous authors. We propose a stratotype section in the Saryjaz and Ottuk River junction where the sediments described below conformably overlie variegated siltstones and siliceous shales of the Oljobai formation. The main occurrence of the formation is to the east, in the Saryjaz River headstream area. The Eastsaryjaz section consists of graded arkosic sandstones with graded beds being 10-70 cm thick. Graded beds 10-30 cm thick comprise distal turbidites. Medium- to coarse-grained sandstones, more rarely gritstones, prevail in the thicker rhythmic layers. They alternate with chert, siliceous shale, argillite or clay-rich limestone which are 3-5 cm thick, although occasionally reach up to 30 cm. Northward material transport was determined along rare slump folding in argillites. Horizons of marbelized limestones, 10-20 m thick, occur among the turbidites at the Saryjaz River spring in the upper third part of the section. The formation is not less than 750 m thick. It is presumed to have an early to middle Ordovician age, based on the conformable position on Arenigian sediments of the Oljobai formation and Llanvirnian conodonts found along the Ottuk River basin (fauna catalogue, site 14).

Compiler : A.V. Mikolaichuk

3.3. Late Ordovician structural complex

3.3.1. Stratified formations

The Ichkebash section type

This stratigraphic unit is defined for the first time and groups together sediments which have previously been described as “Ichkebash and Kanachu formations” within the Naryn sector. It had been assumed that the middle and late Ordovician sediments of the Ichkebash formation conformably rest on early Ordovician layers of the Ishym-Naryn section (Zubtsov, 1972b). However, according to our research in the Saryjaz River basin, the folding occurred near the boundary of middle and late Ordovician, and the Tez formation unconformably covers Vendian-Cambrian sediments. The latest lithologic-stratigraphic research in more western areas of the Inner Tien-Shan (Jetym, Nura, Takhtalyk Ridges) has shown that the stratigraphic thickness of the Ichkebash formation must be redefined since reliable correlations amongst the middle and late Ordovician strata are not established (Neyevin, 2008).

Tez Formation (O_3tz). D.I. Yakovlev first defined this subdivision (1937), and a detailed study of the “sandstone formation of the Tez River” was carried out by V.I. Knauf (1954). The sediments of this formation are widespread in the valleys of the Saryjaz and Kuilyu Rivers. Well exposed sections along the Tez River basin with fossils occurrences mean that this would be a good stratotype section, however the area is difficult to access. A section along the

Kensu River (right tributary of the Saryjaz River) may serve as the neostratotype due to remoteness of the Tez River region, and it has the maximum stratigraphy as well.

The Tez Formation occurs mostly on the eroded surface of the late Riphean granitoids and over an angular unconformity with Vendian and Cambrian sediments in the watershed of the Chon Taldysu and Kichi Taldysu Rivers (Zubtsov, 1972, Grishenko, 1985). We have observed unconformable relationships of the Tez formation with the Shortor formation on the left bank of the Kuilyu River. The formation is divided into 3 parts in structure. Coarse clastic rocks prevail in the lower part, and the fragment content is variable. Granite pebbles usually prevail in conglomerates which lie directly on the late Riphean granites. However, more variable pebble compositions are found in other places (the rocks of Jakbolot and Shortor formation or limestones of Middle Ordovician) (Zubtsov, 1972; Grishenko, 1985). Variously grained micaceous sandstones with rare interbeds of black siltstone occur above the basal conglomerate. This part is 100-300 m thick. An intraformational unconformity has been observed in sandstones in the Kode River which probably testifies to strong subsidence in the sedimentary basin. The middle part of the formation is represented by limestone and calcareous sandstone members. Grey lumpy and detritic limestones with clastic admixtures contain a diverse range of fossils such as trilobites, brachiopods, corals, gastropods, nautiloidei, and algae. This carbonate part of the formation varies in thickness from a few metres to 25-40 m. Sediments of the upper part rest, with a gradual transition, on the limestones and represent a thick homogenous layer consisting of grey-green fine- and medium-grained sandstones alternating with black shales and grey-green thinly bedded siltstones. The layer thickness varies within 10 and 70 cm, and occasionally even up to 1.5-2 m. Graded beds were observed but are rare; polymict sandstones with typical mica detritus prevail, but arkosic variations occur as well. This upper part of the formation is 680-1000 m in thickness. The topmost 100 metres of the section along the Kensu River consist of brownish sandstone with interbeds of limestone. We cannot exclude the possibility that these rocks already belong to the Kanachu formation which is widespread in the Jetym Range and the more western areas of the Tien-Shan. Total formation thickness is 700 – 1300 m.

A late Ordovician (Caradocian – Middle Ashgillian) age of the Tez Formation is substantiated by numerous brachiopods, bryozoans, graptolites and algae (fauna catalogue, site 56, 72, 145-150, 207, 209-212, 297).

Compilers : A.V. Neyevin, A.V. Mikolaichuk

4. South Tien-Shan Geological Province

4.1. Pre-Sinian structural complex

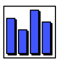
4.1.1. Stratified formations

Choloktor Formation (m,gPR_1čk) defined and mapped by E.V. Khristov in the axial part of the Kokshaal Range, near the Choloktor and Sauktor glaciers along the right bank of the Saryjaz River (Khristov, Shilov, 1990). Granitoids of the Akshiyrak Formation intrude metamorphites and the correlations with the Paleozoic sediments have not been observed. Metamorphic formations in the regions modern structure compose two thrust sheets with the northern vergence formed before the granite intrusion (Khristov, Shilov, 1990) the Choloktor Formation predominantly contains dark and thin-bedded biotite-quartz, two-mica, and rarely some mica-garnet granolepidoblastic shales. Biotite augen gneiss with quartz-potassium feldspar augens and single marble members of 30-120 m thickness occur there. The formation is 2500 m thick. U/Pb dating on zircons from the gneisses of the Jetyikat River source provides ages of 1 795 ±30 Ma (isotope age catalogue). The Choloktor Formation is compared with the Lower Proterozoic of Tarim as well as with the Sinditag group, the Kuruktag ridge (Biske, Shilov, 1998).

Compiler: A.V. Mikolaichuk

4.2. Sinian-Ordovician structural complex

4.2.1. Stratified formations

 **< (Double click to view the stratigraphical columns)**

Airansu section type

Airansu Group (R_3-Var) defined by E.V. Khristov (1992) in the Airansu River valley (Maibash Range) where it outcrops in the tectonic slices. Lavas, clastic lavas and basalt tuffs which contain layers of vinous jaspers and limestones with the clastic texture occur in the observed section's bottom. The amount of basalt reduces in the section's middle part and is replaced by black and red silicites, and limestones. Green and red tuffstones, breccias with silica rock packs and flows of spilites and hyalobasalts prevail in the upper part. Petrochemical data on the Airansu basalts (6 samples) had shown high content of TiO_2 (1.53-4.30 %) and acids (7.14%) including K_2O – to 2.90 %. The group includes lavas and tuffs of the dacite-rhyolite content together with the main vulcanite rocks. Vulcanites contrasting content and high basalts alkalinity indicate their intraplate origin and define conditions of the marginal-continental riftogenic basin together with signs of the shallow-water sedimentation (Biske, Shilov, 1998).

Airansu Group is 2000-2500 m thickness. Direct data of the group's age are not available. The Late Riphean – Vendian age is assumed on the basis of the overlying Vendian-Cambrian sediments and probable analogy with some Sinian layers of the Tarim margin (basalts of Kuruktag and Aksu group) as well as occurrence of recrystallized oncolites in limestones (Biske, Shilov, 1998).

Compiler: Z.I. Chernavskaja

Karamoinak Formation (Vkr) defined by E.V.Khristov (1992) in the Airansu River valley (Maibash Range) where it lies on the Airansu Group sediments. The formation's appearance is described by variegated thinly-bedded terrigenous sediments lying in the shelf section bottom. The formation consists of red-brown, violet and green polymict sandstones and siltstones with rare interbeds of quartz gritstones which are 1-10 m thick. The rocks texture is a thin-bedded one, often cross-bedded. The up-sections are described by more fine-grained composition – dark-grey, black and brownish siltstones prevail there. Thin lenses of "trash" diamictites with floating pebbles (1-2 cm) of sandstones, siltstones and acid vulcanites occur among them. The formation top contains interbeds of oncolite dolomitic and marlaceous limestones (to 5-10 m) and red argillites with hematite ores occur together with them.

The formation's apparent thickness is 300 m. The formation's age is based on the microphytolithes found in the carbonate layers (*Osagia, Volvatella, Ambigolamellatus, Vesicularites*) defined by Sh.B. Klinger as the Vendian. These data allow comparing of the described section with the Jakbolot Formation of the Middle Tien-Shan (Khristov, 1992).

Compiler: Z.I. Chernavskaja

Chultag Formation (Ɛ-Očl) defined by V.M.Sinitsyn (1957) in the Kelpin mountains. Within the described area it is developed on the Maibash Rang, at the Terekty-Maibash interfluve where it conformably lies on the Karamoinak Formation. The formation section is represented by the various-bedded algal grey and pinkish dolomitic limestones with *Ozagia sp.* fossils containing packs of black and light-grey dolomites (from some tens of meters to 100-120 m), as well as rare interbeds of red limestones and calcirudites or limestone argillites. Additionally, limestones occasionally contain inarticulate brachiopods (Shibkov, Khristov, 1988).

In the eastern part of the Maibash Range and the Airansu-Terekty (eastern) interfluves the Chultag Formation is 1200-1500 m thickness. In the Airansu-Maibash interfluves where it is shown by grey bedded thick-tabular dolomites the formation thickness reduces to 200 m, and in the lower part of the Saryjaz gorge the limestones are replaced by black and variegated shales, which also contain some limestone interbeds that hold Middle and Upper Ordovician algae (fauna catalogue, site 245). On the Saryjaz River left bank above the source to the north of Koyukap the following section is observed: Polymictic conglomerates of Jamansu Formation lies with revinement on the 40-meter member of grey tabular cherts which rests above shales. Cambrian-Ordovician sediments had been defined on the basis of faunal fossils complex and location in the section (Shibkov, Khristov, 1988).

Compiler: Z.I. Chernavskaja

4.3. Paleozoic structural complex

4.3.1. Stratified formations

< (Double click to view the stratigraphical columns)

Maibash section type

Jamansu Formation (S_2-D_1jm) described by E.V. Khristov along the Jamansu River (Maibash Range) where it rests with revinement and basal breccias in the bottom on the Chultag formation sediments (Shibkov, Khristov, 1988). Besides it is developed at the Airansu-Maibash interfluves. Its analogs have also been defined at the Engylchek headwaters where it composes the bottom of the Kokshaal section type (Khristov, 1989).

Maibash section type formation predominantly consists of limestones interbedded (in different combination) with breccias, conglomerates, polymictic sandstones and effusives of acid composition. Stratigraphic revinement clearly defined in the lower third part of the formation allows defining of two subformations in its content.

Lower subformation is represented by conglobreccias, conglomerates, limestones, calcareous sandstones, trachyrhyolites and their tuffs. The subformation section predominantly contains banding limestones; its third part consists of polymictic conglomerates and conglobreccias, from various-pebbled to block ones. Layers of red-brown calcareous sandstones with rare gravel intrusions occur sometimes. Conglobreccias and conglomerates compose the subformation bottom. Conglobreccias' clastic material is practically unsorted and unrounded and consists of light-grey dolomites (70 – 80%), variegated siltstones and sandstones; cherts, jaspers and basalts are very rare there. Conglobreccias of some sites (left bank of the Airansu) are replaced by dolomites at the short distance and disappear from the section completely. Trachyrhyolites and tuffs compose the formation up-section and they differ by the potassic trend (K_20 – 4,84-6,74 %, Na_2O – 0,93-1,54 %) (Biske, Shilov, 1998). The lower subformation is 300-350 m thickness.

Upper subformation is described by terrigenous-carbonate composition (variegated sandstones, gritstones, conglomerates and limestones in the lesser quantity). The revinement signs are observed in the correlations with the lower subformation. The subformation bottom consists of conglomerates which are according to the fragments content – the volcanic ones and according to size – gravel and various-pebbled to fine-blocked ones. Underlying trachyrhyolites of red color prevail in the fragments content, cherts and limestones occur rarely. Layers of thick-grained and gravel bedded polymictic sandstones (from the first centimeters to first tens of centimeters) are limited by the conglomerates. Sandstones are often thickly cross-bedded. Limestones replace terrigenous rocks on strike and up on the section. The subformation section's lower part is up to 200 m thick. The following part is represented by fine-grained thin-bedded black limestones (150-180 m). It is conformably replaced by thin-fine-grained polymictic sandstones of green, grey-green color (350-400 m), and of rare interbeds of limestones and siltstones. The section is completed by fine-grained thin-bedded black limestones (at least 150 m). The Jamansu Formation upper subformation sediments in the left bank of the Airansu River are up to 880 m thick.

Sedimentary and volcano-clastic variegated deposits belong to the Jamansu formation of the Maibash section type and conformably underlie the Jangart dolomite-limestone Group in the Karagaity and Kumar river valleys and were conditionally defined by E.V. Kristov as Ordovician-Silurian sediments. In the Karagaity River valley described sediments are represented by rhyodacite tuffs containing interbeds of tuffstones, tuff-siltstones, and sandy limestones, and in the Kumar River valley the formation is predominantly volcanic siltstones and sandstones, which are sometimes intruded, in the up-section by gravel-conglomerate interbeds and rare basalt tops.

Analogs of the Jamansu formation had been defined in more southern (Kokshaal) section where they rest on the apparent bottom. Bedded limestones and syngenetic breccias outcrop in the Kaiche subtype (right tributary of the Kaiche River) which include dolomitized and dark clayey diversities with the Lower Devonian coral complex (Biske et al., 1985). Jamansu Formation in the Maibulak subtype (Engilchek headwaters) consists of variegated greywacke sandstones and shales with thick members of siliceous breccias and pudding-stones with quartz, cherts and strongly altered granite pebbles (700 m). Limestone horizons which contain recrystallized *Favosites pactum Chekh*., *F. brusnitzini Tchern* corals of the Lower Devonian Kunjak horizon occur above (definition of I.A.Chernova). Upper part of the sequence is represented by black clotted lenticular-bedded organogenic limestones with limited layers of calcareous shales (250-300 m). These limestones contain *Favosites cf. fidelis Pocta, F. aff. nikiforovae Chekh., F. aff. bonus Yanet., Squameofavosites cf. thetidis Chekh., Gladopora pygmaea Yanet., Gephuropora multiplicata (Dubat*) fauna in the lower part which determine its age within Kunjak-Manak horizons or Lochovian – lower Pragian stage. The upper third part contains corals *Favosites nikiforovae Chekh., F. admirabilis Dubat, F. aff. sublatus Dubat, F. aff. multilicatus Yanet., Cladopora rectilineata Simps., Cladopora cf. pygmaea Yanet., Egosiella vulgaris Miron.,* defining Emsian stage; the top contains *Favosites ex gf. goldfussi d'Orb., Thamnopora ex gr. reticulate (Bl.)* determining Middle Devonian (definition of I.A. Chernova). The formation is 1150 m thick.

Late Silurian – Early Devonian formation age is assumed on the basis of faunal definitions and its location in the section under the sediments containing Lower and Middle Devonian coral and amphipor fossils (Shibkov, Khristov, 1988).

Compiler: Z.I. Chernavskaja

Oblaitor Formation (D–C_1 ob_1). It is defined and described by E.V. Khristov as an independent stratigraphic unit mostly of carbonate composition (Shibkov, Khristov, 1988). It conformably alternates Jamansu Formation through bedding. We offered the name "Oblaitor" within the legend unification process. Typical sections are located in the Kumar-Oblaitor interfluves.

Lower subformation has undergone significant compositional alteration. In the north, beside the Kumar-Oblaitor interfluves, black or variegated pelitomorphic and fine-grained limestones interbedded by calcareous siltstones, calcareous shales and fine-grained cross-bedded quartz sandstones, which are a few centimeters thick (the section lower part is to 50 m thick). Following that is a 340-meter sequence of light-grey fine-grained dolomites with an unclearly shown thin- and lenticular- cross-bedded texture. Grey aphanitic thick-tabular limestones appear in the up-sections. The section's thickness within the studied area is 525-550 m. The carbonate section of subformation which is to 440 m thick outcrops clearly on the Karagaity River valley and is represented by black crinoidal, crinoidal-coral, clayey, grey organogenic-detrital and crystallic limestones. Marmorized thin and medium-bedded limestones are spread in the up-sections. Sediments of the described stratigraphic unit are shown by dolomites with complete thickness of 545 m in the north of the research area, in the Maibash Mountains.

Upper subformation displayed at the Kumar - Saryjaz watershed where it conformably rests on black tabular limestones with coral fauna of the Lower-Middle Devonian. It consists of grey and light-grey aphanitic and fine-grained thick-tabular or massive limestones. Limestones with thin- and medium-bedded textures caused either by alteration of pinkish-grey and dark grey color in interbeds ranging from mm to 1-2 cm thickness, or concentration of straw-grey sandy material into the filamentary interbeds occur here and there. The upper subformation is 500 m thick.

The formation age is assumed on the basis of faunal fossils found in the Lower subformation. Corals and stromatopors of the Lower-Middle Devonian had been found there (fauna catalogue, site 246, 247, 277).

Compiler: Z.I. Chernavskaja

Kumar Formation (C_2km). It was first defined and described as an independent stratigraphic unit by E.V. Khristov (Shibkov, Khristov, 1988) along the Saryjaz River left tributary, near the Kumar stream where it conformably overlaps the Oblaitor Formation. We offered the name “Kumar” in the process of the legend unification.

The formation section is mostly composed of carbonates. Pelitomorphic and fine-grained crinoidal-detritous black limestones containing lenses (10-15 cm) of yellowish- and red-brown marl clastic-clotted and clastic-detrital limestones. The Lower Bashkirian *Earlandia vulgaris (Raus. et Reitl.); Pseudoglomospira dainae (Vdov.); Dainella sp.; Omphalotis sp.; Globoendothyra globula (Eichw.); Pseudoendothyra sp., Pseudostaffella cf. proozawai Kir.* foraminifers and *Koninckopora sp.* algae had been collected in the marl limestones (definition of S.B.Gushin). Grey and light-grey pelitomorphic thick-tabular and massive limestones (80 m) and calcareous shales with minor occurrences of thin-bedded sandstone interbeds (70 m) replace them. The section middle part is shown by grey and light-grey pelitomorphic and massive limestones (120 m) the lower part of which contains 5-meter horizon of black bituminous detritous and crinoidal-detritous limestones with the Upper Bashkirian foraminifers. Marmorized dark-grey thin-bedded limestones alternating (from 1.5-5 m to 50 m) with light-grey massive-bedded limestones or lenses of sandy-siltstone content (120-150 m) compose the upper part. Kumar formation is 390-420 m thick.

The formation age is based on the paleontology definitions: the Lower Bashkirian foraminifers and the Upper Bashkirian algae and foraminifers of crinoidal-detritous limestones found in the marlaceous limestones (fauna catalogue, site 250).

Compiler: Z.I. Chernavskaja

Jetkait Formation (C_3–P_1dt). First described by E.V. Khristov (Shibkov, Khristov, 1988) at the watershed area of the Kokshaal Range. The section is fully shown in the Jetkait River Valley. The formation bottom is sliced by a fault and there are no correlations with Bashkirian sediments. Terrigenous and volcanogenic rocks allowing to define two subformations in its content, occur on the mostly formation carbonate composition.

Lower subformation is represented in the apparent bottom by grey sparkling thin-grained massive dolomites occurring at more than 400 m higher. Volcanogenic-carbonate member which is divided into 3 parts in structure, overlies them conformably. It is in total 208 m thick: at the bottom – black and grey tabular and thin-bedded limestones (100 m), in the middle part (38 m) – grey-green rhyolite tuffs, tuff silicite, black limestones to 1.5 m thick beds, vilolet-black tuff shales and the upper part – black and grey fine-grained and thin-bedded banded limestones (70 m). Volcanogenic-carbonate member thickness increases eastward (Maibash-Terekty watershed) to 260-290 m.

Upper subformation had not been observed in a complete volume anywhere. The section lower part outcrops on the Jetkait Range bank where it is shown by light-grey, sometimes by greenish thin- fine-grained micro-thin-tabular marmorized limestones (300 m) replaced by black thin-bedded thick-tabular marmorized limestones (more than 100 m).

Grey massive marmorized unclearly-bedded limestones containing thin shale pro-beds (5-15 cm) and alternating with packs of uneven bedded siltstones, sandstones, argillites, dark grey limestones containing fusulinid fossils (420-440 m) occur in the section part which outcrops to the west from the Uchchoky pass. Pink marmorized limestones with thin beds of red clay (300 m) occur above. Black fine-grained limestones with rare interbeds of marls and argillites with fusulinid fossils (about 180 m) complete the section. Packs to 70 m thick of white loose unclearly-bedded gypsum appear at the same level among white marbles in the Jetkait River's right tributaries. The section's minimum thickness in this area does not exceed 480 m. Calcareous shales unevenly alternate with limestones, siltstones and sandstones, comprising the main section in the upper part of this subformation, which is up to 550 m thick. The upper subformation minimum in the studied region thickness is 1030 m.

The formation's age is based on the Late Carboniferous Gzhelian age foraminifers (fauna catalogue, site 251, 252).

Compiler: Z.I. Chernavskaja

Jangart Group (D-P_1jn) was initially defined for Devonian-Permian carbonate deposits of the Maibash section which is at least 2000 m thick (Biske et al., 1985). We use this taxon only for description of the research area's southern part, where the carbonate section stayed undivided due to its remoteness.

Compiler: Z.I. Chernavskaja

Sauktor Formation (P_1sk). It represents the topmost element of the Maibash section type and rests on the underlying sediments without an apparent unconformity. The complete formation section has been described along the Aksai river, Jangart River left tributary (Biske et al., 1985). Sandy limestones, shales and rhythmical sand-shale horizons occur in the lower half of the section and the upper one consists of gritstones and conglomerates. The section has a regressive type and is at least 700 m thick (Biske et al., 1985).

Within the research area, a 200 m thick section of the formation outcrops in the Jetkait headwaters, where it overlies the Jetkait formation sediments without apparent unconformity. It is represented by black calcareous siltstones with grey and brown fine- medium-grained sandstone interbeds. The formation's upper horizons are about 350 m thick, and outcrop at the tectonic block along the Kuyukap River left bank. Here the formation's upper horizons are composed of black calacrous siltstones, polymictic various-grained sandstones, gritstones and various-pebbled conglomerates, which are bed-sorted and angular pebbles, much of which is tuffs and lavas sourced from acid effusives. Thick forms of the Karachatyr biostratigraphic horizon schwagerins which indicate the Early Permian age of the Sauktor formation occur in single samples from the Jetkait headwaters' debris fall (Shibkov, Khristov, 1988).

Compiler: Z.I. Chernavskaja

Kokshaal section type

It represents a thick complex of terrigenous deposits with a stratigraphic range from the Lower Devonian to the Lower Permian, and is spread throughout the whole Kokshaal Range. They rest on the Late Silurian – Early Devonian sediments, described above as the Jamansu Formation. These sediments are distinguished by a significant predominance of thin-clastic terrigenous flysch sediments (turbidites), large thickness and absence, with little exclusion, of breaks in the section. The described sediments have a full set of diagnostic signs of bathyal complex: occurrence of turbidites, predominance of pelagic fauna complexes, absence of volcanic occurrences and successive deepening of sedimentation which reached its maximum in the Early – beginning of the Middle Carboniferous when formed a "condensed" section of carbonate-clayey-siliceous sediments reduced in thickness (Khristov, Mikolaichuk, 1983). These signs, spread within 500 km on strike provide a basis for separation of this section type.

Specific formations within the research area distinguished by their stratigraphic volume caused a necessity to define two subtypes – Kaichi and Maibulak.

Kachi subtype

Airytor Formation (D_{1-3} at) defined by M.B.Ivanov and M.M. Purkin in 1961 on the Kaiche River Valley. The most complete sections of it defined in the Jangart River Valley and in the Sauktor river down-stream where it conformably overlaps the Jamansu formation (Biske et al., 1985). To the east from the stratotype area, within the investigated territory, the Airytor formation spread along both banks of the Saryjaz River and in the Uchchat River valley where it is represented by up-section outcrops in the cores of anticlinal folds (Shibkov, Khristov, 1988).

Lithologic features of the Airytor Formation determined by predominant siltstone-shale content and occurrence of large quantities of calcareous material. Black calcareous thin-tabular siltstones, and rare dark grey calcareous shales which are thinly interbedded (1.5 – 2 cm) with thin-grained silty sandstones, brown on the surface, compose the main section background. Horizons of pelitomorphic and thin-grained thin-bedded sandy limestones to 1.5- 2 m thick, appear in the up-section. The Airytor Formation minimum thickness in the studied area is 495 m. Its Devonian age is assumed on the basis of the flora fossils and conodonts (fauna catalogue, site 248,275).

Compiler: Z.I. Chernavskaja

Kaichi Formation (D_3–C_1kč) conformably replaces the Airytor one. Stratotype section locates along the Kaiche River left bank, its tributary – Chonsarytor River. Horizons of red shales and siltstones, thick-grained sandstones and gritstones with horizons of greenish quartzite-like sandstones with phytodetritus appear above the Airytor shales (Biske et al., 1985). Its foot in the Saryjaz-Taldybulak interfluves is marked by the typical member of variegated (pistachio-green, green, cherry) shales (to 25-30 m). Green, grey-green quartzite-like sandstones interbedded with chloritic shales overlap the Airytor formation here and there (Shibkov, Khristov, 1988).

