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CHARACTERISTICS OF URANIUM DISTRICTS OF THE RUSSIAN FEDERATION

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Abstract

Uranium deposits are discovered in 15 ore districts of the Russian Federation. They are subdivided into four groups: Streltsovsky district with existing production centre, Stavropolsky district with depleted deposits, three prospective districts and ten reserve districts. The overview of new data on these districts is presented. Streltsovsky district with Priargunsky Production Centre include 19 molybdenum–uranium deposits of structure-bound volcanic type in caldera. The main activities in Stavropolsky district with two depleted uranium deposits are connected with restoration works and wastes rehabilitation. Except Streltsovsky district there are no more deposits in the Russian Federation prepared for uranium production. At the same time some uranium deposits of Vitimsky, Zauralsky, and West-Siberian districts are prospective for new development of production centres. They belong to the sandstone type, related to paleovalley or basal channel, and are suitable for ISL operation. The deposits of the other districts are considered to be reserve and considered unprofitable for uranium production at present and in the nearest future. The biggest of them is Aldansky district with gold-uranium deposits in potassium metasomatites in areas of Mesozoic activation of Archean cratons. Central Transbaikalsky, Yeniseisky, Yergeninsky, Onezhsky, Ladozhsky, Bureinsky, Khankaisky, Volgo-Uralsky reserve districts include mainly small-size deposits of vein, volcanic, surficial and metasomatite types with low uranium grades.

1. INTRODUCTION

After the USSR disintegration there left 60% off all Nuclear Power Stations capacities and only 26% of Known Uranium Resources on the Russian territory. Russian nuclear power plants demand and export supplies are provided by accumulated uranium stocks and by uranium produced from the deposits of Streltsovsky district in the Eastern Transbaikal region. Considerable part of the produced uranium is being exported. To 2010 the stocks may be exhausted due to increasing capacities of nuclear power plants and possible increasing of export because of rising prices for uranium. Thus the problem of new development in uranium resources and production is urgent for the Russian Federation.

Uranium deposits were discovered in 15 ore districts which are distributed mainly in the southern part of the Russian Federation. The vast areas to the north of 60° parallel remain practically untouched by exploration. These districts can be subdivided into four groups (Table I):

1. Streltsovsky district with existing production centre,
2. Stavropolsky district with depleted deposits,
3. Three prospective districts (Vitimsky, Zauralsky, West-Siberian) include deposits with "Known" resources recoverable at costs of $80/kg U or less, which are prospective for the development of new uranium production centres,
4. Ten reserve districts (Aldansky, Central Transbaikalsky, Yeniseisky, Yergeninsky, Onezhsky, Ladozhsky, Volgo-Uralsky, Bureinsky, Khankaisky, Chukotsky) include deposits of high cost uranium resources which may have economic potential for the future production.