Alteration of thickness (180-250 m) thin-rhythmical sandy-shaly and thick gravel-sandy members is typical for the Kaichi formation section. Thin-rhythmical members consist of green, or rare of a red-colored, siliceous chloritic tabular slate including interlayers (10-15 cm) of grey-green cross-bedded sandstones which contain ripple marks, hieroglyphs, and phytodetritus accumulation. Thick members are composed of brownish-grey polymictic various-grained (to gravel) sandstones (beds from 15 cm to 2-4 m thickness) which alternate in the section black siltsones and shales (10-15 cm). Horizons of fine- and medium-pebbled conglomerates to 8-15 m thickness occur sometimes there. The formation top outcrops in the Uchat River basin, it is represented by a green member of frequently interbedded (0.5 – 5 cm) micaceous siltstones and thin, fine-grained marmorized limestones. The green-colored member contains interbeds of fine-grained calcareous sandstones in the lower half. The Kaichi Formation is at least 1000-1100 m thickness.

The Late Devonian – Early Carboniferous flora fossils occurring in the whole section and early Carboniferous foraminifers and conodonts found in the up-section determine the formation age (fauna catalogue, site 121, 249, 270, 271-274, 276).

Compiler: Z.I. Chernavskaja

Uchchat Formation (C_{1-2}uč). First defined and described as an independent stratigraphic unit by V.P. Skvortzov in 1966 (Biske et al., 1985). We offered the name within the legend unification process. The formation is spread along the Saryjaz River left bank, where its outcrops are observed south-eastward from the Kaindy River to the Uchchat River valley and then to the Kyzylkapchigai River valley, as well as along the Engilchek River left bank, in the Merzbacher Lake area. According to its stratigraphic position it is similar to the Sarybel and Pikertyk formations of the Saryjaz River right bank (Biske et al., 1985).

According to the E.V. Khristov's data (Shibkov, Khristov, 1988) calcareous-sandy deposits overlie the Kaichi Formation, in the Uchchat River valley. This section consists of alternating dark thin-bedded limestones and dolomites interlayered with calcareous shales (to 90 m), white marbles (80 m), quartzite-like micaceous sandstones with lenses and flows of fine- and medium-pebbled quartz-siliceous conglomerates (20 m), black pelitomorphic limestones (with inclusions of clotted-clastic marly limestones) and interbeds of black siltstones (17 m), calcareous sandstones with gradual beds alternating with calcareous limestones and calcareous siltstones (40 m), fine-grained and pelitomorphic dolomitic limestones (60 m), dark-grey thin-grained limestones with ovoid joints (28 m), red thin-bedded limestones (14 m), red calcareous sandstones and marl lenticular-wavy bedding limestones alternating with black siltstones and containing in the upper part 2-8 meter beds of black massive limestones (60 m). The described sediments' complete thickness is 340-410 m.

In the Engilchek River valley (Maibulak subtype) described sediments conformably overlies shales of the Maibulak Formation and is represented by dark-grey and black thin-bedded limestones with cherts and tuff silicite interbeds (350 m). Polymictic conglomerates and thick-bedded sandstones of presumably Middle Carboniferous (50-100 m) overlap them (Khristov, 1989).

The formation age is substantiated by numerous paleontology definitions. V.P. Skvortzov defined in the Uchchat formation foraminifers of the Upper Tournaisian and whole Visean section (Biske et al., 1985). Organic fossils in the Inylchek River valley are represented by *Archaesphera sp., Planoendothyra sp., Parathurammina sp., водорослей Girvanella* foraminifers (definition of S.B.Gushin) and *Gnathodus sp.*conodonts (definition of V.P. Chernyshuk) defining the Early Carboniferous age of host sediments (Khristov, 1989). Additionally, there are Visean, Serpukhovian and Bashkirian foraminifers (fauna catalogue, site 269, 288, 289).

Compiler: Z.I. Chernavskaja

Kipchak Formation (C_2–P_1kp). It is formed by pre-folded flysch which completes the terrigenous section of the Kokshaal zone. The stratotype section is located on the Kipchak river, Maidantag Range (Biske et al., 1985). Within the investigated area sediments of this group mapped in the Kaindy and Uchchat Rivers valleys and in the North and South Engylchek interfluves (Maibulak subtype).

A 100-meter set of tabular and book clay (shales) lies in the Formation bottom in the Kaindy-Uchchat interfluves, rhythmical alteration (5-30 cm) of similar shales with sandstones (250-300 m) occurring above. Interbeds (0.5-3 m) of clastic-organogenic limestones with foraminifers of the Moscovian age and Upper Carboniferous occur among them. Set of gravel-pebble rocks (80-100 m) with lensed clastic limestones which contain foraminfers of the Lower Permian lies above. Sandy-argillite sediments which are at least 200 m thick complete the section. The Kipchak Formation is at least 700 m thickness there (Biske et al., 1985).

The Kipchak Formation outcrops in the Engylchek headwaters (Maibulak subtype), to a thickness up to 1000 m, and here the sequence is composed of rhythmically alternated dark polymictic sandstones with gradual beds, black calcareous siltstones and argillites. *Pseudostafella cf. proozawai Kir., Profusulinella cf. bona Gr. et leb*. foraminifers and *Beresselidae* algae of the Early Moscovian have been found in thin detritus limestones from the bottom of the section (definition of A.V.Djenchuraeva), (Khristov, 1989). Early Permian foraminifers (fauna catalogue, site 268) were found along the Kaindy left bank. Displaced flora and foraminifers of the Late Devonian-Early Carboniferous had been found along the whole section (fauna catalogue, site 140, 141-143, 281).

Compiler: Z.I. Chernavskaja

Maibulak subtype

It is defined in the Engylchek headwaters, Khan-Tengri mountain range. Described above Jamansu formation lies in the bottom of the Maibulak subtype and reaches there at least 1150 m thickness.

Maibulak Formation (D_2-C_1mb) first described as an independent stratigraphic unit in the Engylchek headwaters where it conformably lies on the Jamansu Formation limestones (Khristov, 1989) and is conformably overlapped by the Kipchak formation. The name is offered in the process of the legend unification. According to its stratigraphic position Maibulak Formation is similar to the Kokshaal Range Airytor and Kaichi Formations volumes.

The formation section is completely represented in the Shokalskiy glacier slope. Chlorite-siliceous and black quartz-sericitic shales lie at its bottom (200 m), and then they are replaced upward by thick-grained quartz sandstones with gravel flows (80 m). The up-section consists of black shales and siltstones hosting horizons of siliceous shales, clastic limestones and calcareous siltstones (350-400 m). The formation total thickness is 680 m.

Palygnatus cristatus Hinde, P. decorosus Stauffer, P. normalis Miller et Yoyng., P.pennatis (Hinde) conodonts of the Upper Givetian stage had been found in the lower limestone horizon and *Siphonodella cf. duplicate (Br. et M*) of the Tournaisian – in the upper horizon (definition of V.P. Chernyshuk), (Khristov, 1989).

Compiler: Z.I. Chernavskaja

Atjailyau section type

It is represented by benthic limestones of the Late Silurian – Early Devonian age. Clayey-carbonate layers of pelagic type replace limestones upwards in the section and then siliceous deposits follow them that reflect a stage of uncompensated subsidence of carbonate platform (Biske et al., 1979).

Belkarasu Formation (S_{1-2}bl) lies at the apparent bottom of Atjailyau section type. The formation whas previously been defined on the northern slope of the Chyrmash ridge (western end of the Atbashi Range), Chon Kargantash and Belkarasu interfluves (Biske et al., 1979; 1985). In the stratotype area the Belkarasu formation is characterised in its lower part by sediments of carbonate-terrigenous and in the upper part by carbonates containing plenty of fossil benthos e.g. corals. The formation in stratotype is up to 700 m thickness. In the investigated area the Belkarasu formation spreads along the Uchkel River left bank, as well as the Atjailyau River and Kaindy River right banks, where it is composed of dark-grey bedded limestones alternating with members of green-grey, grey and dark grey shale and calcareous shales. Interbeds of grey and light-grey micro-bedded limestones up to 10 m thick occur there.

Coral, crinoidal and bryozoans diversities occur among limestones. The formation is 200-400 m thickness.

Numerous tabulate findings among which *Paleofavosites balticus Rukh* are mostly typical and were widely spread in the Early Silurian, define the Belkarasu Formation age (Biske et al., 1985). The Late Silurian corals (tabulate) and stromatopors are found within the research area (fauna catalogue, site 133, 255).

Compiler: Z.I. Chernavskaja

Kargantash Formation (S_2-D_1krq) first described in the Chirmash ridge, along the Chon Kargantash River where it conformably rests on the Belkarasu Formation sediments (Biske et al., 1979; 1985). Kargantash formation consists of black mottled limestones, dolomitic limstones and dolomites. Crinoidal and coral diversities with tabulate colonies occur among limestones. The Formation in the stratotype section is about 1000 m thickness.

Within the investigated area it was defined in the valleys of the Uchkel, Kaindy Rivers and further eastward along the Engylchek -Kaindy watershed where it conformably overlaps the shales and limestones of Belkarasu Formation. Sediments of Kargantash Formation are represented by thin-bedded grey limestones, sometimes by the mottled ones with coral-tabulate fossils and rare interbeds (to 2 m) of dark grey, almost black, dolomitized limestones with numerous fossils of algae, nautiloidea, stromatoporoids, and rugose-corals. These are sediments of reef, pro-reef slopes and shallow littoral facies. The formation thickness varies within 200-1000 m (Biske et al., 1979).

A rich collection of the Late Silurian tabulates and stromatopors (fauna catalogue, site 129, 131, 134, 137, 162, 168, 256, 258, 260) have been found in the Kargantash Formation sediments like in the stratotype section (Biske et al., 1979). *Favosites olifformis Chekh., F. ex gr. goldtussi Orb., F. aff. axaicus Chern., F. sp. (cf. F. admirabilensis Dubat), F. cf. schiriktens Chern., Squameofavosites cf. bohemicus (Pocta), Heliolites aff. pseudoabichenucus Bond, H. aff. portentosks Bond, Pachycanalicels aff. dentata Mir., Favosites aff. admirabilis Dubat., Fav. ex gr. socialis Sok. et Tes., Pachyfavosites kozlovski minima Chekh.* Early Devonian tabulates had been found in the western part of the Atbashi Range, in the upper part of the formation (definitions of I.A.Chernova, L.P. Nogaeva) (Konyuhov et al., 1978; Djenchuraeva et al., 2001). Thus the Pridoli epoch of the Late Silurian – Lockhovian stage of the Early Devonian are assumed as the Kargantash Formation age interval.

Compiler: Z.I. Chernavskaja

Chirmash Formation (D_{1-2}čr) first defined and described in the upper part of the Chirmash ridge carbonate deposits (Biske et al., 1979). In the stratotype area the formation conformably overlaps the Kargantash formation section differing from it by predominance of dark bedded limestone diversites. Dark to black limestones and more massive dolomites hosting yellowish and pinkish diversities with tabulates of the Lower Devonian Kunjak horizon compose the Chirmash Formation lower part. The upper part varies by occurrence of crinoidal-detrital tabular limestones with interbeds of clastic limestones having gradual beds. Large members of light massive limestones which contain tentaculitids occur also. The formation section top is composed of thin-tabular clayey limestones with tentaculitids. Chirmash Formation in the stratotype is 700-800 m thickness. Within the mapped area the formation spread in the Uchkel, Kaindy Rivers valleys and eastward along the Engylchek-Kaindy watershed. It differs from the underlying Kargantash formation by predominance of dark bedded limestones. Three rock members are clearly defined in the Chirmash Formation content, the upper and lower of which are represented by grey massive or thick-bedded limestones, and the medium one by dark grey and grey bedded limestones. The Chirmash formation's minimum thickness within the studied area is about 300 m (Biske et al., 1979). Early Devonian tentaculitids and tabulates of the Early-Middle Devonian define the formation's age (fauna catalogue, site 259, 261, 262).

Compiler: Z.I. Chernavskaja

Atjailau Group (S_1- C_1 at). In the Eastern part of the Saryjaz Range, near the watershed light marbled massive and thick-bedded limestones outcrop, however these are impossible to observe directly. Evidently they present undivided sediments of the Atjailau Section formations described before.

Compiler: A.V. Mikolaichuk

Kattaashutor Formation (C_1 ktt). Its first description is in the S.S. Shultz's report (1940), however the name was coined by us. The observation in the Sarykoinou River source and Kattaashutor Range helped to find out that light marbled limestones of Atjailau Group are stratigraphically overlapped by dark gray clay shale and calcareous sandstone with interlayers and lenses of black bituminous limestones. There are numerous coral and brachiopod fossils in the limestones which are stretched (crushed) in the direction parallel to the rocks bedding. In our collected samples fossils were not determined because of intense metamorphism. S.S. Shultz (1940) wrote that geologist Keidel from G. Merzbacher's expedition (1902-1904) had collected here Early Carboniferous *Spirifer* (fauna catalogue, Site 296). The thickness of the described sediments is not less than 1000m.

The Tashrabat type of section

It was originally determined as an independent stratigraphic unit by E.V. Khristov in the western end of the Atbashi Range, in the Tashrabat River (Biske et al., 1985; Khristov, Khristova, 1978). Stratigraphic sequence in this section was ascertained during geologic survey in the Eastern part of the Atbashi Range (Konyukhov et al., 1978; Chernyavskaya, 2005). In the lower part the thickness is up to 800m of sericite-chloritic, chlorite-zoisite-albite schists and carbonaceous shales black and gray-green colored prevail with interlayers of polymictic sandstones, tuffstones and sandy limestones (the Early Silurian Bogoshty Formation). The upper part of the section with thickness of up to 1100m was assigned as the Tashrabat Formation. It is composed of cherts, siliceous shales, basalts, basaltic andesites and their tuffs with less amount of interlayers and lenses of dolomites and limestones. Despite the fact that the Tashrabat Formation rocks underwent intense dynamic metamorphism numerous corals and brachiopods were collected in them and allowed to determine the age as Late Silurian – Middle Ordovician (Biske et al., 1985; Konyukhov et al., 1978; Chernyavskaya, 2005). Within the investigated area similar volcanogenous-cherty rocks are widespread within the Inylchek Range. Although they are described as a group, it is likely more indepth study would have permitted specific formations to be shown on the map.

Kaindy Group (S_2-C_1kn) was determined by G.S. Biske with co-authors (1979) in the Kaindy River basin, in the area of the Uchchat Pass and the Karaarcha River basin and is represented by volcanogenic sedimentary rocks which are overthrusted onto the carbonate rocks of the Atjailau Section.

Volcanogenic cherty rocks with thickness of up to 580m prevail in the lower part of the section. These are porphyritic basalts and andesites, their tuffs and lava brecia, sometimes rhyolites and volcanites with andesite-dacite content. There are interlayers and beds of platy cherts which sometimes predominate in the section. Siltstones, clay shales, tuffstones and limestones occur also but to a lesser extent. Inherent habit of this part is determined by lava breccia and coarse clastic bomb tuffs.

Clay shales and sandstones sometimes with red and crimson color prevail in the upper part of the section with thickness of up to 250m. There are usually platy cherts, interlayers of tuffs, tuffstones, sometimes lava interlayers. Horizons of limestones with thicknesses of a few tens meters are peculiar for this part. In the investigated area the chemical content of the formation rocks were determined by 7 samples (see geochemistry catalogue), which indicated increased alkalinity of the basalts. Based on the analysis of similar rocks in areas situated to the west, the conclusion was made that genesis of volcanic structures of the Tashrabat section was intraplate (Biske, Shilov, 1998).

The total thickness of the Kaindy Group is 830-950m. Its Late Silurian – Late Devonian age was determined by means of numerous fossils of different groups: Upper Ludlovian brachiopods, Silurian-Devonian rugose corals and tabulates, Upper Devonian foraminifers and algae (fauna catalogue, sites 126, 138, 139, 154, 155, 172, 173, 196, 278-280, 283-287, 290, 291). In adjacent territories the Kaindy Group rocks contain Lower tentaculitids: *Styliolina ex gr. nucleata Karp., Nowakia cf. Acuminiata G. L.* (Biske et al., 1979) as well as Middle Devonian conodonts: *Hindeodella sp., Polygnathus ex gr. linguiformis Hinde* and Middle-Upper Frasnian conodonts: *Palmatolepsis charlottae Müll, Polygnathus sp.* (Puchkov et al., 1985). Within the Akshiiryak Range the uppermost parts of the section are completed with Lower Carboniferous marbled limestones containing *Endothyra sp.* (Biske et al., 1985). Based on the above mentioned the age of the Kaindy Group is accepted as Late Silurian – Early Carboniferous.

Compilers: Z.I. Chernavskaja, A.V. Mikolaichuk

Turkestan ophiolitic complex

Ultrabasite-Gabbro Group (Σ,y PZ_1 st) composes a deformed ophiolitic plate in the Karaarcha Pass. Ultrabasites are represented by apoharzburgitic serpentinites, wehrlites and lherzolites. Gabbro, gabbro-amphibolites, gabbro-norites, norites, quartz gabbro, monzogabbro from the layered complex superpose. The rocks are dark-gray, greenish-gray, medium-grained and with banded taxitic texture. Gabbro is composed of basic plagioclase and clinopyroxene. Gabbro-amphibolites are characterized by deuteric amphibole, gabbro-norites are characterized by clinopyroxene and orthopyroxene as well. Unlike gabbro norites are predominantly composed of orthopyroxene, quartz gabbro contains quartz admixture, monzogabbro contains potassium-sodium feldspar (Shibkov, Khristov, 1988). The rocks of this group are characterized by 5 samples of gabbro and peridotites which are indicated in geochemistry catalogue.

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Dolerite Group (yβ,β PZ_1st). The tectonic plate composed of Dolerite Group formations is overlapped by the tectonic plate composed of Ultrabasite-Gabbro Group formations and thrusts the Kipchak Formation rocks (C_2-P_1kp). The described group contains sheets of metabasalts, spilites and parallel dykes of gabbro-dolerites and dolerites. These rocks belong to basic volcanic and hypabyssal rocks of normal series and are composed of basic plagioclase and clinopyroxene. Metabasalts are characterized by significant extent of alteration (plagioclase saussuritization and pyroxene amphibolitization), while spilites are characterized by microlitic texture. Dolerites are distinguished by phaneritic fine-medium-grained texture, gabbro-dolerites are distinguished by ophitic texture (intermediate rocks between gabbro and dolerite). Petrochemical data of the group rocks are unsatisfactory and are represented by 1 basalt sample (see geochemistry catalogue). Real data on the Dolerite and Ultrabasite-Gabbro group's ages are unavailable. Their Early Paleozoic age is assumed from a presumption that these groups preceded the Kaindy Group.

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The Shirikty type of section

In the type section (Atbashi Range, Shirikty River basin) the next formations outcrop and conformably overlap each other: Shirikty Formation with sandstone-limestone-shale content (S_2-D_1sr), formation of clastic limestones (D_1), cherty-volcanogenic formation (D) and Uchkara cherty-limestone Formation (C_1uk) (Biske et al., 1979). In the Saryjaz district only the lower part of this section was determined. It composes an overthrust that lies on the Kaindy Group rocks.

Shirikty Formation (S_2–D_1šr). It was determined in 1957 in the Atbashi Range by A.E. Dovzhikov (1960) and was described in detail in 1972 by E.V. Khristov in the Shirikty River basin (Osmonbetov, Knauf, 1982). The formation consists of 2 parts. The lower part with a thickness of up to 900m predominantly consists of shales, and sometimes contains interlayers of marbled limestones, as well as sets of sandstones and siltstones. The upper part (nearly 700m thick) is composed of sandstones, siltstones, clay shales with rare limestone interlayers.

Within the investigated area the main field of the Shirikty Formation spread is in the Kaindy River basin. In the lower part of the section there are gray and mottled paper shales and calcareous-clay shales with less interlayers of organogenic limestones (500m), in the middle part the same shales outcrop with interlayers of volcanic sandstones and tuffs (400m), and in the upper part there are gray-green and violet clay shales with beds of black organogenic limestones (more than 800m) (Biske et al., 1979, 1985). The total thickness of the Shirikty Formation is not less than 2000m.

The formation age was determined by numerous fossils: Upper Ludlovian brachiopods and stromatoporoids, Ludlovian, Llandoverian, Wenlockian and Lower Devonian tabulates (fauna catalogue, sites 120, 122-125, 127-128, 130, 132, 135, 136, 152-153, 156-167, 197, 198, 257, 265-267, 282). In the Atbashi Range (Tashrabat River) in the uppermost parts of the Shirikty Formation the next conodonts were determined: *Ozarkodina remscheidensis remscheidensis (Zieg.), Panderodus sp.* (determination by A.V. Neevin), which are inherent for Lochkovian rocks (Jenchuraeva, 2004). Based on mentioned data the age of the Shirikty Formation is assumed as Lludlovian – Lochkovian.

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Atbashi Formation ($gC_{1-2}at$) composes the northern slope of the Atbashi Range, where it was described for the first time by O.I. Sergunkova in 1937 (Osmonbetov, Knauf, 1982). It represents polymetamorphic formations of a subduction zone which include bodies of eclogites and glaucophane schists. The basic part of the formation is represented by schists and gneisses. In the Atbashi Range the lower part of the section is composed of plagioclase gneisses with the lower amounts of biotite-hornblende schists, marbles. The thickness reaches 1500m. The middle part is represented by melanocratic biotite-hornblende gneisses, rarely biotite-pyroxene gneisses with lower amounts of interlayers of biotite, garnet-biotite and biotite-hornblende schists. Towards the upper part of the section the amount of melanocratic rocks gradually decreases (the thickness of the middle part is about 1000m). In the upper part of the formation leucocratic gneisses and schists dominate, there are some micaceous quartzites (the thickness is near 2400m). The total thickness of the formation is about 5000m. In the Late Paleozoic metamorphites which were formed under the high temperatures and pressures underwent low-temperature (retrograde) greenschist metamorphism (Bakirov, Kotov, 1988; Khristov, 1981; Sobolev et al., 1989, Tagiri et al., 1995).

At different periods during the study of the Atbashi formation, the age of metamorphism have differed from one adovating a Pre-Cambrian age, and at other times a Silurian age has been suggested (Mitrofanov, 1982; Osmonbetov, Knauf, 1982). Most recent investigations of eclogites of the Atbashi Formation on phengite and glaucophane gave $^{40}Ar/^{39}Ar$ age of 324-327Ma (Stupakov et al., 2004; Simonov et al., 2008), that conformed to the age of 331±2.0 Ma of the rocks of the eclogite-glaucophane schist complex within the Southern Tien-Shan suture in the territory of the Northern-Western China ($^{40}Ar/^{39}Ar$ method on phengite) (Gao, Klemd, 2003). Isochronous dating conforms to geological data well. The

Atbashi Formation gneisses are overlapped with unconformity by Late Carboniferous rocks (Lesik, Mikolaichuk, 2001).

In the investigated area schists and gneisses which are spread around the head of the Northern Inylchek Glacier, and are composed at their base of a carbonate sheet are classified as the Atbashi Formation. Metamorphic rocks were discovered only among glacial and slope rocks of the area and the field of spread of the formation was determined during satellite images and aerial photograph interpretation.

Compilers: Z.I. Chernavskaja, A.V. Mikolaichuk

5. Overlapping Late Paleozoic Basins

5.1. Devonian volcanic-plutonic belt

In the Northern Tien-Shan the southern part of the Kazakh Devonian volcanic-plutonic complex (by Bakhteev, 1987) or Devonian marginal continental belt of the Central Kazakhstan (by Grankin et al., 1997) outcrops. It represents superimposed volcanogenic, terrigenous-volcanogenic troughs and subvolcanic bodies and intrusive complexes conjugated with the volcanites.

Three main stages in the development of the Devonian orogenic magmatism of the Central Kazakhstan were determined (by Kurchavov et al., 1998). The Early Orogenic Stage (the beginning of the Devonian) is characterized by differentiated basalt-andesite-rhyodacite association where intermediate-basic rocks prevail. An Early Devonian complex belonging to the gabbro-diorite-granodiorite-tonalite series is comagmatic to those volcanites. The Middle Orogenic Stage (the end of the Early Devonian- the beginning of the Middle Devonian) is characterized by “bloom” of rhyodacite-rhyolitic ignimbrites, lavas and tuffs, as well as a Middle Devonian complex of leucocratic granites, which was associated with them. In contrast, the Late Orogenic Stage (the end of the Middle Devonian – the beginning of the Late Devonian) is characterized by basaltic andesite – rhyolite association with increased and high alkalinity and dominance of intermediate-basic or silicic rocks. Complexes of small intrusive bodies of monzonites, monzodiorites, quartz syenites, granosyenites and subalkaline granites are comagmatic with them.

Rocks in Devonian volcanogenic troughs of the southern part of the volcanic-plutonic complex superimposed on the Pre-Cambrian and Early Paleozoic rocks were determined before as the Middle Paleozoic effusive-sedimentary complex of the Northern Tien-Shan (by Knauf V.I., 1960). Subsequent formations from the bottom up in the section are composed of: Barkol, Aksu, Karakol, Aral and Taldysu formations (by Osmonbetov, Knauf, 1982).

5.1.1. Stratified formations

Barkol Formation (D_1br). The type section of the formation is located outside the investigated area in the western part of the Kyrgyz Range (by Zakharov, 1986; by Apayarov, 2007). In the Northern Tien-Shan in the basement of the Devonian volcanogenic troughs the formation rocks overlie a structural and angular unconformity on Pre-Devonian formations (by

Malygina, Dodonova, 1972). Kazakh geologists describe similar rocks as the Kastek Formation (by Gutermakher, 1978).

Andesibasalts, andesites, their tuffs, and tuffstones outcropping between Bayankol and Koichi rivers in the northern part of the area investigated were determined as the Barkol Formation. They lie on the Early Paleozoic volcanites of the Turgenaksu Formation with ambiguous relations. In the waterhead of the Ulkenkokpak River and along the Tokmakchumchuk Branch rocks of the Barkol Formation with conglomerates in the basement overlie the Late Ordovician – Early Silurian granitoids of the Aktash Formation (Gutermakher, 1978).

Typical structure of the Barkol Formation was described in the left bank of the Bayankol River in the section along a left tributary of the Charynbai Branch (Gutermakher, 1978). The formation is dominantly represented by lavas of brown, brown-violet andesites, basaltic andesites from 2 to 100m of thickness, containing fewer horizons of andesite tuffs (10-45m) and lava breccias (1-13m), and rarely some thin (up to 3m) layers of brown fine-grained volcanic sandstones. Apparent thickness of the rocks in the section is 450m.

Subaerial effusion of andesites was accompanied by subvolcanic bodies of andesite porphyrites (**$\delta\pi D_1b$**) having intrusive contacts with lavas and tuffs of andesites. Andesites in the subvolcanic bodies are characterized by better devitrification of the matrix, large (up to 2-3mm) and numerous (up to 50-70% of the rock amount) phenocrysts of plagioclase and hornblende. They do not differ from andesites in lavas by the chemical content (Gutermakher, 1978).

The chemical content of the formation rocks is determined by 3 samples (see geochemistry catalogue). In the TAS diagram (Le Maitre et al., 1989) their figurative points are located in the fields of andesites and trachyandesites. The percentage of K_2O in the rocks is 3.12-3.80%, and the ratio K_2O/Na_2O varies from 0.64 to 1.62.

Fossils were not discovered in the formation rocks. The Early Devonian age of the formation is determined by its position in the section and comparison with rocks similar on the content which compose volcanogenic troughs outside the researched area.

Compiler : F.Kh. Apayarov

Aksu Formation ($D_{1-2}as$). It was determined outside the researched area in the central part of the Kyrgyz Range in Aksu River basin (Grischenko, 1967).

Aksu Formation rocks spread in the north-western and north-eastern parts of this area. There is a small outcrop in the western part of the area in Kokkiyanynsu River basin. The formation is represented by trachydacites, rhyodacites, rhyolites, their tuffs, ignimbrites and near-surface (subvolcanic) intrusive bodies of rhyodacites, rhyolites and granite porphyries which are related to the first ones. Intermediate, rarer basic volcanites associated with acid volcanites also occur.

In the north-western part of this area in Jergalan, Tyup and Chonjanalach rivers basins, contact between the formation and more ancient rocks is tectonic. It is overlapped with ravinement by Carboniferous rocks and is intruded by Early – Middle Devonian leucogranites, quartz monzonites, Middle Devonian granodiorites and Permian leucogranites. In the most complete and uniform section of the formation in the right bank of Chonjanalach River rhyodacites and their tuffs prevail, as well as ignimbrites being widespread. In the lower part of the section tuffs are agglomerate and gravel-lapilli, in the middle part they are psammitic, and in the upper part they are gravel-lapilli. On weakly weathered surfaces of the ignimbrites fiamme can be observed. Some layers of the rocks are from 24 to 330m in thickness. Incomplete thickness of the formation rocks in the section is 1654m. Thickness of gentle layers of the acid volcanites exceeds 800m in banks of Tyup River. There are single layers of andesites among the acid volcanites in Jergalan River basin.

In the north-eastern part of the researched area the Aksu Formation differs from the type sections of the formation by widespread trachyandesites and trachybasalts. It is closely related to the underlying Barkol Formation which was described together with the Kastek Formation as the Middle Devonian (by Gutermakher, 1978). The formation is overlapped by Carboniferous rocks. The most complete section of the Aksu Formation was described in the left bank of Ulkenkokpak River (by Gutermakher, 1978). In the apparent basement there are brown small-shingle conglomerates (10m), light brown polymictic grits (60m) and yellow thin-banded siltstones (8m). Above there are lavas of pinkish-brown, lavender dacites, cherry-brown andesite-dacites, amygdaloidal trachyandesites containing rare layers of tuffs and lava breccias (321m), lavas of dark-brown amygdaloidal trachyandesites (20m). Further above there are lavas of violet-brown, vinous rhyolites and their tuffs occasionally containing layers of lava breccias (265m). The rhyolites are usually fluidal, sometimes their texture is “roed” (spherulitic), which is typical for rhyolites of the Aksu Formation in many volcanogenic troughs of the Northern Tien-Shan. Red-brown small-shingle conglomerates overlie acid volcanites (8m). Lavas and lava breccias of brown, dark-brown trachybasalts complete the section (28m). The thickness of the section is 720m.

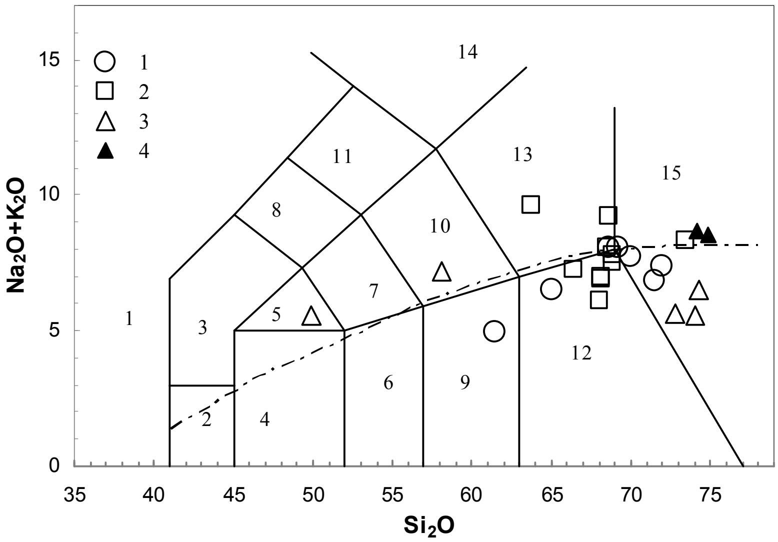

Fig. 5.1.1.1. Position of effusive and subvolcanic rocks of the Aksu Formation in the TAS diagram.

Fields (by Le Maitre et al., 1989): 5 – trachybasalts; 9 – andesites and quartz diorites; 10 – trachyandesites; 12 – dacites and granodiorite porphyries; 13 – trachytes, trachydacites; 15 – rhyolites and granite porphyries. The dot line indicates the low boundary of the subalkaline rocks spread (Bogatikov et al., 1981)

The legend: 1, 2 – basins of Jergalan, Tyup, Chonjanalach rivers: 1 – effusive rocks; 2 – rocks of subvolcanic bodies; 3, 4 – basins of Ulkenkokpak and Bayankol rivers: 3 – effusive rocks; 4 – rocks of subvolcanic bodies.

In the Tyup and Kokkiyanynsu interfluve the Aksu Formation rocks with conglomerates in the basement overlie the Cambrian – Lower Ordovician Turgenaksu Formation rocks and the Upper Cambrian – Lower Ordovician Tashtambektor Formation rocks. It is overlapped by intermediate volcanites of the Upper Devonian Aral Formation. Yellow plagiodacites, light gray dacites, psammitic tuffs of dacites, andesite-dacites lie on the conglomerates (by Grischenko, 1995). Overlying rocks are represented by yellow-gray lithic-crystal tuffs of plagiodacites and dacites containing less dacite lavas. Red- and dark-brown, lilac-gray andesite-dacites and their tuffs lie above. A horizon 30-40m thick of red-brown, brownish-gray tuffaceous and volcanic sandstones containing layers of lithic-crystall tuffs and trachyandesites completes the section. The formation thickness reaches 380m.

Subvolcanic rocks of the Aksu Formation (**λζπ,γπD1-2a**) are represented by stocks, linearly stretched bodies, dikes and sills with different thickness. Central parts of the bodies are usually composed of rocks with clear crystal structure (granite porphyries, granosyenite porphyries). There are cryptocrystalline structures often containing fragments of host rocks around the bodies. The rhyolites and rhyodacites are characterized by fluidal texture that is subparallel to the contacts with host rocks.

The chemical content of the formation rocks is determined by 29 samples (see geochemistry catalogue). Figurative points of effusive and subvolcanic rocks are shown in the TAS diagram (fig. 5.1.1.1).

Changes in the compositions of the rocks in the section along the left bank of Ulkenkokpak River are prenounced with the replacement of trachyandesites by rhyolites and the rhyolites by trachybasalts. In the western part of the researched area the content of the rocks is more homogeneous. It is differentiated from andesite-dacites to rhyolites.

According to the classification (Le Maitre et al., 1989) almost all of the researched rocks can be categorized as having a high percentage of potassium, only rarely are they moderately potassic. The ratio K_2O/Na_2O varies from 0.23 to 2.20. The lowest ratios (up to 0.53) are determined in trachybasalts, andesites and trachyandesites.

Chemical content of rhyodacitic ignimbrites does not differ from content of rhyodacites, but rhyolitic ignimbrites are characterized by very high percentage of SiO_2 that increases 77.2% and can reach 80.7%.

Fossils were not discovered in this formation's rocks. There is one U/Pb dating for rhyodacite (isotope age catalogue). The age determined as 382Ma conflicts with geological data. The Early – Middle Devonian age of the formation is determined by its position in the section, intrusion by Early – Middle Devonian granites and comparison with rocks similar on the content which compose volcanogenic troughs outside the researched area.

Compiler : F.Kh. Apayarov

Aral Formation (D_3ar). The type section of this formation is located outside the investigated area in the western part of the Kyrgyz Range (by Malygina, Dodonova, 1972; by Osmonbetov, Knauf, 1982).

The Aral Formation rocks spread in the western part of the researched area between Tyup and Kokkiyanynsu rivers, in Kokkiyanynsu River basin. The formation rocks overlie the Aksu Formation rocks and underlie the Middle Carboniferous carbonate-terrigenous Tyup Formation rocks. The formation is dominantly represented by greenish-gray, dark-brown, brownish-gray amygdaloidal trachyandesites, andesites, rarer trachytes and their tuffs. There are greenish-gray and vinous basalts, trachybasalts, greenish – light gray plagiodacites. The plagiodacites are usually located in the middle part of the section. There is a horizon up to 30m thick and 3km of length of brown, dark-brown tuff-conglomerates, psammitic and psephitic lithic-crystal tuffs in the basement of the formation. The formation thickness in the right bank of Kokkiyanynsu River is 373m. Eastward the thickness reaches 480m (by Grishenko, 1985).

The chemical content of the formation rocks is determined by 5 samples (see geochemistry catalogue). In the TAS diagram figurative points are concentrated in the fields of andesites and trachyandesites; one point is located in the field of basalts. The rocks according to their position in the diagram SiO_2–K_2O belong to rocks with high percentage of potassium and belonging to the potassium-sodium type of alkalinity (K_2O/Na_2O = 0.76-1.71).

Fossils were not discovered in the formation. The Late Devonian age of the formation is determined by its position in the section and comparison with rocks of a similar content which compose volcanogenic troughs outside the researched area.

Compiler: F.Kh. Apayarov

5.1.2. Intrusive formations

Sauruksai Formation (**$q\xi,q\mu,\xi\gamma,\varepsilon\gamma,l\gamma D_1s$**). We separated it out of the Late Ordovician – Silurian Aktash Formation (Gutermakher, 1978) and Early – Middle Devonian Formation of monzodiorites and granosyenites (Esmintsev, 1989). It spreads in the north-eastern part of the investigated area. Massifs composed of the formation rocks are located in the zones directed in the north-west. The Brondoturuk Massif is classified as the described formation as well. It is located more west, between Turuk and Chonjanalach rivers. The area composed of the formation's rocks is nearly 300km^2. The type Sauruksai Massif (17km^2) is located in the banks of Keksentas River, to the north of the Sauruksai River mouth.

The formation is represented by quartz syenites, granosyenites, subalkaline granites, rarely monzodiorites and quartz monzonites. Granites are represented by hornblende-biotite, biotite and leucocratic types. Quantitative sense of rocks varies appreciably in various massifs. The largest (near 90km^2) Kopyl Massif is generally composed of bright orange coarse-grained granosyenites and granites. The type Sauruksai Massif is dominantly represented by gray coarse-grained, usually porphyritic quartz syenites and granosyenites. The Borondoturuk Massif is composed of pinkish-gray, gray medium-grained porphyritic granosyenites and equigranular quartz monzonites.

Petrochemistry. The chemical content of the formation rocks is determined by 32 samples (see geochemistry catalogue). The rocks belong to the subalkaline series (fig. 5.1.2.1).

Percentage of K_2O in the rocks is 3-8% (average percentage is 5%) and insignificantly exceeds percentage of Na_2O (ratio K_2O/Na_2O is 0.87-2.0; average ratio is 1.37).

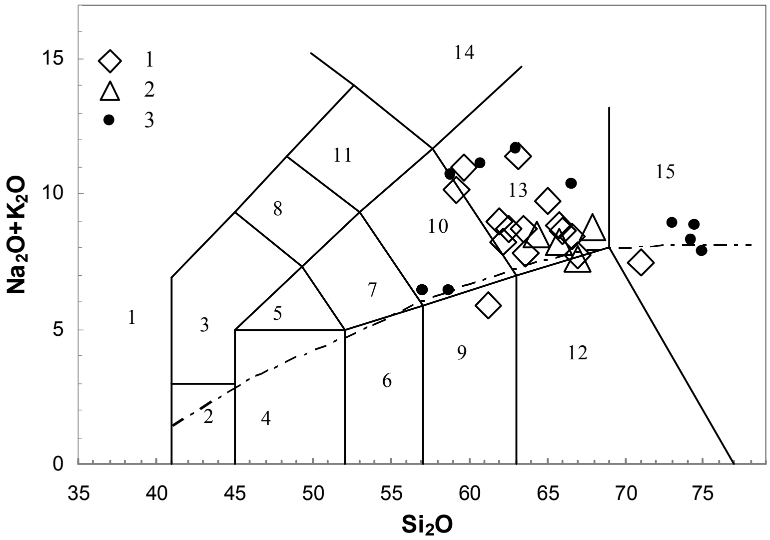

Fig. 5.1.2.1. Position of the Sauruksai Formation rocks in the TAS diagram

The dot line indicates the low boundary of the subalkaline rocks spread (Bogatikov et al., 1981)

Fields (by Middlemost, 1994): 9 – diorites; 10 – monzonites; 11 – felspathoid monzosyenites; 12 – granodiorites; 13 – syenites, quartz monzonites; 14 – feldspathoid syenites; 15 – granites.

Legend: rocks of the Sauruksai Massif (1), rocks of the Borondoturuk Massif (2) and rocks of the rest formation massifs (3).

Age. The Sauruksai Formation rocks intrude the Lower Paleozoic rocks, granitoids of the Late Ordovician – Early Silurian Aktash Formation and are intruded by granites of the Early – Middle Devonian Bazunbai Formation. The Lower Carboniferous red sandstones lie on a ravinement on the granosyenites of the Borondoturuk Massif. There are 3 K/Ar and 7 U/Pb datings for the formation rocks (isotope age catalogue). Similar ages were defined for quartz monzonites in the left bank of Ashutor River on biotite (403±10Ma) and on zircon (414±7Ma). The age of zircons from quartz monzonites of the Sauruksai Massif is 400±8Ma and the age of zircons from granosyenites is 413±8Ma. Isochronous age of zircons from granosyenites of the Borondoturuk Massif is 412±28Ma.

Available data allows the age of the Sauruksai Formation to be determined as the Early Devonian.

Compiler: F.Kh. Apayarov

Alama Formation ($D_{1-2}al$). It was determined by Zakharov I.L. in 1988. The type massif is located in the western part of the Kyrgyz Range and is composed of rocks formed during 3 phases (Apayarov, 2007). Within the investigated area the formation rocks spread locally in the north-western part of the area. They occupy less than 10km^2 and form 3 small massifs. The formation is represented by rocks of phases 2 and 3 in the investigated area.

Phase 2 **($\varepsilon l\gamma_2 D_{1-2}al$)** is represented by bright pink and pinkish-gray medium- and coarse-grained porphyritic granites (the Terimtorbulak Massif) and leucogranites. Porphyritic phenocrysts (with sizes of up to 3cm) are represented by microcline.

Phase 3 **($l\gamma,\gamma\pi_3 D_{1-2}al$)** is represented by pink-red, pink and grayish-pink fine-grained granites and leucogranites, granite porphyries.

Petrochemistry. The chemical content of the rocks was determined in one granite sample (see geochemistry catalogue). Percentage of SiO_2 and Na_2O+K_2O is accordingly 70.80 and 7.93%. Ratio K_2O/Na_2O equals 1.22.

Age. The formation rocks intrude granites of the Late Ordovician – Early Silurian Suusamyr Formation, acid volcanites of the Lower – Middle Devonian Aksu Formation. There are 1 K/Ar and 1 U/Pb datings for the rocks (isotope age catalogue). Age of the fine-grained granites intruding the acid volcanites of the Aksu Formation is determined on zircon and is 412±6Ma. Age of the porphyritic granites on biotite is 413±12Ma.

We accept the age of the Alama Formation as the Early – Middle Devonian.

Compiler: F.Kh. Apayarov

Bazunbai Formation ($\gamma,\varepsilon\gamma,l\gamma D_{1-2}b$). We separated it out of the Devonian Bayankol Formation (Gutermakher, 1978). The formation is spread in the north-eastern part of the investigated area. The formation composed of the large Bazunbai Massif and several small massifs with the total area of about 50km^2. The type Bazunbai Massif (near 45km^2) represents an intrusion bounded in the south and north with faults and trending to the west-north-west for 24km from Bayankol River to Ulkenkokpak River.

The basic content of the Bazunbai Formation is represented by medium-, coarse-grained, equigranular and porphyritic leucocratic biotite granites which are usually greisenized. Content of biotite is within 1-5% and usually increases up to 10% in places where intrusive bodies contact with host rocks. The thickness of biotite granites in internal contacts of intrusive bodies reaches 100-150m (Gutermakher, 1978). There are granosyenites and quartz monzonites in small amounts. There are widespread pegmatite veins and aplite dikes. Greisenized leucogranites with pegmatites in the left bank of Aktas River form the Karagaily-Aktas Dyke-

Apophysis well-known in the area. It trends in sub-lateral direction for 1700m. The thickness reaches 100m.

Petrochemistry. The chemical content of the formation rocks is determined by 7 samples (see geochemistry catalogue). Percentage of SiO_2 is within 68.03-75.46%; percentage of Na_2O+K_2O varies from 7.10 to 9.10%. K_2O/Na_2O = 0.79-2.62; average ratio is 1.53. The rocks belong to the potassic-sodium subalkaline series.

Age. The Bazunbai Formation rocks intrude the Lower Paleozoic rocks, granitoids of the Late Ordovician – Early Silurian Aktash Formation and Early Devonian Sauruksai Formation. There are 12 K/Ar dates for the formation's rocks (isotope age catalogue). They were determined on muscovite from different rocks of the Karagaily-Aktas Dyke-Apophysis. The age in the 7 most ancient dates is within 390-414Ma. The age of the leucogranites is determined in 3 samples: 397±7, 404±20 and 405±20Ma. Additionally, the age of biotite from subalkaline granites from the left bank of Bazunbai River is 390Ma (Gutermakher, 1978).

Available data allows the age of the Bazunbai Formation to be determined as the Early – Middle Devonian.

Compiler: F.Kh. Apayarov

Joldusai Formation (qμ,γδD_2?j). It was determined by Severinov V.A. in 1990. It is found in the north-western part of the investigated area, in Jergalan, Tyup and Uchkashka river basins. The formation rocks compose 3 massifs and small bodies with the total area of up to 12 km^2. The type Joldusai Massif (about 4 km^2) is located between the Jergalan and Tyup rivers.

The formation is represented by greenish-gray, pinkish-gray medium-grained often porphyritic quartz monzodiorites, quartz monzonites and granodiorites. There are quartz diorites in small amount. The typical feature of the formation is high content of pyrite and magnetite.

Petrochemistry. The chemical content of the formation's rocks is determined by 11 samples (see geochemistry catalogue). The rocks belong to the subalkaline and calc-alkaline series. (fig. 5.1.2.2). The percentage of K_2O in them is within 2.35-5% and exceeds percentage of Na_2O in all analysis except one. K_2O/Na_2O = 1.19-1.91; in one case K_2O/Na_2O = 0.76. In comparison with similar rocks of other formations iron content is higher. General percentage of FeO is 4.08-6.03%, average percentage is 5.18%.

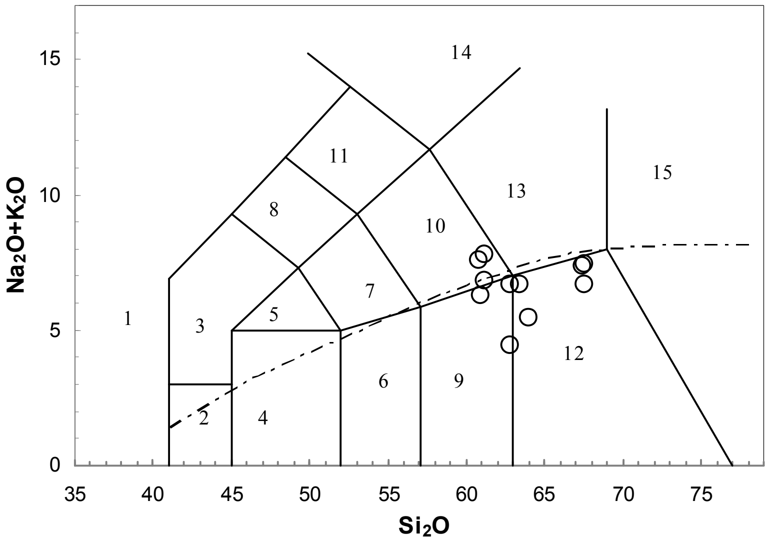

Fig. 5.1.2.2. Position of the Joldusai Formation rocks in the TAS diagram

The dot line indicates the low boundary of the subalkaline rocks spread (Bogatikov et al., 1981)

Fields (by Middlemost, 1994): 9 – diorites; 10 – monzonites; 11 – felspathoid monzosyenites; 12 – granodiorites; 13 – syenites, quartz monzonites.

Age. Rocks of the Joldusai Formation intrude Late Ordovician granodiorites and quartz monzonites of the Almalysai Formation, Late Ordovician – Early Silurian granites of the Suusamyr Formation, acid volcanites of the Lower – Middle Devonian Aksu Formation. The formation is overlapped by conglomerates of the Lower Carboniferous Kyzyljar Formation and the Upper Carboniferous Tyup Formation and is intruded by Permian granites and leucogranites of the Achiktash Formation. Age is determined by 2 samples with the K/Ar age method (isotope age catalogue). On biotite from quartz monzonites the age is 459±15Ma, on biotite from syenite porphyries it is 469±20Ma. The above-mentioned geological data, as well as the fact that small bodies and massifs of Early- Middle quartz monzonites and quartz monzodiorites occur in Devonian volcanogenic troughs (Osmonbetov, 1982; Apayarov, 2007) allow the age of the Joldusai Formation to be determined as the Middle Devonian.

Compiler: F.Kh. Apayarov

Donarcha Formation (μδ, γξ D3d). We separated it out of the Early – Middle Devonian Kyzylsu Formation of syenites-granosyenites (Esmintsev, 1989). It is located in the eastern part of the investigated area. The formation rocks compose a massif (the area is less than 6km^2) which is a joint intrusion. The intrusion trends to the west from Sauruksai River to Ashutor River for 16km. Its width varies from 350 to 900m.

The formation is represented by gray monzodiorites, quartz monzonites and abundant bright pink to orange leucocratic syenites, granosyenites usually containing orthite. The monzodiorites are intruded by granosyenites (Esmintsev, 1989).

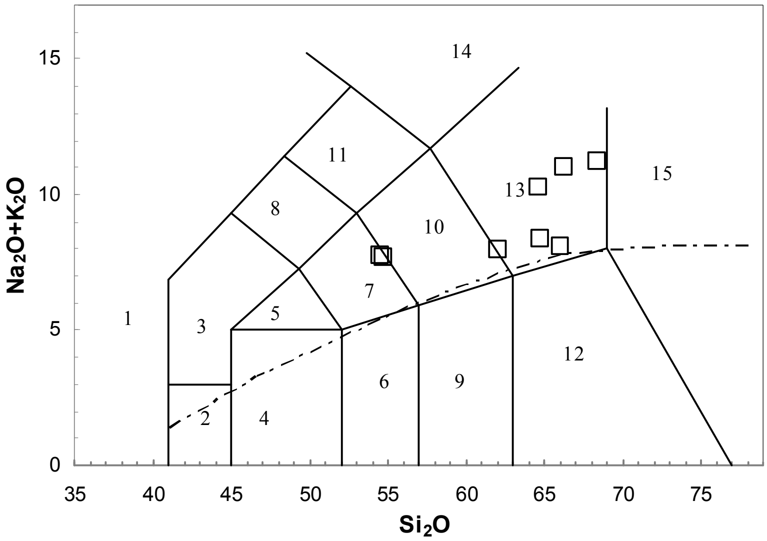

Fig. 5.1.2.3. Position of the Donarcha Formation rocks in the TAS diagram

The dot line indicates the low boundary of the subalkaline rocks spread (Bogatikov et al., 1981)

Fields (by Middlemost, 1994): 7 – monzodiorites; 10 – monzonites; 13 – syenites, quartz monzonites.