TABLE I. URANIUM DISTRICTS OF THE RUSSIAN FEDERATION

Uranium Districts of Russia Table. 1

Districts	Grade U,%	Principal deposit type (ore setting)	Host rocks (lithology)	Strati-graphy*	Shape of ore bodies	U mine-rals **
District with existing production centre						
Streltsovsky		Volcanic	felsite, rhyolite,		stockwork,	
19 deposits (2depleted, 4-large, 7-mid., 6-small)	0,2	(Mo-U in caldera structure controlled)	dacite, basalt, conglomerate	Up.Jur.- L.Cret.	vein, tabular	P,C,B,G
			granite, marble	PZ_3-PR_1		
District with depleted deposits						
Stavropolsky	0,1	U vein-	rhyolite,	Quat.	vein,	P,G
2 small, depleted		stockwork	mudstone		lens	
Prospective disricts						
Vitimsky		Sandstone basal channel	sandstone,		ribbon,	
10 dep.(2-mid., 8-small)	<0.1	(U-REE in paleovalleys)	sand, clay, conglomerate	Tert.	lens, tabular	P,C
Zauralsky	<0.05	Sandstone basal channel	sandstone, sand,	Up.Jur.,	tabular,	
2-mid,1-small,1-deplet.		(Sc-REE-U in paleovall.	siltstone	Quat.	lens	P,C
West-Siberian	<0.15	Sandstone basal channel	sand, clay	Up.Jur.-	tabular,	P,S
1- mid., 3 - small		(U in paleovalleys)		L.Cret.	lens	
Reserve districts						
Aldansky	<0.1	Metasomatite (Au-U	gneiss, granite	Early.AR	vein,	B
9 dep.		in K metasomatites)			stockwork	
Central Transbaikalsky						
1-mid., 2-small	0.2	U vein	granite	M.-Up.Jur	vein	G
1-mid., 4-small.	<0.1	Volcanic (Mo-U in cal-dera structure controll.)	sandstone, dacite, rhyolite	M. Jur.- L.Cret.	tabular, vein, lens	P,C
2-mid., 3-small	<0.1	U sandstone	sandstone,conglom.	L.Cret	tabular	P,C
3-small	<0.1	As-U vein	granite, diorite	M-Up.PZ	vein	P
Yeniseisky						
2- mid.	<0.2	U sandstone	sandstone, siltstone		tabular	P,S
4-small	< 0.1	Volcanic (Mo-U in calde ra structure controlled)	felsite, tuff, rhyolite	Up.Dev.	lens, stockwork	P,C
Ergeninsky	<0.1	Lignite (U-REE in clay	clay, fish bone	Cenoz.	tabular	P,S
13dep.(1-mid.,12-small)		with bone detritus)	detritus			
Onezhsky		Metasomatite	siltstone,		stockwork,	
5 small	< 0.1	(U-V in carbonate-mica albite metasomatites)	shist, dolomite, sandstone	PR_1	vein, tabular	P,C
Ladozhsky						
1-mid., 1- small.	0,1	U unconformity (?)	sandstone	Riphean	lens, tabular	P,C
Bureinsky	< 0.2	Volcanic, vein-stockw.	felsite,	K_{1-2}	vein,	P,C,G
9 small		.(Mo-U in caldera)	rhyolite		stockwork	
Khankaisky						
3 small	<0.1	Mo-U vein	rhyolite	D	vein	P,C
1 small		Surficial (U paleovaleys)	sandstone	KZ	lens, ribbon	C,S
Volgo-Uralsky		Surficial				
2 small	<0.2	(U in paleovalleys)	clay, sand	Up.Perm.	lens,	
2 small	0,03	(U-bitumen in sediments	limestone	L.Perm.	tabular	C,P
2 small	0,01	(U epigenetic in lignite)	lignite	Quat.		
Chukotsky	0.1	Volcanic (Mo-U in cal-	volcanite,	Jur.	vein,	P
4 small, 1 depleted		dera structure controll.)	terrigene sediments		stockwork	

* - Stratigraphy: L-Lower, M-Middle, U-Upper, AR-Archean, PR-Proterozoic, PZ-Paleozoic, MZ -Mesozoic, Dev-Devonian, Perm.-Permian, Jur-Jurassic, Cret-Cretatious, Tert-Tertiary, Quat-Quaternary

** - Principal uranium minerals: P- pitchblende, C- coffinite, B- brannerite and U-Ti phases, G- supergene minerals, S- sooty pitchblende

The data on the main uranium districts and resources of the Russian Federation became available after the well known paper "Uranium Resources of the Union of Soviet Socialist Republics" at IAEA Technical Committee Meetings in August 1991 [1]. Since that time there were numerous publications in Russian geological editions and several presentations at IAEA Technical Committee Meetings [see references]. The idea of this paper is to summarise and to make the overview of new data on uranium deposits of the Russian Federation.

2. DISTRICT WITH EXISTING PRODUCTION CENTRE

Priargunsky Mining-Chemical Complex in Eastern Transbaikal region is currently the only uranium production centre in the Russian Federation. It processes the monometallic uranium and polymetallic molybdenum–uranium ores of Streltsovsky district deposits, which are classified as structure-bound volcanic type [1,2,3,4]. The average U grade is 0.18%. There are 19 deposits in the district (Fig. 1): 17 deposits are situated in volcanic rocks and sediments (13 of them are in stratified effusives of sheet facies and 4 in effusives of neck facies) and 2 large deposits in the basement rocks (dep. Antei in granite, dep. Argunskoye in granite and marble). The principal ore control factor is structural. The type of host rocks does not exert influence on ore grade [5].

Since the beginning of uranium mining in 1970 ten deposits have been brought into operation and only two deposits are depleted by open pit operation. Most deposits have been explored underground and conserved now.

Relatively high grade ores (over 0.3%U) of *deposit Antei* are the main object of current mining. Vein-like ore bodies are localised within two sub-parallel steeply dipping faults 1 km long and 350–1400 m from the surface. The upper borderline of Antei is flat dislocation in the structure eluvium of granites directly under the dacites of Streltsovskoye deposit. The latter include 20% of the district total resources.