Petrochemistry. The chemical content of the formation rocks is determined by 8 samples (see geochemistry catalogue). The rocks belong to the subalkaline series (fig. 5.1.2.3). The percentage of Na_2O in the monzodiorites exceeds that of K_2O (K_2O/Na_2O = 0.55-0,60). The K_2O/Na_2O ratios in the quartz monzonites and granosyenites are from 0.94 to 1.55.

Age. The Donarcha Formation rocks intrude metamorphites of the Middle Riphean Sarytor Formation and rocks of the Vendian(?) – Early Cambrian Accretionary complex. There are 2 K/Ar and 6 U/Pb datings for the formation rocks (isotope age catalogue). Similar ages using 3 isotope ratios were determined on zircons from the monzodiorites (samples 13571, 13042): 376 and 372Ma accordingly. Samples of the granosyenites (1211-1, 1211-2, 1211-3, 1211-4) were collected within one outcrop. The age of zircons from the granosyenites was determined by isochron and equals 377±13Ma (fig. 5.1.2.4). One microcline from the granosyenites (Sample 1211-3) was dated at 228±15Ma by the K/Ar age method. Uranium-lead isochronous age of zircons from the granosyenites and monzodiorites equals 376.0±8.3Ma (fig.

5.1.2.5). Pb/Pb isochronous age on the same zircons was determined as 376.3±7.4Ma, MSWD = 0.47.

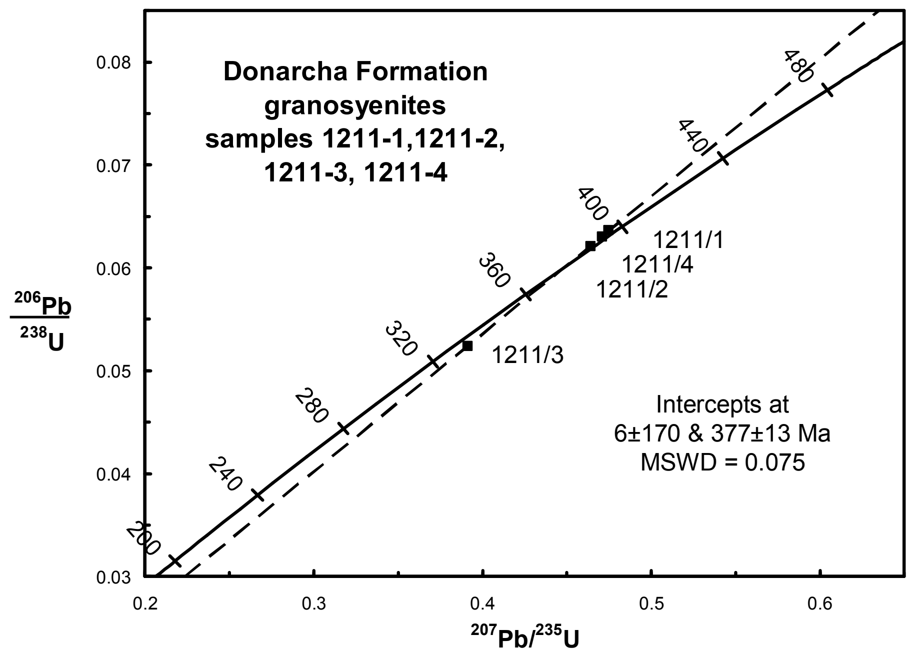

Fig. 5.1.2.4. Concordia diagram for zircon U-Pb data from granosyenites.

Zircons from the Donarcha Formation rocks differ from zircons from monzodiorites, quartz monzonites and granosyenites of more ancient formations of the area and are characterized by a high ratio of the radiogenic ^{208}Pb to the radiogenic ^{206}Pb. Ratio $^{208}Pb/^{206}Pb$ in zircons from the granosyenites equals 0.393-0.423, from the monzodiorites equals 0.295-0.322.

Available data allows the age of the Donarcha Formation to be determined as the Late Devonian (Frasnian).

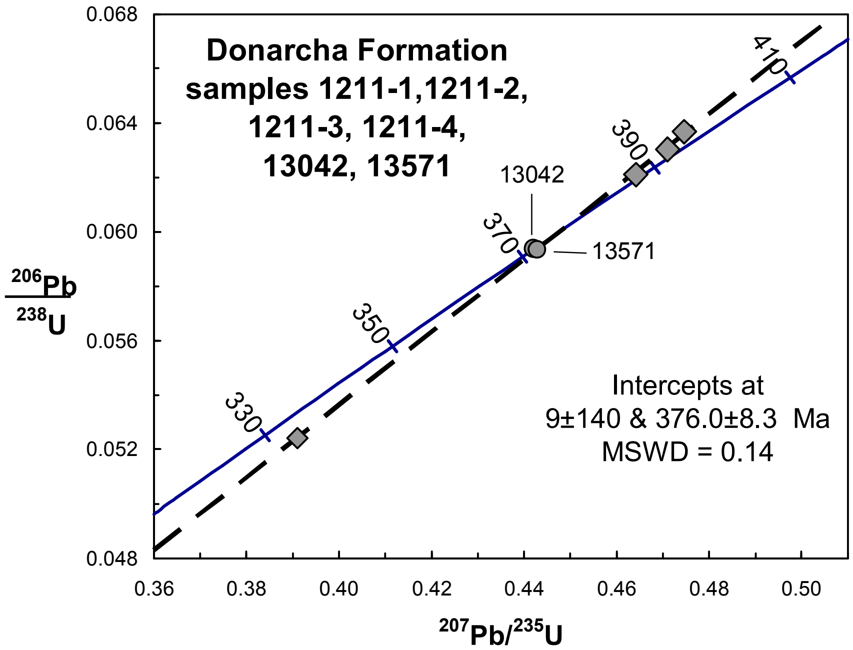

Fig. 5.1.2.5. Concordia diagram for zircon U-Pb data from granosyenites and monzodiorites.

5.2. Karatau-Naryn carbonate platform

Kuilyu-Saryjaz section type

The Late Paleozoic sediments of the Middle Tien-Shan (since Givetain to Bashkirian) formed within the passive continental margins and composed wide shelf basin spread from Bolshoi Karatau Range in the west to the East Akshyirak Range (Mikolaichuk, Djenchuraeva, 2000; Cook et al., 2002; Alekseiev et al., 2008). Within this 1000 km long zone, formations are kept in a surprisingly uniform order that is described in detail in the Moldotau Range as the Kavak section type (Khristov, 1971). Pinching-out of section's lower unit (Tyulkubash formation) and the occurrence of volcanic deposits are observed in some sections of the Kuilyu-Saryjaz region. Such changes of geological structure allow us to assume the Late Paleozoic of that region is an independent section type.

Tyulkubash Formation (D_{2-3} tl). Widely spread within the Middle Tien-Shan, from the Central Karatau (Kazakhstan) on the west to the Saryjaz range on the east. The formation was described by Veber V.N. in 1935, and its name originates from the Tyulkubash mountain where its stratotype lies (Zanina, Lihareva, 1975). The fullest sections of the Tyulkubash Formation lie along the Airtash River, in the Akshyirak range (western) and in the Jetym range (Airansu river basin) where it has a ternary structure.

The formation's lower part (400-800 m) consists of the variable-pebble conglomerates and which are replaced by the red-colored sandstones with siltstone interbeds in the separate areas. The middle part (450-1200 m) consists of the red sandstones and siltstones with a limited number of lenses and interburden of gritstones. The upper part (350-450 m) consists of the red siltstones and shale with minor occurrences of sandy limestones.

Within the studied area the Tyulkubash Formation is spread in the middle (interfluves of the Mykachi and Tez streams) and the upper course of the Saryjaz River (interfluves of the Echkilitash and Kengsu streams) where it lies on the Cambrian and Early Ordovician sediments in the sharp angular unconformity. Present in the lower part of the section there are red coarse-grained sandstones with the floating pebbles of rounded and semi-rounded cherts and granites. There are also some rare lenses of red siltstones and fine-pebbled conglomerate interbeds among the sandstones. That part is 400 m thick. The upper part of the formation is represented by calcareous sandstones with limestone and red siltstone interbeds, where grey sandstones enriched by the phytodetritus appear. Transformation into the overlying Jalbakan formation's limestones is gradual. The upper part is 270-300 m thick (Severinov, 1990).

The formation age is proved by the fossils of the Middle and Upper Devonian fishes collected in the Chatkal region's sections (Osmonbetov, Knauf 1982). The offered age is confirmed by the finding of new club-moss formal taxon *Tujukophton gen. et sp. nov* in the investigated area *(*fauna catalogue, site 294*)*.

Compiler: A.V. Neyevin

Jalbakan Formation (D_3fm db). The formation was defined first by Skvortsov V.P. in 1964, in the research of the Upper Devonian section in the Kassan region. Named by Gushin S.B. (Djenchuraeva, 1990) after the Jalbakan stream (Chatkal Range) where the described sediments are fully displayed, and is where the Lectostratotype of the formation is located. The formation is divided into two parts. The lower part is represented by the red sandstones and siltstones, replaced by the calcareous shales with interbeds of clayey and sandy limestones. Dolomite and shelly limestones prevail in the upper part of the formation, with interbeds of gypsum and anhydrites appearing here and there. The formation is 50 to 1300 m thick within wide area.

In the investigated area the Jalbakan formation forms a narrow block from the west till the Taldybulak River in the east, occurring along the south-eastern slope of the Saryjaz Range. Jalbakan Formation is divided there into two parts by its lithologic composition. A layer of conglomerates 5-6 m thick occurs at the apparent base of section. Grey and black siltstones, calcareous shales, fine-grained polymict and calcareous sandstones, yellowish-white limestones with the carbonaceous material, marly limestones and marls lie above. The lower part is 200 m thick. The upper part of section is separated from the lower one by the horizon of fine and medium-pebbled conglomerates of 35 m thick. The motley calcareous shales, marls with yellowish-white limestones and polymict sandstones interbeds occur above, and form a 475 m thick part.

Additionally, the Formation sediments also occur on the right bank of the Saryjaz River, in the interfluves of Tuyuk and Echkilitash Rivers, where it conformably lies on the Tyulkubash Formation sandstones. The Formation at this location is similar to the composition described above.

Jalbakan formation sediments within the mapped area are poor in terms of organic fossils: only solitary foraminifers and corals (rugoses)of the Late Famennian exist (fauna catalogue, site 41, 48, 54, 66).

Compiler: A.V. Neyevin

Arpatakyr Formation (D_3-C_1ar) was first described by Zakharov (Knauf, 1971) as the Taldysu formation. As this name was also used for a formation of Late Devonian volcanites in the Kyrgyz Range, it was changed by Dodonova T.A. (1974), who offered the current name after the Arpatakyr valley located among the Kuilyu River and its right tributary, the Kursai River. The formation deposits compose two strips of east-west strike. Northern strip outcrops in the Saryjaz, Mukachi and Karagaite Rivers valley for 8 km, with outcrops in the Kurskai River's (right tributary of the Kuilyu River) left bank being referred to the same strip. A stratigraphic overlapping of the formation sediments on the uneven eroded surface of the Late Riphean granites (Saryjaz Formation) had been determined there. Grey massive limestones up to 10 m thick containing Late Devonian foraminifers (fauna catalogue, site 208) outcropped at the formation bottom, on top of which lies red agglomerate tuffs, the volcanic bombs of which represent alkaline basalts, comprising 25 to 75% of the rock's content. These tuffs are overlapped by the alkaline basalts. The volcanogenic deposits are no more than 50 m thick (Malygina, Dodonova, 1972; Grishenko, 1985). The most complete section of the northern strip outcrops along the Mukachi river basin. Brown basalt tuffs with siltstone interbeds and flows of amygdaloidal trachybasalts and lava-breccias of 3-8 m thick are found in the section bottom. Up-section Vulcanites prevail, which are represented by amygdaloidal alkaline basalts, aphyric basalts, trachyandesites and their clastolavas. Agglomerate and lapilli tuffs are minor. Brown or vinous-brown rock colors prevail; while green-grey ones are rare there. The section is 855 m thick (Grishenko, 1985).

The Southern strip outcrops in the Tez river headwaters and traced for 15 km. Arpatakyr formation lays there with angular unconformity on the Tez formation sandstones (Grishenko, 1985). The Tez River section differs from the previously described one because of the significant volume of terrigenous-carbonate deposits. According to our observations carried out together with E.V. Khristov in 1981 the limy various-pebbled conglomerates with grey sandy cement are outcropped in the apparent formation bottom (6-8 m). Dark-grey siltstones, black micro-bedded clayey limestones, light-grey or beige glossy dolomites (70 m) overlap conglomerates. Green aphyric basalts and clastolavas (~ 100 m) lie above with the 10 m layer of red-brown tuff-siltstones in the bottom which are sampled for the chemical analysis (geochemistry catalogue, sample 354). Effusives, in their turn, are overlapped by the carbonate deposits (about 80 m), among which occur black medium-pebbled limestones with rare interbeds of grey-green thinly-bedded cherts, similar to the Late Tournaisian sediments of the Kavak section. According to the data (Grishenko, 1985) the Arpatakyr formation does not exceed 375 m in the southern strip and equally represented by basalts, tuffs and terrigenous-carbonate deposits. Several basalt outcrops of 1-2 km^2 explored in the eastern part of the Saryjaz Range are attributed to the described deposits conditionally.

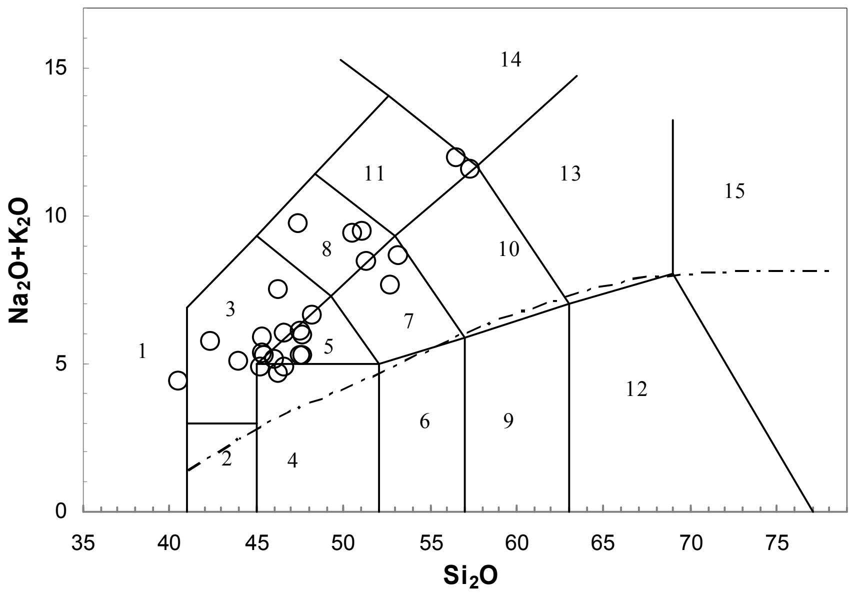

Fig. 5.3.1.1. Composition of volcanic rocks from the Arpatakyr Formation in the TAS diagram.

Fields according to Middlemost (1994): 1- foidite; 3 tephrite – basanite; 4- basalt;5- trachybasalt; 7- basaltic trachyandesite; 8 - basic feldspar rocks; 10 – trachyandesite. Dotted line is lower boundary of sub-alkaline rock compositions (Bogatikov et al., 1981).

The chemical composition of the Formation's effusive rocks is defined by 25 samples (see geochemistry catalogue). Their figurative points are located in fields of subalkaline and alkaline rocks (Fig. 5.2.1.1). High content of K_2O (fig. 2) is characteristic for effusive rocks. The K_2O/Na_2O ratio varies from 0.12 till 4,83. Thus in most samples (72 %) amount Na_2O exceeds K_2O content.

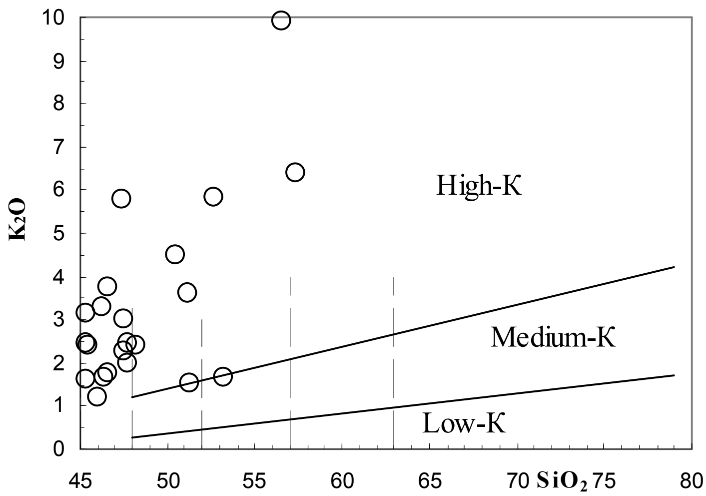

Fig. 5.3.1.2. Content K_2O in volcanic rocks from the Arpatakyr Formation.. Fields according to Middlemost (1994)

Algae and foraminifers of the Late Devonian and Tournaisian (fauna catalogue, site 81, 208, 311) are collected in the Arpatakyr formation limestones. Since limestones and dolomites along the Tez River are very similar to the Jalbakan formation deposits then we admit that they had facial correlations and we assume the Late Devonian- Early Carboniferous age for the Arpatakyr Formation.

Compiler: A.V. Mikolaichuk

Tuyukkan Group (C_1 tk). This group's sediments were first defined by Zaharov I.L. in 1971. The name was offered by Grishenko V.A. (1985) after the Tuyukkan valley, located on the south-eastern slope of the Saryjaz Range. Deposits of Tuyukkan Group lie conformably on the Jalbakan formation. The base of the Group consists of sedimentary limestone breccias of 10-15 m thick, above which lies dark-colored bedded detrital and occassional bituminous limestones divided by the variably oriented calcite veins. Lenses, thin interbeds and irregular-shaped black cherts' concretions occur there widely. Gypsum interbeds to 6 m thick occur rarely among the limestones. The group is 480-600 m thickness.

The age of Tuyukkan Group is shown by the presense of foraminifers of the Tournaisian and the lower part of Late Visean (fauna catalogue, site 57, 73). Tuykkan group is similar by its stratigraphic content to the Sonkul, Akchetash, Japryk and Karakiya formations of Southern Sonkul side (Burg, Mikolaichuk, 2008).

Compiler : A.V. Neyevin

Karashilbi Group (C_{1-2} kr). Sediments of the group were first described by Zaharov I.L. in 1971. The name was given by Grishenko V.A. (1985) after the Karashilbi Stream (Saryjaz Range). The Group consists of light, reddish-grey massive limestones often densely networked by variably oriented calcite veins which gradually replace dark thin-bedded limestones with cherts of Tuyukkan group. Karashilbi Group's sediments are 350-650 m thick.

The age of the group is determined by the numerous findings of foraminifers (Zaharov, 1971; Severinov et al, 1990 and current research) in the interval of the Late Visean –Bashkirian (fauna catalogue, site 68, 233, 308,309). Karashilbi group is similar to Itelguya and Mingjilkiy Formations of the Southern Sonkul side by its stratigraphic content (Burg, Mikolaichuk, 2008).

Compiler : A.V. Neyevin

Kyzylbulak Formation (C_2 kb) defined by Zaharov I.L. in 1971, named by Grishenko (1985) after the Kyzylbulak River (Saryjaz Range). Sediments of the formation are developed on the small sites in the paraxial part of the range where they lie unconformably on the Karashilbi Group. Sections of Kyzylbulak formation display henna-red fine-pebbled conglomerates with well rounded pebbles which comprises cherty rocks and limestones. Red anisomerous sandstones with siltstone and shale interbeds occur among the conglomerates. The formation's observed thickness is 280 m.

Kyzylbulak formation is the upper member of joint Paleozoic section of described area. Within the investigated area the formation rocks are poor by the organic fossils. Their age is determined by algae and other fossil fragments as the Moscovian (fauna catalogue, site 181, 310). Re-deposited corals of Devonian age also occur there (fauna catalogue, site 80).

Compiler : A.V. Neyevin

5.3. Sonkul – Turuk basin

5.3.1. Stratified formations

< (Double click to view the stratigraphical columns)

Echkilitash section type

Kensu Formation (C_1kns) is traced as a narrow band (no more than 2 km wide) for 75 km from the Ottuk River head in the west to the Saryjaz River head in the east. Authors of 1: 50 000 surveys (Grishenko, 1985; Severinov, 1990) described these sediments under the different names defining more than 5 Carboniferous age formations in the mentioned area. Revision itinerary have proved to us that a olistostrome complex which formed on the continental slope is developed there and represented by breccias, conglo-breccias or olistoplaques of different ages. Psammitic, siliceous or carbonate deposits of background sedimentation replace along strike a cone of coarse deposits. The most representative formation section showing all the range of facial changes lies along the Kensu River, which we offer to define as the stratotypic one (Chernyshuk et al., 1989; section 335).

In the Ottuk-Kensu interfluve on the eroded surface of the Late Riphean lies the various-grained arkosic sandstones with siltstone lenses, which are at first tens of meters thick. Above the basal horizon the section is consists of black limy siltstones, shales, grey slime limestones, green cherts and siliceous shales, which are thinly interbedded (350 m). In the section’s middle part which is 590 m thick, the limestone volume increases to 50% and the layers of breccia limestones and carbonate breccias occur. Further up-section there is a 40 m thick portion consisting of fine-clastic limy breccia.

Eastward thin-bedded autochthonic sediments along the Kensu River are facially replaced by breccias and 5 km to the south the formation section completely consists of breccias which lie unconformably on the Famenian oolites (Jalbakan Formation). The breccia section is more completely investigated along the Tuyuk River (Chernyshuk et al., 1989; section 165. Severinov, 1990; section 18). According to opinion of the authors mentioned above in the formation bottom of the Tuyuk-Echkilitash interfluve the co-sedimentation breccias and limestone conglomerate-breccias are present. The fragments size varies from gruss to the blocky ones. Breccias are not sorted by the clastic materials' size. The main part consists of grey thinly-bedded dolomite fragments, marl, detrite and pelitomorphic limestones and calcarenites, with rare oolites and siliceous limestones present as well. Cement is limy or marly, rarely calcite and crustified ones. Gradual transition on strike from breccias to normal bedded limestones which are apparently olistolithes are observed there. That section part is 100-250 m thickness. Numerous Late Tournaisian and Early Visean algae and foraminifer fossils have been found in the carbonate fragments. Up-section which is 360-470 m differs with better rounded and sorted clastic material and the content of fragments is more diverse. Fragments of the Jalbakan formation sediments (Famenian) and olistolithes consisting of Shortor Formation sediments or Saryjaz granites occur in breccias. The last ones had been mapped as the tectonic blocks in the field of carbonate breccias (Severinov, 1990). Breccias alternate with interbeds of autochthonic crinoidal-detrite limestones similar to ones from the section along the Kensu River and contain foraminifers of the Late Visean. To the east from the Mintur River the formation outcrops along the both banks of the Saryjaz River, where the breccias (conglomerate-breccias) content diminishes and the formation section becomes equivalent to the one along the Kensu River.

Total formation thickness varies from 450 m to 959 m. Foraminifers of the Faminian, Late Tournaisian and Early Visean (fauna catalogue, site 42) are found in the carbonate breccias as the known autochthonic rocks are described by the Late Visean brachiopods and foraminifers (fauna catalogue, site 29,37, 38 49, 61,64, 71, 180). Points 37 and 38 are the key ones for the formation age assessment, since they contain foraminifers of the Late Visean and reworked brachiopods of the early Visean. Thus the Kensu Formation is defined as the Late Visean one.

Compiler: A.V. Mikolaichuk

Echkilitash Formation (C_1eč). The formation is limited by the Echkilitash –Tuyuk streams interfluve. The outcrops total area does not exceed 16 km^2. The formation is defined by S.B. Gushin in the process of unification of the region stratigraphic scheme (Chernyshuk et al., 1989). The stratotype section lies along the Echkilitash stream, the right tributary of the Saryjaz River where the described formation lies conformably on the limy breccias of the Kensu formation. Thin-tabular calcareous shales and calcareous sandstones with the crinoidal-detrite limestone interbeds are spread in the bottom part of the formation. The last ones become predominant rocks in the up-section. The bottom part is 185-225 m thick. The formation top part consists of clastic, crinoidal-detrite and pelitomorphic limestones, calcareous shales and green-colored limy ashy tuffites. That part is 375-380 m thickness. Total thickness of the formation is 560-605 m. The formation age is determined by the Serpukhovian foraminifers and algae findings (fauna catalogue, site 44, 45, 50-52).

Compiler: A.V.Neyevin

Ayusai section type

Turuk Formation (C_1tr) defined during a survey of 1: 200 000 scale (Mozolev, Zakharov, 1963), with the name being suggested by Grishenko V.A. (1985). The formation is traced as two strips of E-W strike within the watershed part of the Terskey Range. The Stratotype section is on the northern slope of the Terskey Range, in the Turuk River headwaters where the described sediments lie following erosion on the Devonian monzonites or overlie an angular unconformity with the Early Paleozoic formations. In the first case the formation bottom contains an arkosic layer consisting of unsorted sandstones and gritstones (to 250 m), which are alternated by the polimict unsorted conglomerates (to 80 m) in the up-section and along strike. Pebbles within conglomerates represent Early Paleozoic basement rocks (granitoids, marbles, graphitic shales, effusives). Fragments' size varies from fine pebbles to boulders. Pebble amounts vary greatly, although generally they account for about 80% of the rock volume. The matrix in conglomerates is either sandy or occasionally limy. The Turuk Formation section above the basal horizon is represented by a rhythmical alteration of sandstones and siltstones. Layers are 5-30 cm thick. Thin-bedded rock structures are typical there, grey-green color rocks prevail and lilac or brown are rarer. The formation up-section contains conglomerate-gritstone horizons (3-20 m) among sandstones and siltstones. Allochthonous materials (granites, limestones and rhyolites) and angular fragments of siltstones and sandstones of the described layer are among the fragments. The Turuk Formation is 1000-1300 m thick (Severinov et al., 1990). Sparse findings of brachiopods and floristic fossils allow the Early Carboniferous age of the Turuk Formation to be defined (fauna catalogue, site 175, 194, 213). We assume that described sediments are limited by Visean by analogy with the Kensu Formation of the Echkilitash section type.

Compiler: A.V. Mikolaichuk

Ayusai Formation (C_1as) is defined in the process of 1: 200 000 scale survey (Mozolev, Zakharov, 1963), and the name was offered by S.B. Gushin (Chernyshuk et al., 1989). Outcrops of this formation’s sediments are observed in the watershed part of the Terskey Range from the Turuk River to the eastern border of the described area. Stratotype section is on the northern slope of the Terskey Range along the Ayusai River (Mozolev, Zakharov, 1963). According to the data of the authors mentioned above (Ayusai River) and according to our observations spent in the Jaak River valley, the Turuk Formation ends with the horizon of dark grey shales with interbeds of pelitomorphic limestones. Black shales lie above with a gradual transition (40 m). They are overlapped by massive-layered organogenic limestones with the brachiopods and corals fossils alternating in the section by light-grey massive crinoidal, marmorized or dark-grey dolomitic limestones (400-580 m). Share of terrigenous deposits enlarges in the up-section. It begins with horizon of hard greenish-grey limy siltstones. Dark-grey thin-bedded calcarenites alternate with brachiopod limestones within the section (300-500 m). Black carbonaceous limestones equally interbedded by limy siltstones complete the formation section (450-550 m). Total formation thickness varies within 1150-1600 m. The formation Late Visean –Serpukhovian age assumed on the basis of numerous brachiopods and foraminifers findings (fauna catalogue, site 29, 114-119, 176-179,182, 232).

Compiler: A.V. Mikolaichuk

Karakyr Formation (C_1krk) defined by S.B. Gushin next to the western border of the studied territory (along the Karakyr Stream) in the process of unification of the region's stratigraphy scheme (Chernyshuk et al., 1989). The formation had been traced 18 km along the northern slope of the Terskei Range from the stratotype section to the Tyup River upstream. It lies unconformably with the basal conglomerates in its basement (to 50 km) on the Early Paleozoic and Devonian sediments. The formation consists of calcareous shales, organogenic-clastic materials and shales replaced in section by the vinous-red siltstones and grey and red polymict sandstones. The formation is 65-235 m thick. Conglomerates and limestones of the Tyup formation lie above the Karakyr Formation with an erosion and the stratigraphy unconformity. Karakyr formation comprises foraminifers of the Late Visean (fauna catalogue, site 15,70). On A.V. Jenchuraeva's conclusion, this foraminifers complex is identical to foraminifers of the Dungurme Formation of Southern Sonkul area.

Compiler: A.V. Mikolaichuk

5.3.2. Intrusive formations

Sarykoinou Formation ($\gamma\delta,q\mu C_1s$). This granitoid formation has first been defined as the Sarykoinou Formation of early to middle Devonian age consisting of quartz diorites, monzodiorites and granosyenites (Esmintsev, 1989). It locally extends into the headwaters of the Ashutor, Karasai and Sarykoinou Rivers. The granitoid forms two small E-W trending massifs. Formation rocks form two small massifs stretched latitudinal (E-W). The Sarykoinou massif (about 20 km^2) is the type area and is located in the watershed area of the Terskei Range. It stretches from the Sarykoinou River westward for 20 km and is 2.3 km wide. The main part of the massif is covered by glacial deposits. The second massif (North-Sarykoinou, nearly 6 km^2) is located to the north in the Sarykoinou and Jamansai Rivers.

The formation consists of grey, coarse-grained biotite quartz monzonites, granosyenites, granodiorites, biotite-hornblende monzodiorites, and monzonites. Hornblende-biotite quartz monzonites are rare. Granodiorites occur mainly in the North-Sarykoinou massif, whereas biotite-hornblende monzodiorites and monzonites are found in the southern part of the Sarykoinou massif. Monzodiorites and granodiorites are accompanied by light-grey biotite granites.

A poorly developed foliation is observed in rocks of the Sarykoinou and Jamansai Rivers. Monzonites are locally intensively foliated and become granite-gneisses. Westwards, in the headwater region of the Ashutor and Karasai Rivers, the rock, as a rule has a strong cataclastic fabric.

Petrochemistry. The chemical composition of the complex is defined by 22 samples (see geochemistry catalogue). The Sarykoinou massif rocks belong to the sub-alkaline group (Fig. 5.3.2.1.), whereas calc-alkaline rocks prevail in the North-Sarykoinou massif. K_2O varies between 2.81 and 5.14 %, whereas Na_2O ranges from 3.11 to 4.28%, and the K_2O/Na_2O ratio is 0.74-1.50 with a mean of 1.01±0.18.

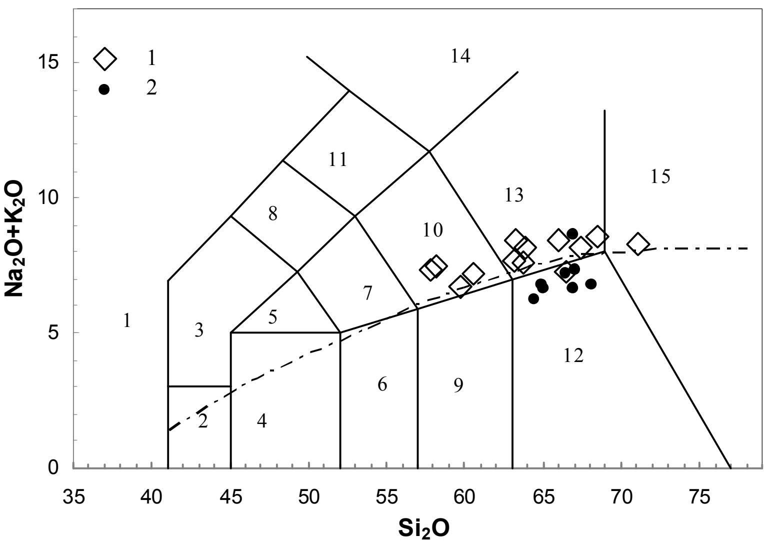

Fig. 5.3.2.1. Composition of granitoid rock from the Sarykoinou Formation in the TAS diagram.

Dotted line is lower boundary of sub-alkaline rock compositions (Bogatikov et al., 1981).

Fields according to Middlemost (1994): 9 – diorite; 10 – monzonite; 11 – feldspar monzosyenite; 12 – granodiorite; 13 – syenite, quartz monzonite; 15 – granite. Open diamonds are samples from Sarykoinou massif, full circles are samples from North-Sarykoinou massif.

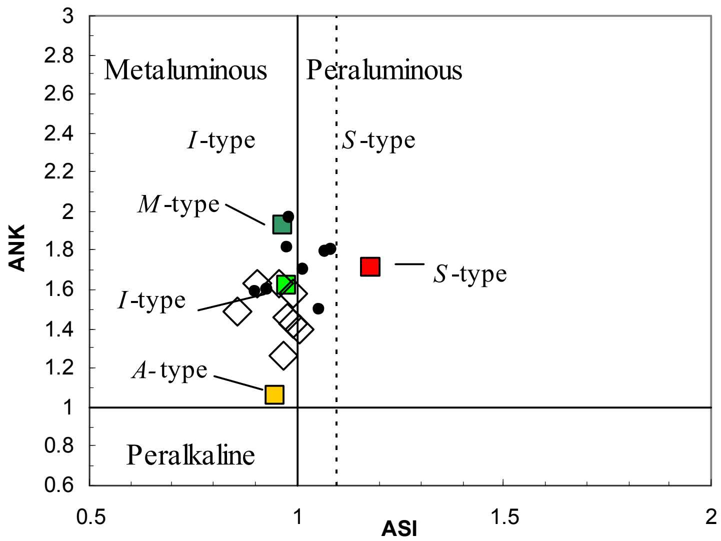

Fig.3.2.2. Granitoids of Sarykoinou Formation at the ASI – ANK diagram with *I*-type and *S*-type granitoids' fields. ASI = $Al_2O_3/(CaO+Na_2O+K_2O)$ mole.; ANK = $Al_2O_3/(Na_2O+K_2O)$ mole. Rhombuses indicate medium contents of *I*-type, M-type, A-type and *S*-type granites (Whalen et al., 1987).

Granitoids mostly are metaluminous and consist of *I*-type granites. Granitoids of the Sarykoinou massif are characterised by higher values of alkalis in comparison to typical granites (Fig. 5.3.2.2).

Age. Granitoid rocks of the Sarykoinou Formation intrude Archaean to Palaeoproterozoic metamorphic rocks of the Kuilyu formation and are, in turn, intruded by the early Permian East Sonkul granitoids. The rocks age is defined by three dated samples (isotope age catalogue). Muscovite from a quartz monzonite (sample 13276) has a K/Ar age of 223±10 Ma, and this age reflects cooling below ca.400 °C. U/Pb conventional multigrain zircon dating of a hornblende-biotite quartz monzodiorite (sample 1093) is 413±8 Ma, and the dated zircons contain cores and overgrowth zones (Esmintsev, 1989). Single zircons from a granite-gneiss (sample MAV90/07) show simple growth zoning under cathodoluminescence, and five grains yielded an early Carboniferous mean $^{206}Pb^{238}U$ SHRIMP age of 336 ±3.3 Ma (Fig. 5.3.2.3).

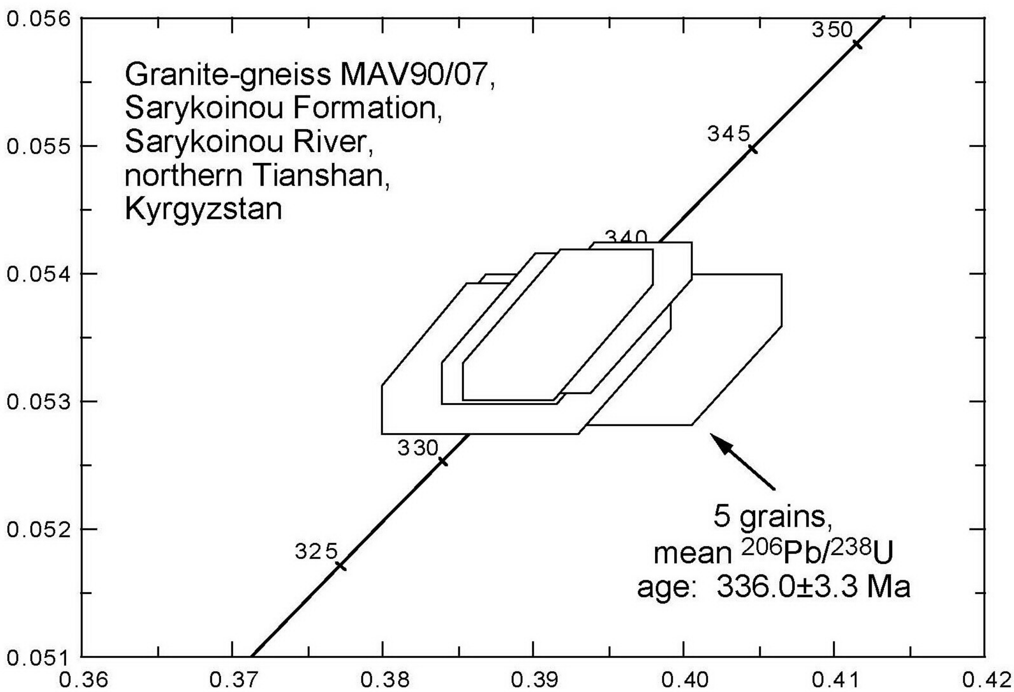

Fig. 5.3.2.3. Concordia diagram for U-Pb SHRIMP data from zircons of a granite-gneiss (after A. Kroener, personal communication).

Compiler : F.Kh. Apayarov

5.4. North Tien-Shan basin

< (Double click to view the stratigraphical columns)

A single marine basin has been traced from the western end of the Kyrgyz Range along the northern slopes of the Terskey Range to the border with China (Shlygin et al., 1971, Skrinnik, Mikolaichuk, 2003). It had appeared in the Late Devonian and finished its evolution in the middle of Bashkirian age. We have accepted a regional stratigraphic scheme approved by the III Kazakhstan stratigraphy meeting (Abdulin, 1991), supplemented by the data on the Kyrgyz part of the investigated area. It is based on materials of geological surveys of the region (Gilev, 1997; Guttermaher, 1978; Krasnoborodkin, 1984) and results of paleontologic-stratigraphic researches (Galitskaya-Gladchenko, 1958; Chernyshuk et al., 1989) which allowed the definition of two section types of the Lower Carboniferous sediments within the studied area: terrigenous Jergalan-Tiek and carbonate-terrigenous Kungey.

Jergalan-Tiek section type.

Kyzyljar Formation (C_1kz). It is defined by A.Ya. Galitskaya-Gladchenko in 1958, and the name was offered by S.B. Gushin in the process of unification of the region's stratigraphy scheme (Chernyshuk et al., 1989). The formation stratotype is located in the Kyzyljar valley along the Tyup River, where it unconformably lies on the Devonian sediments and represented in its lower part by the conglomerates with single sandstone interbeds, and in the upper part by sandstones and conglomerates with gritstone lenses. Rhyolites, andesites and granites prevail in the conglomerate pebbles. The rock color is vinous red and pink. Sediments are 535-800 m thickness. Organic fossils are not available. Apparently the Kyzyljar Formation represents coastal facies of the North Tien Shan basin, replaced to the east by deeper marine sediments of the Kopyl formation. The upstream of the Kyzyltor River shows that the Kopyl Formation lays above the Kyzyljar conglomerates (Knauf, 1954; Galitskaya-Gladchenko, 1958), therefore we determine its age as the Tournaisian (most probably the Early Tournaisian).

Compilers: L.I. Skrinnik, A.V. Mikolaichuk

Kopyl Formation (C_1kp) defined by Mozolev L.N. and Zaharov I.L. in 1963 in the Kopyl Range of the described area. The name was accepted in the Unified stratigraphy scheme for Southern Kazakhstan (Abdulin, 1976). The formation sediments form an outcrop band 1-1.5 km wide and 20 km long in the northern part of the region (south-west slopes of the Kopyl Range, Tiek Mountain) where they lie with erosion on the Devonian granitoids. Kyzyltor River head shows the overlap of Kyzyljar conglomerates by Kopyl formation (Knauff, 1954; Galitskaya-Gladchenko, 1958) from where the formation sediments are traced till the Tekes(eastern) River.

The section of the formation in the stratotype area is rather uniform. The basement is comprised of conglomerates 10-15 m thick with rubbles and pebbles of the directly underlying rocks. The Formation's lower parts are comprised of dark-grey and black thin-bedded sandstones and siltstones with the numerous floral fossils. There is a small number of conglomerate, limestone and cherty siltstone interbeds. The upper part consists of predominantly arkosic and quartz sandstones of vinous-brown and vinous-pink color. Sediments are 1250-1650 m thickness (Gilev,1997; Guttermaher, 1978). The Kopyl formation age is determined by the few foraminifers and flora fossils as the Tournaisian-Visean (fauna catalogue, site 90, 91, 109, 174)

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Kokpak Formation (C_1kkp). It is defined on the northern slopes of the Terskei Range (Krasnoborodkin, 1984). Stratotype of the Kokpak Formation goes along the Ulken-Kokpak River to the north of the studied area (Krasnoborodkin, 1984; Gilev, 1997). The formation sediments with conglomerates in its basement overlay the Kopyl formation and are represented by the thin bedded sandstones, siltsones, loamy limestones and calcarenite in its lower part. The interbeds of tuff-sandstones and tuffites occur there (Gilev, 1997).

The upper part of Kokpak formation differs by the coarse rhythm. Thin-bedded members of siltstone-sandstone-limestone content replace polymict sandstone and limestone horizons there (5-20 m). Limestone horizons are replaced by the psephitic calcarenites (limestone conglomerates and gritsones) to the west. The thickness of sediment varies from 1500 to 1700 m (Guttermaher, 1978; Chernyshuk et al., 1989). Fauna of brachiopods and foraminifers had been collected along the entire section and it allows dating of Kokpak formation as the Late Visean and Serpukhovian age (fauna catalogue, site 30-32,107,108, 110, 111, 214-216, 227-229).

Compilers: L.I. Skrinnik, A.V. Mikolaichuk

Kokjar Formation ($C_{1-2}kk$). It was defined by V.K. Krasnoborodkin in 1984 in the valley of Kokjar River (Abdulin et al., 1991) where a narrow band of the formation outcrops (300-500 m wide) can be traced till the upstream of the Tekes River (eastern). The lower border with the Kokpak Formation is the conformable with the gradual calcareous increase, as sandstones are replaced by limestones. The section of Kokjar Formation displays light-grey pelitomorphic and organogenic limestones and dolomites alternating by the rare interbeds of arkosic sandstones. The dolomite part increases in the upper part of the section and to the west along strike they are replaced by limestone conglomerates and sandstones. Maximum thickness of the described sediments is determined in the Tekes River (eastern) upstream and reaches 530 m (Guttermaher, 1978; section 23). Numerous brachiopod and foraminifer collections defined the Bashkirian age of host rocks (fauna catalogue, site 34, 112,113, 183, 186-192).

Compilers : L.I. Skrinnik, A.V. Mikolaichuk

Ushkhasan section type

The given section type of the Early Carboniferous sediments fully occurs in the Ushkhasan Range (Buduty Hasan River) where the carbonate deposits of Kungei Formation of the Visean- Early Serpukhovian age stratigraphically overlapped by the terrigenous-carbonate layer of the Late Serpukhovian and Early Bashkirian (Bublichenko et al., 1979). Only the lower unit of the Ushkhasan section had been determined within the studied area.

Kungey Formation (C_1kn). The formation had been described by Chabdarov N.M. (Abdulin, 1976) in the geological mapping of the Kungei Range where it displays massive pelitomorphic and organogenic limestones with siltstone, sandstone and ash tuff interbeds (from 10 to 20% of the formation content). The dominant rock types are the massive and tabular organogenic and pelitomorphic limestones. Its thickness varies in the stratotype area from 400 to 1100 m. Kungei Formation sediments either lay unconformably on the Devonian and Early Paleozoic sediments or overlap Devonian granitoids with clear erosion (Chabdarov et al., 1971; Krasnoborodkin, 1984; Gilev, 1997). The formation section within the studied area comprises predominantly tabular organogenic limestones often alternating to the massive pelitomorphic and bioherm limestones. There are a limited number of loamy limestones and horizons of sand-siltstone containing numerous floral fossils. Apparent formation thickness varies from 700 m to 1250 m (Guternaher, 1978). The lower and middle part of the formation comprises fossils of brachiopods, corals and foraminifers typical for the second part of Visean age and the upper parts; the fossil content is typical for the Early Serpukhovian age (fauna catalogue, site 92-97, 101, 102, 223-226).

Compilers : L.I. Skrinnik, A.V. Mikolaichuk

5.5. Chu-Sarysu basin

< (Double click to view the stratigraphical columns)

Sediments of the North Tien-Shan basin described above are characterized by the endemic complex of foraminifers showing that they had been deposited in the epicontinental basin only episodically merged with Paleotetis (Mikolaichuk, Djenchuraeva, 2000; Skrinnik, Mikolaichuk, 2003). According to the oral report of Djenchuraeva A.B. the foraminifers complex of sediments overlapping Kokjar Formation beginning from the *Pseudostafella antiqua* foraminifer zone does not differ from the foraminifers typical for the ocean. It can be the result of either transgression or structural change of the region.

According to the Kazakh geologists' data the independent tectonic-sedimentary unit formed at the beginning of the Late Carboniferous named the Chu-Sarysu Basin. Its evolution had been directed to the general degradation and dehumidification till the end of the Permian age (Shlygin et al., 1971).

Tyup Formation, (C_2tp). It was defined by S.S. Shultz (Gryushe, 1940). The stratotype area is located in the described region (Tyup River). Galitskaya-Gladchenko A.Ya. (1958) noticed that the Tyup Formation sediments lay on multiple-aged formations. It transgressively overlaps Pre-Carboniferous sediments on the elevations and in the depressions it extends over sections of the Lower Carboniferous (as they had been cleared the lower parts of the Bashkirian horizon) without apparent unconformity. In the Tyup River valley the formation section displays gritstones, sandstones and siltstones (110 m) overlapped by sandstones (250 m). Layer of beige thick-bedded limestones (110-140 m) known as "Uchkashka" lies above (Severinov, 1990; Chernyshuk et al., 1989). S.B. Gushin (Chernyshuk et al., 1989) offered a section along the Tekes River left side as the key section (Lectostratotype). Basal conglomerates 15 m thick alternate sandstone, limestone and dolomite (70 m) interbeds in the up-section. The "Uchkashka" limestones lie above. The total thickness of the formation in the given section equals 210 m. In the Karakol River valley (head of the Tuyukkokpak River) the lower terrigenous part of the formation does not exceed 20-65 m. Dark-grey massive limestones and dolomite limestones 415 m thick lie above (Gutermaher, 1978, sections 17, 27). The foraminifers, brachiopods and bryozoans of the Tyup Formation carbonate layers determine its age as the Early Bashkirian (fauna catalogue, site 16-22, 24, 27, 35-36, 58-60, 65, 67, 98, 99, 185, 218, 219, 230, 231).

Compilers : L.I. Skrinnik, A.V. Mikolaichuk

Chaarkuduk Formation (C_2čr) mapped by V.I. Knauf in 1954 in the Jergalan - Kokjar Rivers' watershed. The name was offered by Galitskaya-Gladchenko A.Ya.(1958), who gave the first full description of the Formation section. It is represented by alternating speckled (vinous, blue and green) sandstones, siltstones, light-grey marls and limestones with the interbeds of grey, white and rose floury gypsum lying conformably on the Tyup Formation sediments. Near the Chaarkuduk Pass the formation sediments have their maximum thickness (530 m). Grey banded gypsum prevail there (350 m) comprising the lower part of section. Knauf V.I. (1954) had described a section similar by its content in the region of the Tiek Pass which consists of grey floury gypsum 200 m thick at the apparent basement of section. Polymict sandstones of red and green-grey color with the rose gypsum interbeds (180 m) lie above. To the west, in the Jergalan - Tyup Rivers' watershed the formation thickness reduced to 40-70 m (Chernyshuk et al., 1989).

Few faunal fossils among the formation sediments (fauna catalogue, site 220, 243) give a wide age range (Serpukhovian-Bashkirian). Basing on the "Uchkashka" limestone correlations Gushin B.S. had defined that the Chaarkuduk formation sediments belong to the *Psedostaffella pracgoskyi* foraminifer zone, thus belong to the Early Bashkirian (Chernyshuk et al., 1989). This conclusion agrees with the references of the Early Bashkirian *Psedostafella antique (Dutk., Choristites bisulcatiformis Semich* foraminifers findings in the upper horizons of Chaarkuduk formation (Chabdarov, Sevastyanov, 1971).

Compilers: L.I. Skrinnik, A.V. Mikolaichuk

Tekes Formation (C_2-P tk) had developed in the Jergalan-Tuyukkokpak Rivers watershed. The small-scale survey had shown it as the Moscovian conglomerates layer (Knauf, 1954; Mozolev, Zaharov, 1963). The name had been offered by Esmintsev A.N. (Gutermaher, 1978; Skrinnik et al., 1998) who described the stratotype section in the Tekes and Tuyukkokpak Rivers head water. The Tekes Formation lies on the Chaarkuduk above an erosive contact (Severinov, 1990) and elsewhere overlaps above an angular unconformity the Carboniferous and Ordovician sediments. Fast facial variability and wide range of the section thickness are typical for the formation. Two sub-formations had been determined: the lower one – red sandstone-conglomerate and the upper one – motley siltstone-sandstone (Esmintsev, 2000).

Basement of the lower sub-formation comprises a member of red medium and coarse-grained arkosic and quartz sandstones with the gritstone and conglomerates lenses 200-600 m thick. The crossbedded structures often occur there. Various-pebbled, often rubble conglomerates, stratified lenticular-bedded and crossbedded sets of sand-gritstone content (1000-1900 m) occur above the section. They are overlain by various-grained arkosic sandstones (1000-1800 m) which have both parallel- stratified and unidirectional, and cross bedding. Interbeds and lenses of gritstones, fine-pebbled conglomerates and limestone interbeds occur in the minor number among sandstones. The lower sub-formation section occurs in its southern and eastern outcrops, and in the north-west direction the psephitic deposits fall out of the section, leading to the reduction of the sub-formation’s full thickness to 800 m.