The uranium production is provided mainly by traditional sulphuric acid leaching at the hydrometallurgical plant and a small amount is produced by heap leaching. The possibility of increasing production with low grade ores is being considered using heap leaching and in place leaching methods of ore processing. Ore bodies from the upper complex of the section in sediments and felsite with pitchblende, molybdenite-pitchblende and supergene mineralization are considered to be most favourable for these methods [6].

3. DISTRICT WITH DEPLETED DEPOSITS

Stavropolsky district include two depleted uranium *deposits: Beshtau and Byk.* Uranium mineralization is presented by oxidized sulphide-pitchblende veins and stockworks in xenoliths of bituminous sediments within the apex of granite porphyry and rhyolite bodies [1].

These deposits have been exploited by two underground mines since 1950, which were closed in 1975 (Beshtau mine) and in 1990 (Byk mine). From 1965 to 1989 ore bulk was processed not only by traditional sulphuric acid leaching at the milling plant, but also by in place leaching and heap leaching. From 1980s to 1991 ore bulk from Vatutinskoye U deposit (Ukraine) and from Melovoye U deposit (Kazakstan) was also processed at the Lermontovsky milling plant. After 1991, when U production has been stopped, apatite flotation concentrate is being processed at the milling plant.

Currently the main activities are connected with the environmental issues in the rehabilitations of wastes. Rehabilitation of mining wastes dumps of mine 1 (deposit Beshtau) at the surface of 36 ha is mainly completed. Rehabilitation of waste rocks of mine 2 (deposit Byk) at the surface of 18 ha is underway and planned to be finished in 1999. The project of milling complex (buildings and territories) remediation is at the planning stage. Rehabilitation and decommissioning of milling tailes pond at the surface of 118 ha has been started in 1996 and planned till 2005. The radiation survey of the region at the surface of 3200 ha was conducted in 1996.

4. PROSPECTIVE URANIUM DISTRICTS

The resources of Streltsovsky district deposits and uranium stocks are not sufficient to provide the requirements of the Russian Atomic industry and export commitments after 2010. Currently most of world uranium production is provided by very profitable deposits with high-grade ores (Canada) and by deposits suitable for in situ leaching (Kazakstan, Uzbekistan).

Deposits of Vitimsky, Zauralsky and West-Siberian districts are considered to be most prospective for new uranium production centres development in the Russian Federation. They are presented mainly by small and middle-size valley type sandstone deposits (sandstone basal channel type by IAEA classification) with low-grade ores, which are favourable for in-situ leaching operation. Deposits of Vitimsky and Zauralsky districts have been already described at IAEA-TCM [7] and in the "Red Book 1993" [2], that is why their description is excluded here.

4.1. West-Siberian district

The district is situated in south-western edge of Siberian platform. Deposits are located in the Upper Jurassic–Lower Cretaceous and Paleogene-Neogene platform sediments in an area of more than 5.000 km^2. Their geological setting is very much similar to deposits of Zauralsky district [2,7,8].

Malinovskoye deposit is the biggest one in West-Siberian district [9]. It is located about 100 km north-east from town of Kemerovo. Paleovalley is of meridian trend, 50 km length, 1–3 km width, 70m and 300m depth respectively in the mouth and in the source part. Cambrian volcanic–sedimentary rocks with granite and diorite intrusions and Devonian terrigene and terrigene–volcanic sediments with post Devonian granite and syenite intrusions constitute the basement of paleovalley (Fig.2). The average thickness of Mesozoic–Cenozoic alluvial sediments, which fill the paleovalley, is 300 m.

The productive horizon with U mineralization is presented by grey alternating sand, gravel, clay and siltstone, which are enriched by coal and organic material, especially in the lower part of the section (Fig.3). It is covered by overlying strata of Lower Cretaceous red clay 50–110 m thickness. The U ores are localised at the depth 100–300m from the surface in united sheet-like strata up to 50m. thickness, which consists of tabular-, lens- and roll-like ore bodies up to one km in length, 100–300m wide. Uranium grades are 0.013–0.139%, sometimes up to 1.32%. Principal U mineral is sooty pitchblende, minor pitchblende, coffinite. The ores have favourable technological properties for ISL mining: clay fraction less then 20% (average – 17%), low-carbonate content (CO_2-0.5%), recovery is 40–97% (average–76%), filtration factor is 0.65–17 m/day.