The upper sub-formation had been mapped along the Turuk River and in the Tuyukkokpak – Tekes Rivers watershed. It lies conformably with the gradual transfer on the lower sub-formation and displays usually grey, greenish-grey and red sandstones, siltsones with single interbeds of gritstones and limestones (to 1 m). Sediments show multidirectional cross bedding with the crossbedded groups' thickness of a few centimeters. The observed thickness of the described sediments is 635-980 m (Skrinnik et al., 1998; Esmintsev, 2000).

The Late Carboniferous (Moscovian) – Permian age of Tekess formation has been determined based on the following data. In the area of Chaarkuduk Pass the re-deposited (in the conglomerate pebbles) forms of foraminifers and algae of the Early Bashkirian (fauna catalogue, site 23,222). The flora fossils of the Late Carboniferous – Permian that have been collected in the Tekes River head (fauna catalogue, site 103), and within the same age range, there are numerous palynological definitions of the spore-pollen complex (fauna catalogue, site 105, 106, 144, 234-236, 240-241).

Compilers: L.I. Skrinnik, A.V. Mikolaichuk

6. Permian – Triassic post-collision complex of the Central Tien-Shan

6.1. Intrusive formations

Differentiated Sills Formation (γ,υ P_1). Subvolcanic basic sheets were mapped in the Kaindy River basin (Borubaev, 1966; Iordan, 1967), where they occurred among Paleozoic sections with volcanogenic, carbonate and terrigenous content. In 1982 Yu.L. Semyonov conducted special investigations and ascertained the Kaindy Group of differentiated sills represented the Eastern unit of the unified (picrite-gabbro-dolerite) formation, which was observed among rocks of the Southern Tien-Shan for the space of 1000km including the Nuratau Mountains in the west.

Sizes of the sills of the Kaindy Group vary within the wide range: from 20-50m to 1.5-2km in length and from 2-3m to 30-70m in thickness. Sills with thickness of a few meters are composed of gabbro-dolerites, and in some places there are little amounts of porphyritic picrites among them. Thicker bodies are differentiated as a rule. Gabbroid sills are often differentiated from olivinites, pyroxenites, gabbro-pyroxenites to leucocratic gabbro-dolerites. Transitions between the mentioned rock varieties are gradual and are determined only by decrease of dark-colored components in the content. (Dodonova, 1974; Semyonov, 1982).

Gabbro-dolerites are represented by microcrystalline and medium-crystalline varieties consisting of saussuritized plagioclase (labradorite) and clinopyroxene (augite). The rocks contain brown hornblende, biotite and titanomagnetite in a little amount. Accessory minerals are represented by apatite and sphene. In melanocratic varieties olivine appears (5-10%), which is usually replaced by serpentinite and talc. The texture is gabbro-doleritic, ophitic. There are rarely gabbro-dolerites with porphyritic texture consisting of augite phenocrysts and microcrystalline ophitic matrix, but there are amygdules infilled by chlorite.

Porphyritic picrites are medium-crystalline dark-green rocks with porphyritic phenocrysts of serpentinized olivine. There is also brown titaniferous augite (10-20%), brown hornblende and biotite in a little amount. Ore minerals are represented by titanomagnetite, and accessory minerals are represented by apatite. The matrix is composed of chlorite and saussurite (Dodonova, 1974, Semyonov, 1982). Sills chemical composition is defined by 6 samples (see geochemistry catalogue).

Differentiated sills intruded into a sheet-plicated structure of so-called upper sheets of the Southern Tien-Shan (Biske, 1995, 1996). Associated with them metamorphites of the Atbashi Formation and ophiolites of the Northern-Eastern Fergana are overlapped with unconformity by Moscovian flysch-molasse sediments (Lesik, Mikolaichuk, 2001). In turn differentiated sills are intruded by Early Permian leucogranites of the Inylchek Formation in the investigated area. Based on Yu. Litasov's verbal information (Institute of Geology and Mineralogy, Siberian Branch of the RAS), the K/Ar age from dolerites of this formation in the area near the mine of Kyzylkia Settlement is 298±7Ma. Based on the set of above-mentioned data the age of the Differentiated Sills Formation is assumed to be Early Permian.

Compilers: A.V. Mikolaichuk, Z.I. Chernavskaja,

Permian intrusive formations are widespread in the researched area. They are represented by 7 formations with different contents. The Early Permian age of 5 of them is proved by U/Pb datings of zircons generally determined by use of SHRIMP (Mao et al., 2004; Konopelko et al., 2006, 2008; Chiaradia et al., 2006). Intrusions were formed after collision events which had caused forming of a continental massif including complexes of the Northern, Middle and Southern Tien-Shan. Geographically the formations are subdivided into 2 groups, divided by the zone of the Atbashi-Inylchek Fault. The northern group includes the Achiktash, Eastsonkul and Terekty formations. The southern group unites the Inylchek, Adyrtor, Akshiyrak and Surteke formations. Rocks of the northern group intrusions except Achiktash Formation intrusions have petrochemical and geochemical features of rocks formed under subduction and collision conditions (Solomovich, 1996). Typical features of A-type granitoids are determined for rocks of the southern group (Konopelko et al., 2007; in press). Similar age of some intrusions of the northern and southern groups and their close location within the unified continental massif presume connection of magma formation with regional (deep-seated) zones of strike-slip faults. Divergence in the content of the rocks, their petrochemical and geochemical features is probably caused by different fusion sources (Solomovich, Trifonov, 2002; Konopelko et al., 2006, 2007).

Eastsonkul Formation (P_1es). It was named before as "Sonkul Formation" (Osmonbetov et al., 1982). The type Sonkul Massif of the formation is located eastward of the researched area, southward of Sonkul Lake. In the researched area rocks of the formation are located northward of the Inylchek Fault. They form bodies with stretched shapes and different sizes which are bounded by latitudinal faults which are subparallel to the Nikolaev’s Line and Inylchek Fault.

The massifs are usually related to the Nikolaev's Line or located at a short distance from it.

The largest of them is Jamansai Massif (30km^2); it is located in the eastern part of the area in the waterhead of Bayankol River.

There are 3 phases in the formation content. In the complicated and most differentiated Kensu Massif up to 5 phases were determined (Solomovich, 1979). The Jamansu Masif is also multi-phase (Averyanov, Esmintsev, 1995). The rest of the massifs and bodies are composed as a rule by rocks of one, rarely two phases. Phase 3 granitoids or phases 2 and 3 undifferentiated granitoids prevail in the structure of most massifs.

Phase 1 (**μν,μδ,μ1P1es**) is represented by greenish-gray biotite-augite monzogabbro, monzodiorites and monzonites, although there are rare occurrences of biotite-hornblende monzonites and diorites. The percentage of dark-colored minerals can reach 40% in the monzogabbro.

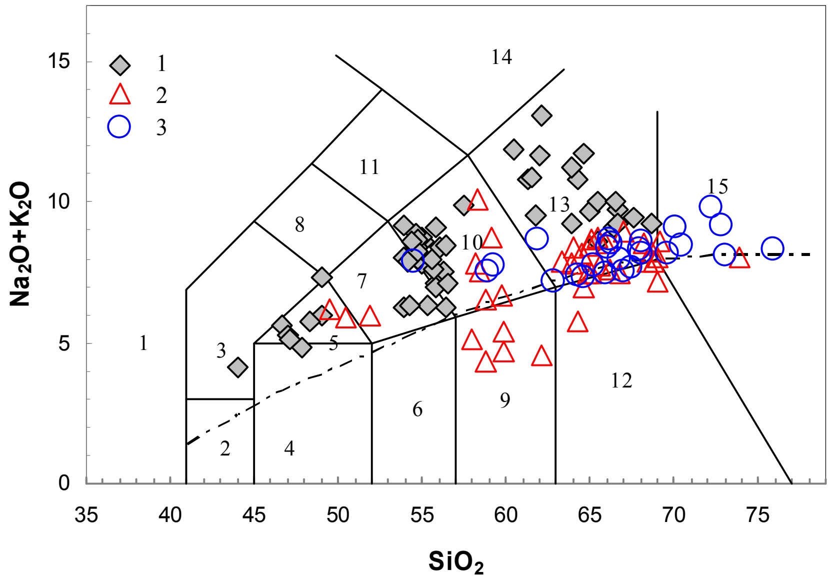

Fig. 6.2.1. Position of the Eastsonkul Formation rocks in the TAS diagram

Fields (by Middlemost, 1994): 1 – foidolites; 2 – peridotitic gabbro; 3 – feldspathoid gabbro; 4 – gabbro; 5 – monzogabbro; 6 – gabbroic diorites; 7 – monzodiorites; 8 – feldspathoid monzodiorites; 9 – diorites; 10 – monzonites; 11 – felspathoid monzosyenites; 12 – granodiorites; 13 – syenites, quartz monzonites; 14 – feldspathoid syenites; 15 – granites. The dot line indicates the low boundary of the subalkaline rocks distribution (Bogatikov et al., 1981)

Massifs: 1 – Kensu; 2 – Jamansai; 3 – the rest massifs and bodies.

Phase 2 (**qμ,ξ,γξ2P1es**) is represented by light-gray, pinkish-gray, and occasionally pink up to pink-red biotite-hornblende quartz monzonites, syenites and quartz syenites, although rare diorites and quartz diorites occur. The percentage of dark-colored minerals rarely exceeds 15%.

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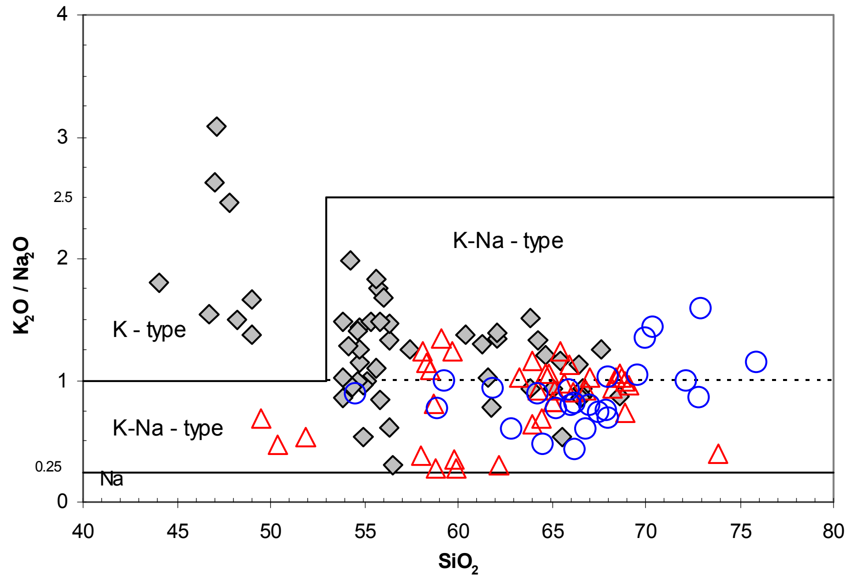


Fig. 6.2.2. Alkalinity type in rocks of the Eastsonkul Formation.

The legend is shown in fig. 6.2.1

Phase 3 (**γξ,γ,γπ3P1es**) is represented by pinkish – light gray hornblende-biotite granosyenites, granites and granodiorites. Peripheral parts of the bodies and small bodies are usually composed of granodiorite porphyries and granite porphyries.

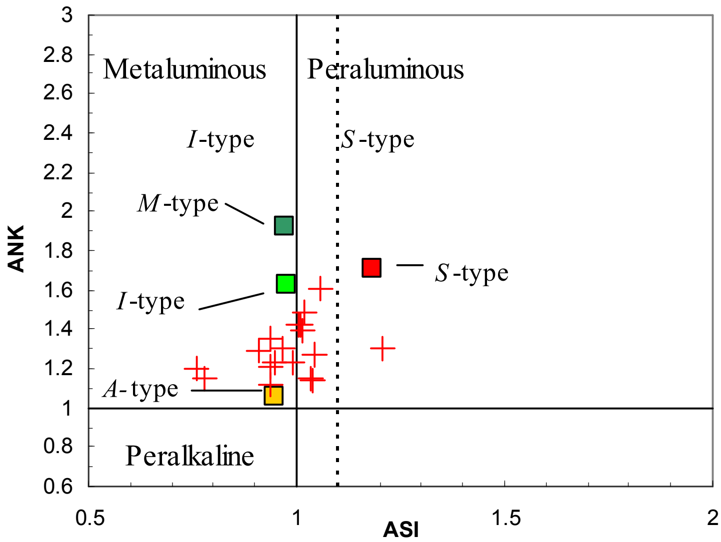


Fig. 6.2.4. Granites of the Eastsonkul Formation in the ASI-ANK diagram with fields of I-type and S-type granitoids (the position of average content of granitoids of different types is shown for comparison (by Whalen et al., 1987)

ASI = $Al_2O_3/(CaO+Na_2O+K_2O)$ mol.; ANK = $Al_2O_3/(Na_2O+K_2O)$ mol.;

Petrochemistry. The chemical content of the formation rocks is determined by 120 samples (see geochemistry catalogue). Most of them were collected from the Kensu Massif (53) and Jamansai Massif (38). The rocks generally belong to the subalkaline series (fig. 6.2.1), to the potassium-sodium type of alkalinity (fig. 6.2.2). Increased alkalinity is typical for the Kensu Massif rocks. Rocks of the Kensu and Jamansai massifs are divided (on the percentage of SiO_2) into 3 groups which probably reflect stages in forming of magmatic melts.

In the ASI-ANK diagram figurative points of granites (SiO_2>68%) of the Eastsonkul Formation are situated between points of typical I -type and A-type granites and are concentrated near A-type granite (fig. 6.2.3).

Age. Rocks of the Eastsonkul Formation intrude rocks of the Lower Carboniferous Turuk and Kensu formations, and granitoids of the Early Carboniferous (336Ma) Sarykoinou Formation. There are 2 U/Pb, 4 K/Ar and 9 Rb/Sr datings for the formation rocks (isotope age catalogue). The age of 288±9 and 293±10Ma was determined on biotite from granosyenite of the Jolkolot Massif and from subalkaline granite of the Upper Ashutor Massif accordingly. Dating on biotite of quartz monzonite from Adyrtor River valley gave the age of 326Ma (Solomovich, 1981). The rubidium–strontium age method was carried out in rocks of the Kensu Massif (Solomovich, 1996). It is necessary to note that alkaline and feldspathoid gabbroids were discovered among the dated rocks. In our opinion they represent xenoliths of alkaline rocks in monzogabbro, possibly sourced from the alkaline and feldspathoid rocks located to the west of the area that form the Early Permian Sandyk Formation (Burg et al., 2004), however the determined isotope ratios in the $^{87}Rb/^{86}Sr$ – $^{87}Sr/^{86}Sr$ diagram did not form a unified isochrone (Solomovich, 1996). Isochrone on 3 points of alkaline and feldspahoid gabbroids gave the age of 301±64Ma (Sr_0 = 0.7075±0.0006). Isochrone on 4 points of monzogabbro, monzonite, quartz monzonite and quartz syenite gave the age of 324±42Ma (Sr_0 = 0.7066±0.0002). Parameters of this isochrone coincide with parameters of the isochrone plotted on 4 points of rocks of the type Sonkul Massif and equal 326±5Ma, Sr_0 = 0.7066±0.0001 (Solomovich, 1996) From this massif uranium-lead age dating of zircon from Phase 3 porphyritic biotite-amphibole granite gave the age of 293±1Ma (Alekseev et al., 2008). The age of granites of the Jamansu and Jolkolot massifs determined by the uranium-lead age method on zircons is 300±5 and 272±6Ma. With the last dating required to be checked because discordant ages on different isotope ratios were determined.

Thus, geological and geochronological data allows us to assume an Early Permian age of the Eastsonkul Formation.

Compiler: F.Kh. Apayarov

Terekty Formation (P_1t). It was determined by T.A. Dodonova (1974). In the researched area the formation is represented by the massif named the same. The Terekty Massif is one of the largest shear related intrusions in the Tien-Shan. The initial shape of the massif and its relation with host rocks are indeterminable. From the south it is cut off by the Atbashi-Inylchek Fault and from the north by a system of faults which run parallel to the first one. The massif occupies 100km^2 in the researched area. It trends in the east-south-eastern direction for 45 km as a narrow (0.5-6.5km) wedge band along the northern bank of the Engilchek River. The massif is appreciably broken by numerous faults including Cenozoic ones. Along the faults the rocks are cataclased and melonitized to a variable extent. There are 3 phases in the formation content.

Phase 1 (**$\delta,q\delta_1P_1t$**) is represented by gray, greenish-gray, dark-gray fine-grained biotite-hornblende diorites and hornblende-biotite quartz diorites. They occur in xenoliths and bodies sized of up to 300x1500m in Phase 2 granitoids. The total area of bodies of Phase 1 rocks in the massif does not exceed 2km^2.

Phase 2 (**$\gamma\delta,\gamma,l\gamma_2P_1t$**) is represented by light gray, pinkish-gray, pink-red medium-grained hornblende-biotite granodiorites and biotite granites, rarely leucogranites. Phase 2 granitoids prevail in the formation composition. Typically, there are abundant little xenoliths of gneisses, gabbroids and hybrid rocks among them (Grischenko, 1985; Konopelko et al., 2008)

Phase 3 (**γ_3P_1t**) is represented by red-pink, pink-gray, and occasionally light gray fine-grained aplitic granites and leucogranites. They form ribbonlike and lenslike bodies with length of up to 8km.

Petrochemistry and geochemistry. Petrochemical and geochemical features of the Terekty Formation rocks are distinguished in comparison to the Inylchek Formation rocks. This comparison is caused by similar age of these 2 formations which are divided by the Inylchek Fault. Detailed geochronological, petrochemical and geochemical research of the rocks of the both formations was carried out by D.L. Konopelko (Konopelko et al., 2008). The chemical content of the Terekty Formation rocks is determined by 18 samples, the Inylchek Formation rocks – by 113 samples (see geochemistry catalogue).

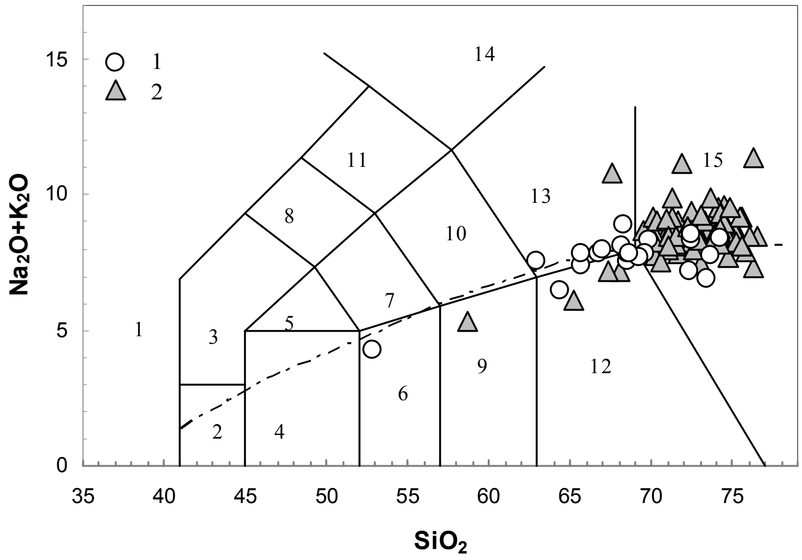


Fig. 6.2.4. Position of the rocks of the Terekty and Inylchek formations in the TAS diagram.

Fields (after Middlemost, 1994): 6 – gabbroic diorites; 7 – monzodiorites; 9 – diorites; 10 – monzonites; 12 – granodiorites; 13 – syenites, quartz monzonites; 15 – granites. The dot line indicates the low boundary of the subalkaline rocks distribution (Bogatikov et al., 1981)

Formations: 1 – Terekty; 2 – Inylchek.

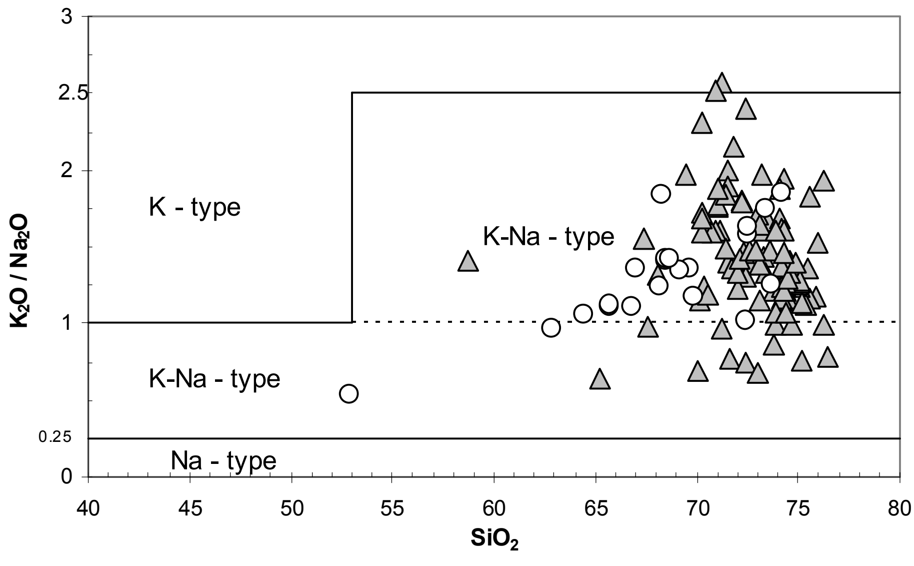


Fig. 6.2.5. Alkalinity type of the rocks of the Terekty and Inylchek formations.

The legend is shown in fig. 6.2.4

The formations rocks cannot be separated in the TAS diagram. Their figurative points are located along the line separating rocks belonging to the calc-alkaline and subalkaline series (fig. 6.2.4). The rocks belonging to the potassic-sodium alkalinity type have a percentage of K_2O higher than their percentage of Na_2O (fig. 6.2.5). Ratio K_2O/Na_2O in the Terekty Formation rocks generally increases depending on whether SiO_2 increases. The Inylchek Formation rocks differ from the Terekty Formation rocks with predominantly lower percentage of TiO_2 whereas the same percentage of K_2O. Average ratio K_2O/TiO_2 in granites and leucogranites of the Terekty Formation equals 13, in similar rocks of the Inylchek Formation equals 33, with this ratio rarely being less than 10 in them.

Granitoids of the Terekty Formation are similar to I-type granites by their petrochemical features (fig. 6.2.6). They differ from the average content with a higher percentage of alkalis. Granites of the Inylchek Formation correspond to A-type granites. They differ from the average content with higher ratios $Al_2O_3/(CaO+Na_2O+K_2O)$ and are generally peraluminous. Granitoids of the Inylchek Formation are characterized by high mafic index that is a distinguishing feature of A-type granites. Average ratio FeO*/(FeO*+MgO) equals 0.90±0.07, whereas for granitoids of the Terekty Formation it is 0.75±0.06.

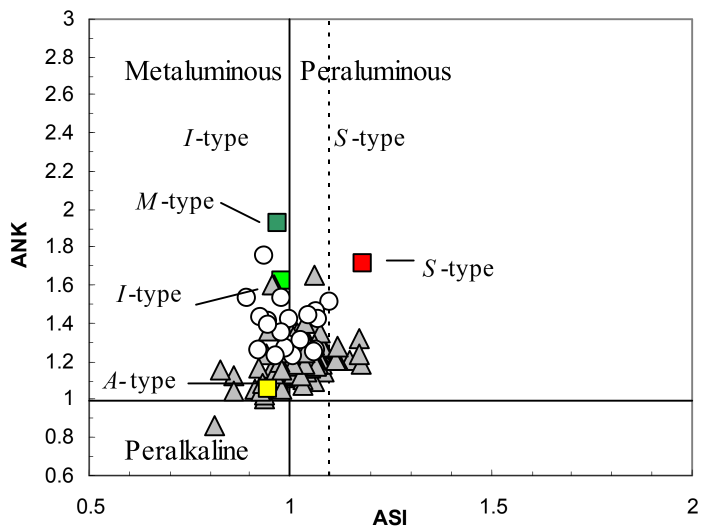


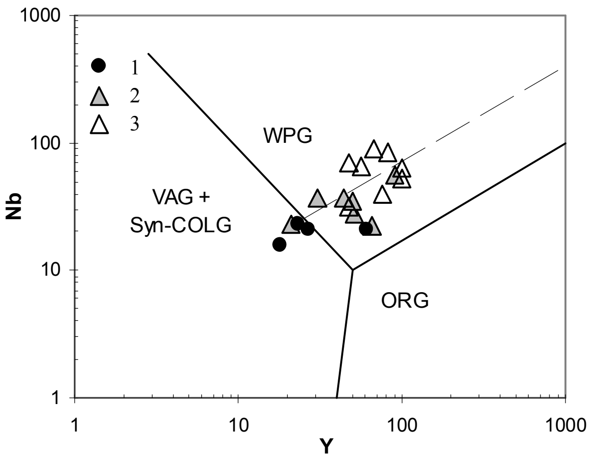
Fig. 6.2.6. Granitoids of the Terekty and Inylchek formations in the ASI-ANK diagram with fields of I-type and S-type granitoids (the position of the average contents of granitoids of different types is shown for comparison (after Whalen et al., 1987)

ASI = $Al_2O_3/(CaO+Na_2O+K_2O)$ mol.; ANK = $Al_2O_3/(Na_2O+K_2O)$ mol.;

The legend is shown in fig. 6.2.4

Granitoids of the formations clearly differ from each other on the content of rare and rare-earth elements. The tin content is the most indicative feature and it does not exceed 5ppm in the Terekty Formation rocks whereas it is within the interval of 10-100 ppm in the Inylchek Formation rocks. Distribution of REE contents normalized to chondrite in the Inylchek Formation rocks differ from the same one in the Terekty Formation rocks with europium minimum. Lines of distribution of normalized REE contents practically coincide in different rocks of the Terekty Massif (Konopelko et al., 2008).

According to discriminant diagrams containing fields of granitoids formed in different geodynamic situations the Terekty Formation granites are classified as subduction ones, whereas the Inylchek Formation granites as intraplate ones.



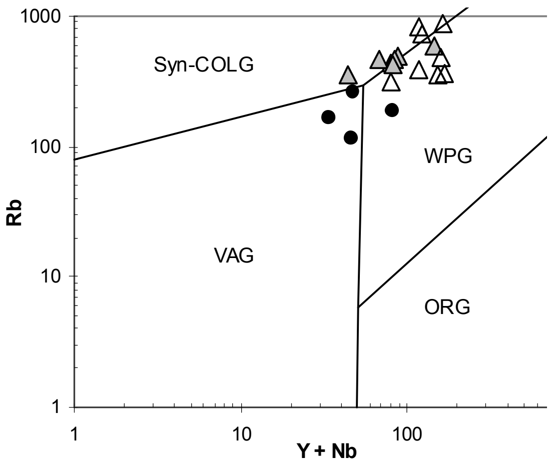


Fig. 6.2.7. Discriminant Y–Nb, Rb/(Y+Nb) diagrams (Pearce et al., 1984) for granitoids of the Terekty and Inylchek formations.

Fields: ORG – granites of the ocean ridges; WPG – intraplate granites; VAG – granites of volcanic arcs; syn-COLG – collision granites.

The legend: 1 – Terekty Formation; 2, 3 – Inylchek Formation 2 – data by Konopelko et al., in press, 3 – data by Solomovich, Trifonov, 2002

In the 10 000*Ga/Al – (Na+K)/Al diagram (Whalen et al., 1987) points of the Inylchek Formation granites are in the field of A-type granites. In this diagram points of the Terekty Massif granitoids are located in the field of M-type, I-type and S-type granites (Konopelko et al., 2008).

Age. Contacts of the Terekty Massif with host rocks are tectonic therefore the age of the described formation is based on results of isotope datings which are not completely unambiguous. There are 10 K/Ar datings on biotite determined during works carried out in 1967-1985. 4 K/Ar datings are within the interval 281-307Ma, the rest are within the interval 343-542 Ma. In 3 samples with "ancient" biotite zircons were analyzed by the classic uranium-lead age method (the portions were 300-500mg). In 2 samples the age of zircons on lead-lead ratios ($^{207}Pb/^{206}Pb$) is 397 and 398Ma although the maximum age on $^{206}Pb/^{238}U$ does not exceed 309Ma. The age of zircons from the third sample is 286Ma on lead-lead ratio and 265Ma on ratio $^{206}Pb/^{238}U$ (see isotope age catalogue).

Based on these data our predecessors came to a conclusion that within the Terekty Massif there were 2 generations of granitoids with similar petrographic features (Grischenko, 1985). In our opinion this considerable range of isotope ages of the rocks of the Terekty Massif is a result of its heterogeneity. Abundant dissimilar xenoliths among Phase 2 granodiorites and results of analysis of zircons in the ion microprobe SHRIMP-II confirm these conclusions. Average $^{206}Pb/^{238}U$ age on 5 analyses of zircons from granite is 291±5Ma and on 6 analyses of zircons from diorite is 294±5.3Ma. If for the granite $^{207}Pb/^{206}Pb$ ages of dated zircons are comparable with $^{206}Pb/^{238}U$ ages, for the diorite $^{207}Pb/^{206}Pb$ age of zircon varies within the interval 325-412Ma (Konopelko et al., in press).

Despite the fact that the structure of the massif is heterogeneous, coincident average $^{206}Pb/^{238}U$ ages of zircons in diorite and granite determine the Early Permian age of the Terekty Formation.

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Inylchek Formation (**P_1i**). The formation unites 6 small massifs and stocks of granitoids: Tashkoro (8km^2), Maidaadyr (6km^2), Sukhodol (4km^2), Inylchek (3km^2), Atjailau (1km^2) and Komsomol (20km^2) within the Engilchek Range. The group of 5 massifs is located in the Engilchek and Kaindy interfluve. The largest Komsomol Massif is at a distance of 60km from them and is located in the head of the Southern Engilchek Glacier. L.I. Solomovich (1996) substantiated they belonged to the unified formation. There are 2 phases of granites in the formation composition.

Phase 1 (**γ_1P_1i**) is represented by light gray, pinkish-gray coarse-grained, rarely medium-grained porphyritic biotite granites. Porphyritic phenocrysts of potassium feldspar, rarely plagioclase sized of up to 3-4cm occupy up to 30%, rarely up to 50-60% of the total rock volume. Phase 1 rocks include xenoliths of quartz monzonites and granodiorites. Phase 1 granites compose the Tashkoro and Maidaadyr massifs.

Phase 2 (**$\gamma,l\gamma_2P_1i$**) is represented by gray, pinkish-gray medium-grained, equigranular biotite granites, leucogranites, lithium leucogranites. Phase 2 granites and leucogranites intrude coarse-grained granites in the Tashkoro and Maidaadyr massifs. The Inylchek and Atjailau massifs are generally composed of medium-grained granites and leucogranites. The lithium leucogranites predominate in the Sukhodol and Komsomol massifs.

Petrochemistry. General petrochemical features are described in the description of the Terekty Formation. The position of the rocks of massifs in the classification diagram is shown here (fig. 6.2.8). The formation's rocks generally belong to the subalkaline series. Practically all points of the Inylchek, Sukhodol and Komsomol massifs are situated in the field of subalkaline granites and leucogranites. Points of the rocks of the rest massifs are distributed in the fields of calc-alkaline and subalkaline granites and leucogranites.

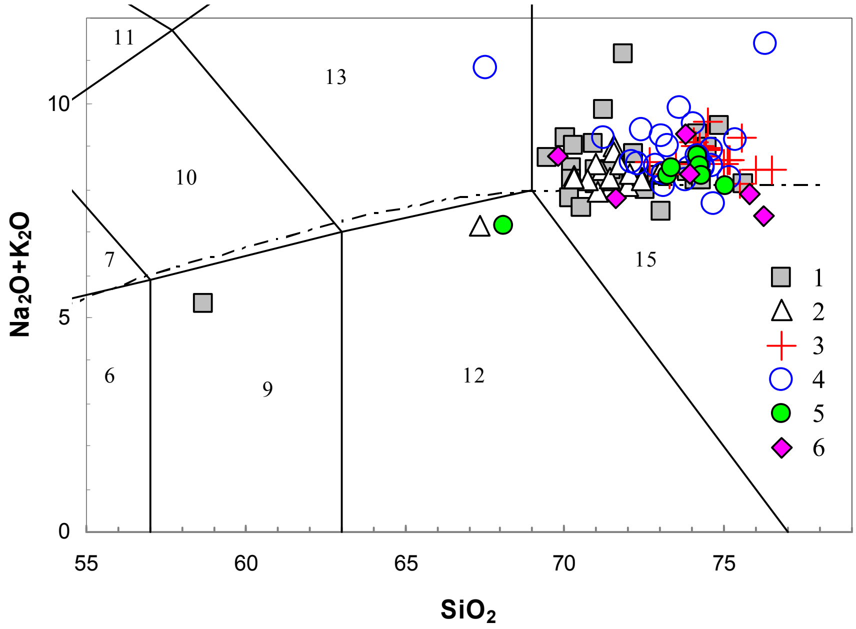

Fig. 6.2.8. Position of the Inylchek Formation rocks in the TAS diagram.

Fields (after Middlemost, 1994): 6 – gabbroic diorites; 7 – monzodiorites; 9 – diorites; 10 – monzonites; 12 – granodiorites; 13 – syenites, quartz monzonites; 15 – granites. The dot line indicates the low boundary of the subalkaline rocks distribution (Bogatikov et al., 1981)

Massifs: 1 – Tashkoro; 2 – Maidaadyr; 3 – Inylchek; 4 – Sukhodol; 5 – Komsomol; 6 – Atjailau.

A typical feature of the formation, except for the Sukhodol Massif rocks, is the clear inverse relation of percentage of TiO_2 and SiO_2, and which has a correlation coefficient (based on 77 samples) equal to –0.8. The Sukhodol Massif rocks are characterized by a low percentage of titanium and independence of silica and titanium oxide from each other.

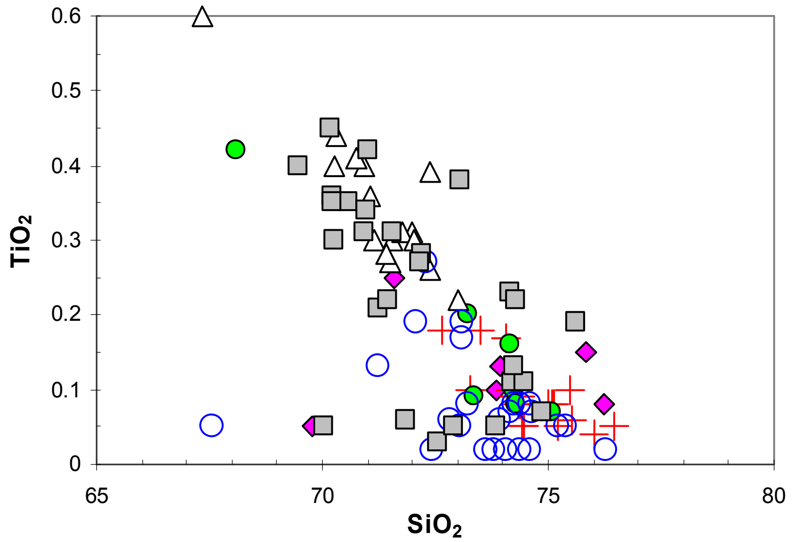

Fig. 6.2.9. Dependence of percentage of TiO_2 and SiO_2 in the Inylchek Formation rocks. The legend is shown in fig. 6.2.8

Age. The Inylchek Formation rocks intrude the sheet-plicated complex of the Southern Tien-Shan composed of Paleozoic rocks, and sills of pyroxenites and gabbro, probably in the Early Permian. There are 12 K/Ar and 10 Rb/Sr ages for this formation's rocks (isotope age catalogue) as well as series of uranium-lead datings on zircons (Konopelko et al., in press). 5 datings of biotite from diorite and Phase 1 granites gave the age of 301-317Ma, with the average being 309Ma; 6 datings of biotite from Phase 2 leucogranites gave the age interval of 265-283Ma with an average of 274Ma. These ages coincide with dates of zircons determined in the ion microprobe SHRIMP-II. The $^{206}Pb/^{238}U$ age on 9 analyses of zircons from granite of the Tashkoro Massif equals 299±4.0Ma, on 6 analyses of zircons from leucogranite of the Inylchek Massif it equals 295.3±4.4Ma, and on 6 analyses of zircons from leucogranite of the Maidaadyr Massif it is 285±4.6Ma (Konopelko et al., in press). Based on the mentioned data the age of the Inylchek Formation is accepted as the Early Permian.

Rubidium–strontium isochronous age of granitoids of the Tashkoro, Maidaadyr, Sukhodol, Atjailau and Komsomol massifs equals 269±8Ma (Sr_0 = 0.70985±0.00229, MSWD =14.6) (Solomovich, Trifonov, 2002). Based on data by Biske et al., 1996 the isochronous age equals 266±2Ma (Sr_0 = 0.7112±0.0007, MSWD = 2.5). During plotting of isochrones the results of analyses of different rocks from different massifs were used and in our opinion this data is not correct.

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Akshiyrak Formation (**P_1a**). The formation includes 2 large massifs: Akshiyrak Massif (450km^2) and Jangart Massif (350km^2), as well as smaller massifs: Jetkait Massif (49km^2), Chon Karagaity (37km^2), Maibash Massif (18km^2) and 2 small stocks in the waterhead of the Maibash River (0.6km^2) and the Airansu River (0.16km^2). The formation was named after the Akshiyrak Massif, that is represented in the researched area by its eastern part with an area encompassing 160km^2 (Grischenko, 1985). Intrusions of the formation are located in the southern part of the researched area in the basins of Sauktor river, Saryjaz river, and in the waterheads of the Terekty and Maibash rivers. There are 4 granitoid phases in the formation composition however relations between Phase 2 and Phase 3 were not observed (Shibkov, Khristov, 1988).

Phase 1 (**$\gamma\delta_1P_1a$**) is represented by gray to light gray, fine-grained to medium-grained, weakly porphyritic biotite-hornblende granodiorites usually with a gneissoid structure and some fine-grained to medium-grained, massive biotite-hornblende quartz diorites and quartz monzonites. The granodiorites form the Chon Karagaity Massif and peripheral parts of the Jetkait Massif. The quartz diorites and quartz monzonites outcrop in the basement of the stocks-satellites of the Jangart Massif in Sauktor River basin. Small xenoliths of quartz diorites occur in rapakivi granites of the Akshiyrak Massif. The total area of outcrops of Phase 1 rocks is nearly 55km^2.

Phase 2 (**$\gamma\xi,\varepsilon\gamma_2P_1a$**) is represented by gray or sometimes pinkish-gray, medium-grained to coarse-grained, porphyritic rapakivi granites and rapakivi granosyenites. The amount of potassium feldspar ovoids usually containing plagioclase edges reaches 40-60%. Phase 2 rocks predominate in the formation. They form the Akshiyrak Massif and the stocks-satellites of the Jangart Massif in the waterhead of Sauktor River.

Phase 3 (**$\varepsilon\gamma_3P_1a$**) is represented by light gray to pinkish-gray, medium-grained amphibole-biotite granites with a massive structure. The amphibole was determined as hastingsite (Solomovich, Trifonov, 2002). Phase 3 granites compose most of the Jetkait Massif and the eastern part of the Maibash Massif.

Phase 4 (**$\varepsilon l\gamma_4P_1a$**) is represented by light gray to pinkish-gray, fine-grained to medium-grained biotite granites, granite porphyries, light pink and red coarse-grained leucogranites, and albite-microcline granites containing tourmaline. The fine-grained granites and granite porphyries form small bodies and dykes which are usually related to faults in the Akshiyrak Massif. The coarse-grained leucogranites intrude the rapakivi granites in the eastern part of the massif. The western part of the Maibash Massif and the Airansu Massif are composed of the amphibole-biotite leucogranites. The leucogranites containing tourmaline intrude the Phase 3 amphibole-biotite granites in the Jetkait Massif.

Petrochemistry. The chemical content of the Akshiyrak formation rocks is determined by 48 samples (see geochemistry catalogue). The TAS diagram (fig. 6.2.10) shows the formation rocks are weakly differentiated from granodiorites to subalkaline leucogranites. Points of Phase 1 rocks are situated in the field of granodiorites, whereas points of rocks from later phases are in the fields of subalkaline rocks. The rocks of all phases belong to the potassic-sodium alkalinity type with percentage of K_2O higher than percentage of Na_2O (fig. 6.2.11). The rapakivi granites and rapakivi granosyenites of the Akshiyrak Massif are characterized by higher K_2O/Na_2O ratios.

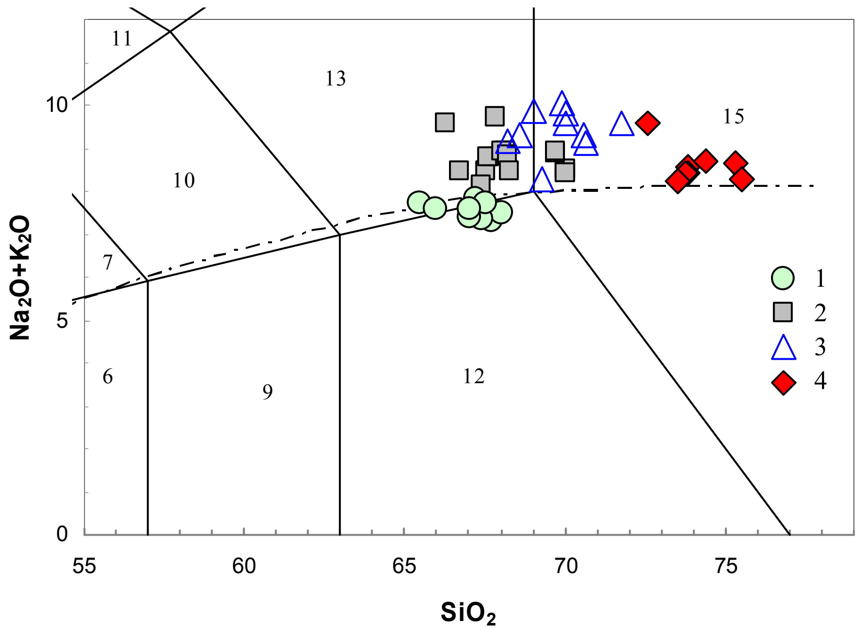

Fig. 6.2.10. Position of the Akshiyrak Formation rocks in the TAS diagram.

Fields (after Middlemost, 1994): 6 – gabbroic diorites; 7 – monzodiorites; 9 – diorites; 10 – monzonites; 12 – granodiorites; 13 – syenites, quartz monzonites; 15 – granites. The dot line indicates the low boundary of the subalkaline rocks distribution (Bogatikov et al., 1981)

Phases of the formation: 1 – the first; 2 – the second; 3 – the third; 4 – the fourth.

Phases 2, 3 and 4 granitoids of the Akshiyrak Formation are similar to A-type granites in terms of their petrochemical features (fig. 6.2.12). Phase 1 granodiorites can be classified as a transitional type of granitoids. Their points are situated between points of typical I-type and S-type granites. Phase 1 granitoids differ from granitoids of the next phases with their low mafic index. Average ratios of FeO*/(FeO*+MgO) in the rocks starting with Phase 1 granodiorites vary in the next sequence: 0.76±0.05; 0.95±0.02; 0.91±0.03; 0.95±0.02

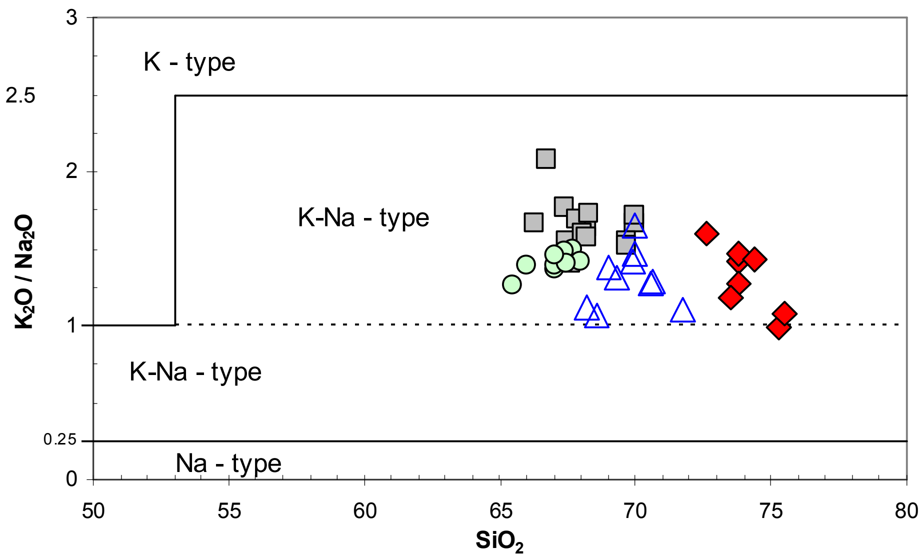

Fig. 6.2.11. Alkalinity type of the Akshiyrak Formation rocks.

The legend is shown in fig. 6.2.10

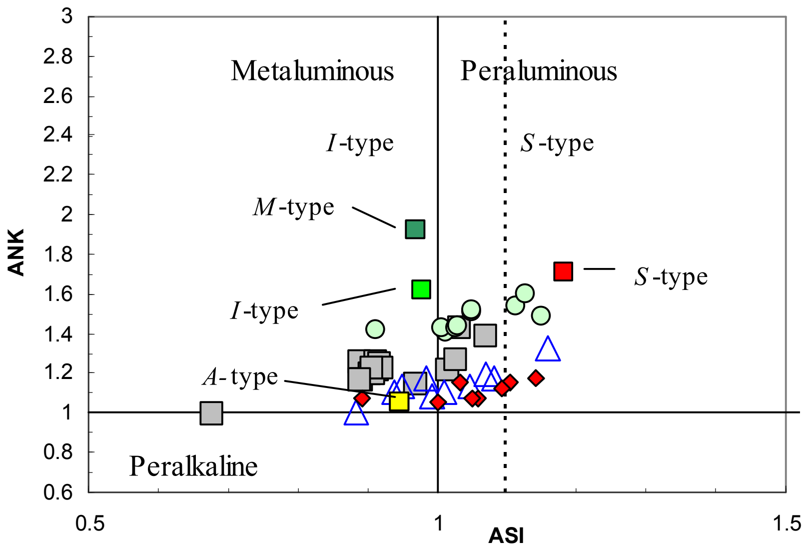

Fig. 6.2.12. Granitoids of the Akshiyrak Formation in the ASI-ANK diagram with fields of I-type and S-type granitoids (the position of the average contents of granitoids of different types is shown for comparison (by Whalen et al., 1987)

ASI = $Al_2O_3/(CaO+Na_2O+K_2O)$ mol.; ANK = $Al_2O_3/(Na_2O+K_2O)$ mol.;

The legend is shown in fig. 6.2.10

Special researches of geochemical features of the rapakivi granitoids of the Jangart, Akshiyrak, Airansu and Maibash massifs showed they belonged to A-type granites. Distribution of REE contents normalized to chondrite in rapakivi granite, rapakivi granosyenite, hastingsite granite and hastingsite leucogranite showed practically complete coincidence of distribution lines. All lines are characterized by Europium minimum, increase of that is directly correlated to silica percentage in a rock (Biske et al., 1996; Solomovich, Trifonov, 2002; Konopelko et al., 2007).

Age. Granitoids of the Akshiyrak Formation intrude rocks with ages from the Silurian to the Late Carboniferous – Early Permian, which at the moment of intrusion had previously undergone sheet-plicated deformation. The age of the formation rocks was determined by the potassium-argon and rubidium-strontium age methods (Solomovich, 1996; Biske et al., 1996; Solomovich, Trifonov, 2002). In the last few years uranium-lead ($^{206}Pb/^{238}U$) dating of zircons has been determined by a SHRIMP analyzer (Mao et al., 2004; Konopelko et al., 2006, 2007; Chiaradia et al., 2006). The above-mentioned authors collected the most part of samples from outcrops located westward of the researched area and these samples are not in the isotope age catalogue.

The age of the rapakivi granosyenites of the Jangart Massif was determined by rubidium-strontium isochrone on 7 points and equals 314±14Ma. Potassium-argon datings on amphibole and biotite gave ages of 310±15 and 293±10Ma accordingly. The age on zircon is 296.7±4.2Ma. The Rubidium-Strontium isochrone on 5 points for rapakivi granites of the Akshiyrak Massif gave the age of 313±13Ma. The age of leucogranites intruding the rapakivi granites on rubidium-strontium isochrone equals 270±4Ma. A Uranium-lead age on zircon of 292±3Ma was determined from rapakivi granite in the western part of this massif. The above-metioned data indicate the Early Permian age of the Akshiyrak Formation.

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Surteke Formation (ξ,qξP_1s). The type massif of the formation is located outside the researched area in the Atbashi Range. The formation is represented by dark-gray and pink-gray, medium-grained to coarse-grained alkali syenites and quartz syenites. The Peak Pobeda Massif is composed by them. The massif (nearly 80 km^2) is located in the south-eastern part of the area, near Peak Pobeda. It is almost completely covered by glaciers. The massif is bounded by a latitudinal fault. The massif pinches out in the western direction and is further traced by small bodies in the waterhead of Terekty River.

The chemical content of the rocks of the Peak Pobeda Massif was not determined.

Age. The formation syenites contain xenoliths of the Jangart Group rocks (**D-P_1jn**) and intrude Phase 4 subalkaline leucogranites of the Early Permian Akshiyrak Formation. In the type Surteke Massif the age of nepheline syenites determined on zircons (SHRIMP) equals 284±2Ma (Chernyavskaya, 2007). Based on the available data the age of the Surteke Formation is determined as the Early Permian.

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Achiktash Formation (**γPa**). The type Achiktash Massif of the formation is located westward of the Issyk-Kul Lake. In the researched area the Achiktash Formation is represented by leucocratic and alkali-feldspar granites, as well as granite porphyries. They form small (less than 4km^2) bodies with a total area of about 11 km^2. All bodies are located northward of the Nikolaev Line, in the north-western part of the researched area in basins of the Tyup river, the Jergalan river and in the edge of the Terskei Range in the source of Tyup River.