The presence of Malinovskoye deposit provided an evidence on the broad uranium potential of the south-eastern part of the West-Siberian platform margin.

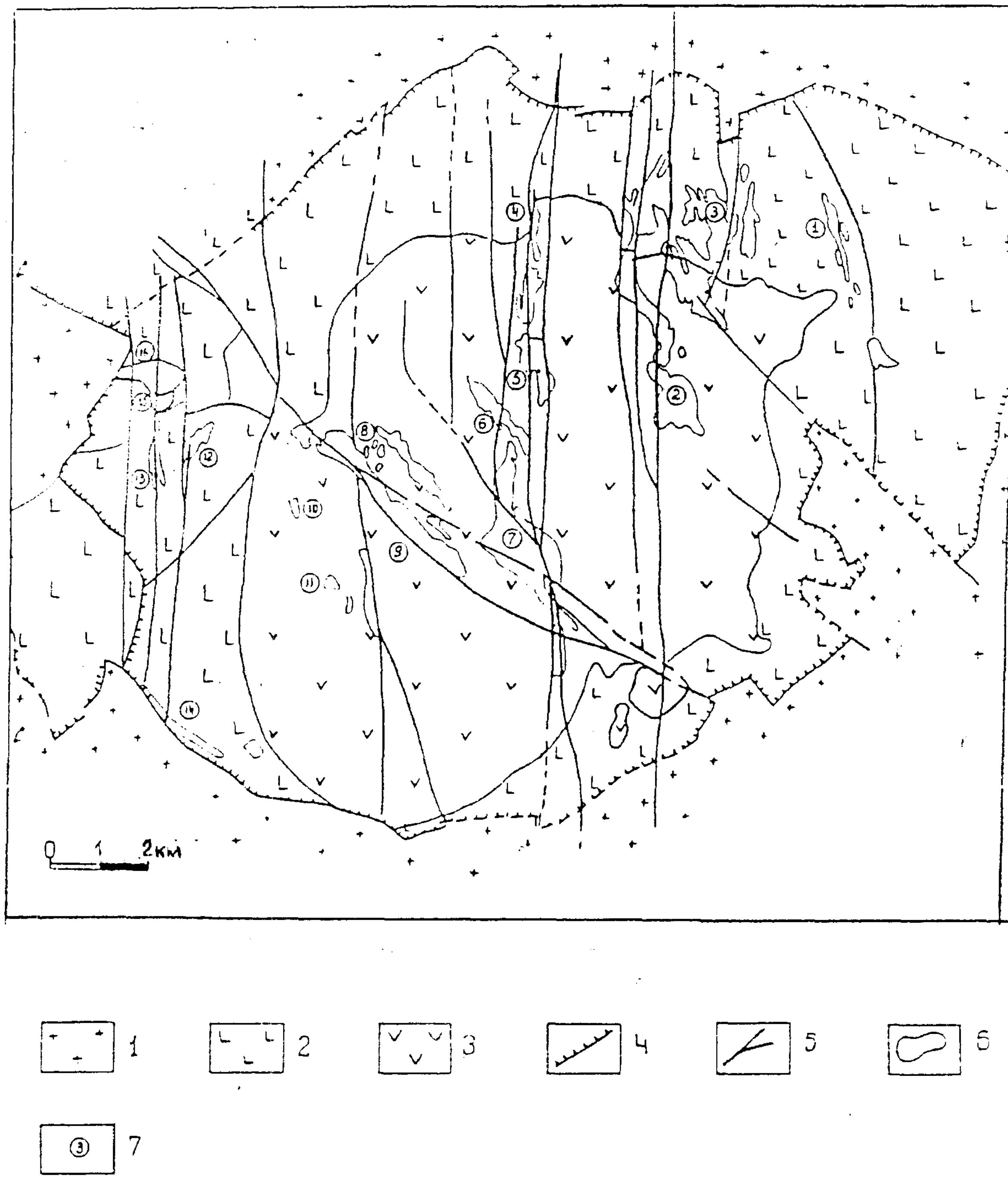

FIG. 1. Schematic geologic map of Streltsovsky district.