Petrochemistry. The chemical content of the Achiktash formation rocks is determined by 6 samples (see geochemistry catalogue). In the TAS diagram their points are concentrated in the field of granites and subalkaline granites, along a line dividing them. The percentage of SiO_2 is within 72.0-76.2% and the percentage of K_2O+Na_2O is within 7.50-8.74%. The alkalinity type of the granites is potassic-sodium. Ratios of K_2O/Na_2O are within the interval of 1.03-2.53.

The granites are peraluminous. The Aluminum unsaturated coefficient (ASI = $Al_2O_3/(CaO+Na_2O+K_2O)$ mol.) exceeds 1.0. In the ASI-ANK diagram points of the formation granites are located to the right from the point of the average content of A-type granite, in the field of A-type leucogranites of the Inylchek Formation.

Age. Granites of the Achiktash Formation intrude Lower Carboniferous rocks and have not the upper stratigraphical boundary. The Permian age of the formation is accepted on the basis of intruding of the Oktorkoi Massif syenites by leucogranites of the Achiktash Formation, since there is a Uranium-lead age on zircon of 295Ma for the syenites of the Oktorkoi Massif (Konopelko et al., 2006).

Compiler: F.Kh. Apayarov

Adyrtor Formation (**γξ,lγPa**). It was determined by T.A. Dodonova and A.D. Zakharov in 1967. The formation is represented by pink-pale and crimson-pink fine-grained alaskite granites forming small (not more than 1km^2) lenslike and isometric bodies in the left bank of Saryjaz River. They trend in a line in the latitudinal direction along big faults. The relatively large (up to 3km^2) Kashkator Massif belongs to this formation. It is located to the north-east of the Adyrtor bodies in the southern slope near the axial part of the Terskei Range. Granosyenites appear in its content. L.I. Solomovich (1981) included quartz monzonites in the formation content which in our opinion should be classified as the Eastsonkul Formation.

Petrochemistry. The chemical content of the Adyrtor formation rocks is determined by 5 samples (see geochemistry catalogue). In the TAS diagram their points are generally located in the field of subalkaline granites. Percentages of SiO_2 are within 71.88-77.32% and percentages of K_2O+Na_2O are within 7.85-9.93%. Ratios of K_2O/Na_2O in granites are within the interval of 1.29-1.49.

In the ASI-ANK diagram the point of the average content of A-type granite is located between points of the Adyrtor Formation granites. Their basic part shifts in the field of peraluminous granites.

Age. Alaskites of the formation in Adyrtor River basin intrude Lower Carboniferous detrital limestones and calcareous siltstones and quartz monzonites of the Early Permian Eastsonkul Formation. The upper age boundary of the formaton rocks was not determined. We accept the age of the Adyrtor Formation as the Permian.

Compiler: F.Kh. Apayarov

7. Mesozoic and Cenozoic Complexes of the Central Tien-Shan

< (Double click to view the stratigraphical columns)

Within the Central Tien-Shan sediments of the Mesozoic and Cenozoic periods are shown only by continental deposits. Thin alluvial and deltaic deposits of the Early Jurassic, which are limitedly spread, lie with the sharp angular unconformity on the Paleozoic basement. Alluvial and lake deposits of the Late Cretaceous-Paleogene then rest, without apparent angular unconformity on the Early Jurassic sediments or Mesozoic weathered crust, which is occasionally up to 50-80 m thick. Layers of a few kilometers thick have formed in the region since Oligocene; they record the onset of orogenic processes and filling of intermontane and intermountain basins.

Today there is a detailed stratigraphy scheme for each basin; it has led to the large number of formations. It is determined that in the sections of each basins there is the same sedimentation sequence: red-colored sediments of Oligocene-Miocene are replaced by variegated or straw-colored Early Pliocene sediments, which are in turn overlain by coarse-clastic grey sediments of the Late Pliocene – Early Pleistocene. Listed regional stratigraphic levels are offered to describe these Groups, which take the basic stratigraphic scheme of Chu and Issykkul basins, since they have been most substantiated by the paleontological records (Abdrahmatov et al., 2001).

Group of Early Jurassic deposits (J_1). The Jurassic sediments lying with sharp unconformity on the Middle Carboniferous section occur within the mapped area, in the north foothills of the Terskei Range, Jergalan-Tyup-Karkara watersheds. Jurassic sediments have a two part. The lower part of 75-165 m thick consists of grey, almost white fine-coarse-grained predominantly quartz sandstones. Fine-pebbled arkosic and quartz conglomerates, gritstones and siltstones with clayey lenses and coal beds of 7-9 m thick occur in limited quantities. The Group's top of 6-30 m thick is represented by variegated fine- to coarse-grained sandstones in which appear layers of fine-pebbled conglomerates, gritstones and argillites. The total section is 80-180 m thick. Plant fossils collected have confirmed the Early Jurassic age of host sediments. Among those defined are: *Necalamites hocrensis (Shimp) Halle, Sphenobaiera longifolia (Pom.) Fl.* (Bakhrameev, 1964), as well as Equisetites *bcanii (Bunb.) Sew., Czekanonskia latifolia Tur.-Ket., Podozamites lanceolatus (L. et H.) F. Braun.*; Definitions of T.A. Sixtel and A.I. Tyrytanova-Ketova (Pomazkov, 1972).

Compiler: M.D. Ghes

Suluterek Formation (K_2-E_2 st). The stratotype section is described near the Suluterek River mouth – left confluent of the Chu River (Chediya et al., 1973). Similar sediments are called Kokturpak Formation in the Issyk-Kul and Naryn Basins. Inequigranular, ungraded calcareous sandstones, gritstones, red - brown plastered clays or carbonate rocks (marls, dolomites, limestones and syngenetic carbonate breccias) unconformably cover the Paleozoic basement. Locally, well-rounded fine to medium-pebbled alluvial conglomerates contain cherts and quartzites. The rocks listed above alternate irregularly. Rare basalt flows belong to the sequence. The stratotype section is 150 m thick though the formation is usually not thicker than a few tens of meters. Pollens and chemogenic dolomites, gypsums, syngenetic carbonate breccias indicate arid conditions and ephemeral desert lakes (Chediya et al., 1973; Fortuna et al., 1994).

The Suluterek Formation is 3-110 m thick within the research area, and consists of brick-red loams alternated by white marls and limestones (Grishenko, 1985; Severinov, 1990). The Late Cretaceous –Eocene formation age is based on the following data: in the south part of Boom canyon, near the red Cenozoic sediments, a deposit of Upper Cretaceous dinosaur bone fragments is known (Efremov, 1944), along the Toraigyr River basin (north bank of the Issykkul basin) findings of Eocene mammals are known (Turbin et al., 1972; Erefurt et al., 1999). According to the Ar/Ar dating the Suluterek formation basalts' age baries within 113 - 46 Ma , but the samples are between 61 and 76 Ma (Mikolaichuk , Simonov, 2006).

Compiler: A.V. Mikolaichuk

Shamsi Group (E_3–N_1šm) conformably lies over the Suluterek Formation. The stratotype section is described along the Tuyuk Stream – left confluent of the Shamsi River in Kyrgyz Range (Chediya et al., 1973). Vinous-red, brown or brick-red sediments represent proluvial cones, and occasionally alluvial sediments for which coarse, cross bedding is typical. Sandstones and loams dominate the lower part of the formation and grade upward into gritstones and conglomerates. Stratified, proluvial sediments with gravel filler and up to 20 cm thick horizons with large pebbles of andesite-dacite and Devonian brown sandstones occur locally. The formation thickness varies from 300 to 1285 m in Borehole S6 (Chediya et al., 1973). The top layers of the Shamsi Group are replaced in the Issyk-Ata and Alamedin rivers interfluve by lacustrine sediments.

The section structure in the north of the mapped area (Issykkul basin) is similar to the stratotype one as a whole. Brick-red polymictic fine-medium-pebbled conglomerates with sandstone and gypsinate loam lenses prevail there, and sediments are up to 900 m thick.

Conglomerate pebbles are shown by rocks composing Paleozoic basement of the Terskei Range (Severinov, 1990). Described sediments become thinner to the south, reaching a thickness of 110-190 m, they consist of conglomerates, gritstones and “waste” loams. Local material of Middle Tien-Shan rocks in the Saryjaz basin and South Tien-Shan rocks in the Kaindy basin occur in the pebbles (Severinov, 1990; Borubaev et al., 1966). Within the Kaindy Basin, conglomerate horizons are containing quartz pebbles completes the formation section in the south (Borubaev et al., 1966). The Oligocene-Miocene age is defined by finds of tortoise *Stylemus karakotensis Riab.*, teeth of giraffe *Samotherium sp.* and *Antilope sp.* in the Issyk-Kul Basin (Turbin et al., 1972), and ostracodes: *Lineacypris? genus*; *Ilyocypris errabundis Mandelst* found in test cores of Borehole S6 (Burg et al., 2004).

Compiler: A.V. Mikolaichuk

Kyrgyz Redstone Supergroup (K_2-N_1kg). The earliest description of the red-colored sediments within this portion of the Tien Shan, were named the Kyrgyz Supergroup (Shultz, 1946). Subsequent work has often subdivided these strata into the Suluterek Formation and the Shamsi Group, although many 1:200,000 geologic map sheets use the Kyrgyz nomenclature.

Due to the minor thickness of Suluterek formation, we use the joint unit on the map to indicate these red-colored deposits, occurring between the Late Cretaceous and the Miocene. Deposits of red loams, gritstones and conglomerates which are up to 300 m thick are known outside the Kokchukur basin (left bank of the Tuyukkokpak River), and are described by Kazakh geologists as the Neogene Ili formation, however there have been findings of Paleogene fossils (Gutermakher, 1978).

Existing biostratigraphic data cannot determine whether the Kyrgyz Supergroup in the Chu and Issyk Kul basins were actually deposited synchronously or diachronously.

Compiler: A.V. Mikolaichuk

Chu Group (N_{1-2}ču). Stratotype section lies along the Nooruz River, Kyrgyz Range (Burg et al., 2004). The lower part of the formation is composed of claystone-siltstone beds (up to 20 m) alternating with medium to fine-grained thin sandstone beds or rhythmically laminated sandy-gritstone (5-10 m), with conglomerates are occurring rarely. The claystone-siltstone interbeds are often pink or grey, locally with a tan tint. Some calcareous siltstones are light coloured. Sandstones and conglomerates dominate the upper part of the section. The dense, gray conglomerate beds of the middle part increase upward in abundance and thickness. The clastic component is well-rounded, moderate to well sorted, up to 15 cm in diameter, and commonly imbricated. This stratum is interpreted as braided-river and alluvial-fan deposits (Bullen et al., 2001).

The lower part of the Group in the Issykkul basin is known under the name of the Soguty formation which is 800 m thick. It is represented by variegated clays alternating with cross-bedded alluvial sandstones and gritstones with conglomerate lenses, of first tens of meters thick. The rocks color is light-brown, pale-yellow or greenish-grey; gritstones and conglomerates are predominantly pinkish-grey. The Group's top, which is 300 m thick, described as the Juuka formation is shown by unsorted cross-bedded conglomerates, gritstones and sandstones composing proluvial cones with thicknesses up to 60 m, which are bedded into clays and loams (till 20 m). The rocks prevailing color is brownish-brown and pale-grey (Severinov, 1990). The Chu Group in the Saryjaz basin achieves 680 m and is represented by conglomerates, gritstones and cross-bedded sandstones alternating with pale-grey clays and loams (beds are 0.5-8 m thick). The pebble content in conglomerates and gritstones is usually monomictic, with granitoidal and carbonate fragments prevailing there (Severinov, 1990). The Group's outcrops in the Kumbulun graben (named after Kumbulun valley at the Engilchek and Saryjaz Rivers' junction) are shown by lake deposits. These are pale-yellow, whitish, bluish and greenish-grey sandstones, loams with some minor marl interbeds, which are up to 250 m thick (Streltsov, Semiletov, 1970; Grishenko, 1985). Facial transition of sandstones and loams to the essentially conglomerate layer is observed in the Kaindy River mouth. Psephitic deposits prevail in the Group's section structure both within the Saryjaz and Kaindy basins. These are various-pebbled, mainly fine-pebbled polymictic conglomerates with some occasional gritstone, sandstone and loam interbeds. Pale-grey rock colors prevail there. In terms of pebbles, sandstones, shales and marbles prevail there, although granites, hornfels, effusives and gabbros also occur. These conglomerates are 450 m thick (Borubaev et al., 1966).

Vertebrates, gastropods and floristic material have been found in the Chu Group deposits, pointing to a Late Miocene-Pliocene age ((Burg et al., 2004). In the studied area (Belkarasu River) vertebrates fossils are known: *Platybelodon grangeri (Osborn)* Late Miocene age (fauna catalogue, sites193). Fossils of *Gasella sp. and Chilotherium sp.,* had also been found to the north from the mapped area (Kylchikbai Stream and Turnalykel hole), which, according to the definition of P.A. Tleuberdieva (Institute of Zoology of Kazakh AS) are the typical specimens of hyparion fauna, widely spread at the end of Miocene – beginning of Pliocene (Severinov, 1990). Magnetostratigraphic correlations correspond to the Lower Pliocene (Bullen et al., 2001).

Compiler: A.V. Mikolaichuk

Sharpyldak Formation (N_2-Q_1šr). Stratotype section was defined at the south side of the Issykkul basin, the Sharpyldak River area (Shultz, 1948), where the Upper Pliocene – Early Pleistocene conglomerates overlap the Chu Group deposits. These deposits within Kazakhstan are described under the name of "Horgoss formation" (Gutermakher, 1978). Occurrence of the Sharpyldak Formation rocks within the KR-920 research area is restricted to three small sites. It rests with angular unconformity on the Chu Group within the Issukkul basin (Jergalan- Tyup right bank) and is represented by soft-cemented grey bouldery-pebble conglomerates with lenses of fine-pebbled conglomerates, gritstones or unsorted sandstones which are up to 380 m thick. The pebble content is polymictic and is evidence of the fact that rocks adjacent to the Terskei Range slopes have served as the float source (Severinov, 1990). The formation section within the Kokchukur basin does not exceed 110 m. These are various pebbled and bouldery conglomerates, which are interbedded with breccias, and rest on the Kyrgyz Redstone without apparent unconformity (Gutermakher, 1978). Outcrops of the given element occur in the lower part of Middle Pleistocene terrace along the Saryjaz River right bank to 25 m thick. They are shown by grey soft-cemented bouldery conglomerates. Fragment sizes lie in the range of 8-25 cm, with boulders up to 40 cm in diameters only occur rarely. Limestones, shales, granites and effusives dominate in terms of fragment content (Borubaev et al., 1966). These sediments have been characterized by palynological complexes, and shown to date from the Late Pleistocene – Early Pliocene (fauna catalogue, site 104, 293 on KR-920 map). The Sharpyldak formation's age is most reliably substantiated in the "Nooruz" section along the Kyrgyz Range's north slope, where the *Stenon horse* fossils had been found and magneto-stratigraphic researches have been carried out. Analysis of the data listed-above allows the conclusion to be drawn that the time span of these described sediments is the interval of 2.6 – 1.5 Ma (Bullen et al., 2001; Mikolaichuk et al., 2003).

Compiler: A.V. Mikolaichuk

Quaternary deposits
General setting and research history

The quaternary sediments of the research area are closely related to its drainage. Most rivers drain the northern slopes of the Terskei Range and flow in the northern direction into the closed basin of Issyk-Kul. In catchments of the Saryjaz River the rivers flow southwards into the closed Tarim Basin. Secondary rivers drain the ranges, dissecting them in the north and south direction (see Figure 1). The conditions of Quaternary sediment formation were complicated with differentiated new tectonic movements and rapidly changing climatic factors.

Glacial and interglacial stages are related with rhythmic change of temperature during the whole Quaternary period.

So far in the study area the research for Quaternary stratigraphy was carried out by: V.V.Reznichenko (1930); M.A.Demchenko (1935); S.V.Epshtein (1954); L.I.Turbin (1961); R.D.Zabirov (1965); L.G.Bondarev (1965, 1973); M.A.Talipov, V.G.Korolev (1970), A.K.Trofimov (1976, 1984, 1988.) and P.G. Grigorenko (1960-1966), who developed the Quaternary stratigraphy of Tien-Shan, which correlates with the alteration of global glacial and interglacial periods. Successive works and isotopic dates (Chedia et al., 2000; Thompson, 2001; Abdrakhmatov, 2001) corroborated this stratigraphic scheme. For all main glacial periods, glacial sediments have been altered downstream into fluvioglacial and then to alluvial ones. The elevation of alluvial terraces above the riverbed is the stable parameter and is used to correlate the terraces of various drainage systems. Even-aged glacial, alluvial and prolluvial sediments form complexes related with Upper Pleistocene (Q_I), Middle Pleistocene (Q_{II}), Lower Pleistocene (Q_{III}) and Holocene (Q_{IV}) glacial epochs and interglacial periods (Trofimov et al., 1976, 1984, 1988; Abdrakhmatov, 1988.) Due to the determinant role of climatic factors, in the Central Tien-Shan Quaternary sediments are characterized by relatively consistent structure and composition. At the same time the climate aridization was progressively increasing. During the Holocene a dry continental climate dominanted, and this resulted in the relative stabilization of glaciers. (Trofimov, 1970; Grigina, 1994).

Alluvial sediments

Stratigraphic documentation of river wash and sedimentation observed in the section of terraces reflects the history of spatio-temporal changes in sediment supply into rivers, transportation and vertical movements of underlying complexes. The terraces within Cenozoic basins of the Tien-Shan are deposited on the Paleozoic base, usually overlain by slightly cemented Cenozoic sandstone and loams, pebbles and boulders up to some tens of meters thick, followed by siltstone, sand and fine gravel with a thickness varying from several centimeters to several meters. Both thickness and composition of siltstone and sandy sediments of the tops of the terraces differ depending on the distance from adjacent terrace elevations or valley sides (colluvial sedimentation) and local history of floods and loess accumulation (Trofimov et al., 1976, 1984, 1988; Abdrakhmatov, 1988; Thompson, 2001).

The Early Pleistocene terraces (Q_I) show thickness of 350 - 400 m in the upper course of the Saryjaz River, 500 - 600 m in the middle course and 900 - 1200 m in the lower course. Along the valley of the Engilchek River the Early Pleistocene terraces are mostly eroded and show an elevation of 800 - 900 m over the river line some 700 m in the upper course. In the upper part of the Kaindy River the Early Pleistocene terraces are developed in Neogene sediments. Their height is 450 - 500m and it decreases down to 300 - 350 m in the lower course. On the northern slopes of the Terskei Range the erosive terraces are predominant, although fragments of thin accumulative cover still occur in the upper zone of foothills where during the Early Quaternary an accumulative denudation plain existed.

The Middle Pleistocene terraces (Q_{II}) are characterized by elevations of 140-180 m above river level for Q_{II}^1 and 50-80 m for Q_{II}^2. They consist of boulder-pebble sediments with interlayers of sands and gravel (10-20 m), which are covered by a layer of loess-like loams (8-15 m). Mostly, they are accumulative however in some places erosive-accumulative. The base of the terraces usually consists of dislocated Cenozoic sediments (Turbin et al., 1972). In the study area frequently intensive cuts can be found. In the middle part of the Jergalan River the terrace Q_{II}^1 elevation above the river amounts to about 520 m. Along the Saryjaz River it varies from 200 to 400 m in the upper course and from 600 to 900 m downstream the Akshiyryak River mouth. Along the right bank of the Saryjaz River and the upstream Terekty River outlet it decreases to 350 m. Usually these are base - type terraces, with an alluvial-prolluvial cover up to several tens of meters in thickness. The Q_{II}^2 terraces are mostly well-developed and well-preserved. They display thickness of 250 - 300 m. The height of Q_{II}^2 terrace along the Jergalan River reaches 400 m and along the Tyup River it varies from 120 m in the lower to 200 m in the upper parts of the valley. Along the western course of the Kaindy River, the terraces transfer into accumulative and decrease to 150 - 200 m. The accumulative cover consists of grey and brownish-grey fluvioglacial pebbles. The minimal age of the Q_{II}^2 terraces in the Tien-Shan determined by the luminescent method was found to be 170±25 thousand years (Thompson, 2001; Abdrakhmatov et al. 2001). This is coincident with the third most recent interglacial period.

The Late Pleistocene terraces (Q_{III}) are relatively low plain-type terraces, well-developed along the valleys of the large rivers. Their height varies along the upper and middle course from 50 - 120 m, 30 - 100 m to 10 - 30 m, reaching maxim of 250, 150 and 70 m along the lower course of the Saryjaz River. These are mostly accumulative terraces and their bases are erosive in twisty areas. Both luminescent and isotopic methods (Bowman et al., 2004b; Thompson 2001; Abdrakhmatov et al. 2001) have determined the age of the Q_{III}^2terraces in the Tien-Shan as being 8.430± 0.6 to 21.6± 0.9 thousand years. Luminescent age dating of correlative Issyk-Kul lacustrine sediments varies from 10.5± 0.7 to 24.0± 1.9 (Bowman et al., 2004a). This data confirms that the river cuts and terrace formation occurred during the global glacial-interglacial intervals.

The Holocene complex (Q_{IV}) includes the sediments of the riverbeds, floodplains and two over-flood plain terraces with an elevation of 2 to 10 m. With the latter one displaying well-rounded gravely-pebbly sediments, which are covered by clays of up to 0.5 m in thickness (Trofimov et al., 1976). The recent rivers wide valleys with terraces are branched into numerous braided riverbeds. The majority of the rivers emerge from the glaciers or small glacial cirques. Similar to the northern slopes of the Terskei Range the Holocene terraces of the Saryjaz Basin show the following heights: floodplains 0.5-3 m, lower-above-floodplain terrace from 3 - 5 m to 10 - 15 m, upper-above-floodplain terrace from 10-15 m to 30 m. Channel fillings and flood-plain sediments consist of pebble/boulder and gravel/pebble grain-sizes with thicknesses of several meters. Samples of charcoal detritus and gastropod shells collected from above-floodplain terraces showed that the formation of the terraces occurred during the Early and Middle Holocene. Isotopic age dating of these samples varies from 3100±710 to 9840±50 years (Korjenkov et al., 1999; Thompson, 2001).

Glacial sediments

The Early Pleistocene moraines (Q_I) of semi-blanket glaciation are usually preserved, regardless their link with recent drainage network on the bottom of subsequent tectonic valleys, incised in the secondary watersheds of the main ranges and in the slopes of these main ranges. Their thickness reached 200 - 300 m, although due to scour they do not exceed tens of meters. In the upper part of the Jergalan – Karkara watershed fragments of the early Q_I Pleistocene moraine are located at an elevation of 3200 - 3400 m, and in the lower part of the Tyup River Valley at an elevation of 3000 m. In the basin of the Saryjaz River the Early Pleistocene moraine is only preserved in its upper part in some erosive surfaces. It occurs as a narrow band on the southern slopes of the western end of the Engilchek Range at an elevation of 3080 - 3120 m (Charimov, 1994). Moraines of the same age from the lower course of the Kaindy River along the left bank of the Saryjaz River and further along the valley of the Engilchek River is located at an elevation from 600 - 650 m to 700 - 900 m from the river line. The glaciers tongues in this area are at an elevation of 3250 m. Everywhere the moraines are formed by boulders, coarsely-rounded to unrounded gravel/pebble material and crushed rocks. In some places they are covered by solifluctive mud-streams.

The Middle Pleistocene moraines (Q_{II}) were usually formed by valley glaciers, seldom foothill glaciers. The height of the moraines reaches from 10 to 350 m. They are formed by unrounded unsorted detrital/lumpy sediments. The moraines of the second phase of the maximal glaciation (Q_{II}^2) are widely developed along the upper course of the Saryjaz River and at the foothill of the Saryjaz and Terskei Ranges, where they were deposited by foothill glaciers, small fragments of the Middle Pleistocene moraines also remained on the left bank of the Kaindy River. In other areas of the studied terrain this glaciation was restricted to valleys. The top of the Q_{II} moraines lies at an elevation of 2750 m.

The Late Pleistocene moraines (Q_{III}) were formed by valley glaciers. They form the bottom of Late Pleistocene troughs and in case of small glaciers they are located in their upper parts. Their surface is swarded, but where they are better preserved they usually show clayey detrital/lumpy unsorted sediments with thicknesses varying from 40 to 300 m (Turbin et al., 1972). Moraines of the third glacial complex (Q_{III}) are developed along the valleys of the big rivers. They are uneven, swarded, partially loessed, and hilly with a remaining ridge of coastal moraines and grounding terraces. Dams of the final stage moraine are observed almost everywhere. The final ridges of these moraines reach the average elevation for Q_{III}^1 at 2850 m, for Q_{III}^2 at 3125 m and for Q_{III}^3 at 3075 m.

The Holocene moraines (Q_{IV}) are characterized by their fresh appearance. They are unswarded and they have well-defined final banks and lateral ridges. They are formed by unswarded pebbly/lumpy material up to 50 - 70 m in thickness, which formed in the hanging cirques and upper parts of troughs. Below the glacier termini and the recent moraines at 3000 - 3500 m, pregracial outwash fields of boulder/pebble material and sands are developed. Narrow bands of Holocene fluvioglacial sediments in the upper parts of valleys gradually transfer into correlated terraces in their middle and lower courses (Trofimov et al., 1976; 1984; 1988). In the Holocene glaciation the described area was affected everywhere. Only in the valley of the Engilchek River they are covered with active ice or washed out. The final ridges of moraine (5-10 m high) decrease to 3360 m. In average the recent moraines drop to an elevation of 3550 m.

Compilers: T.A. Charimov, M.F. Buchroithner

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