Legend: 1) Paleozoic granite; 2) Upper Jurassic volcanics and sediments of lower complex; 3) Lower cretaceous volcanics and sediments of upper complex; 4) Caldera boundary; 5) Fault zones; 6) Ore bodies projection;7) Deposits: (1) Shirondukuevskoye, (2) Streltsovskoye, (3) Antei, (4) Oktyabrskoye, (5) Martovskoye, (6) Lutchistoye, (7) Malo-Tulukuevskoye, (8) Tulukuevskoye, (9) Yubileinoye, (10) Vesenneye, (11) Novogodneye, (12) Pyatiletneye, (13) Krasnyi Kamen, (14) Yugo-Zapadnoye, (15) Zherlovoye, (16) Argunskoye.

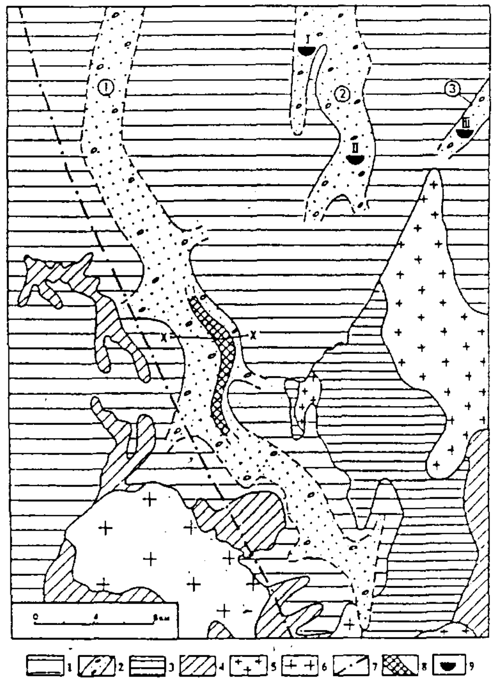

FIG. 2. Schematic geological map of Malinovskoye deposit area (after P.S. Dolgushin).

Legend: 1) Sedimentary complex of West Siberian platform; 2) Mesozoic alluvial productive facies of paleovalleys; 3-6 Rocks of the basement: 3) Devonian volcanics and sediments (red sandstone, siltstone, mudstone, effusives, tuffs), 4) Cambrian volcanics and sediments (porphyrite, sandstone, slates, limestone), 5) Mesozoic granitoid, 6) Pre-devonian granitoid; 7) Kuznetsko-Alatausky fault; 8) Malinovskoye deposit, 9) Uranium occurrences.

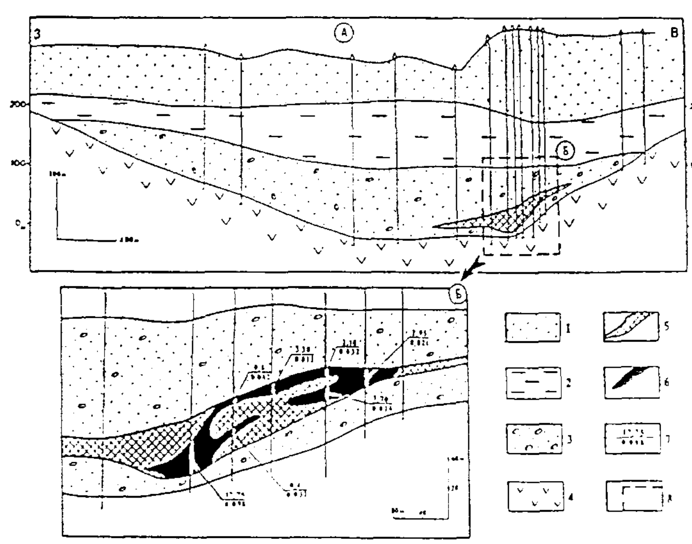

FIG. 3. Cross sections of Malinovskoye deposit (after P.S. Dolgushin).

Legend: 1) Lower and middle cretaceous kaoline clay, sand; 2) Lower cretaceous clay; 3) Lower cretaceous -upper Jurassic productive horizon of grey sand, gravel; 4) Porphyrite of the basement; 5) Ore body, 6) Commercial ores; 7) Parameters; numerator-thickness, m: denominator-U grade, %.

5. RESERVE URANIUM DISTRICTS

There are 10 reserve districts in the Russian Federation. They include numerous deposits which are unprofitable for uranium production at present and in the nearest future due to economic reasons.

5.1. Aldansky district

Aldansky district is situated in southern Yakytiya in the central part of Aldansky shield. It is the biggest reserve district of the Russian Federation [10,11]. Geological setting of the district include three levels of formations (Fig. 4):

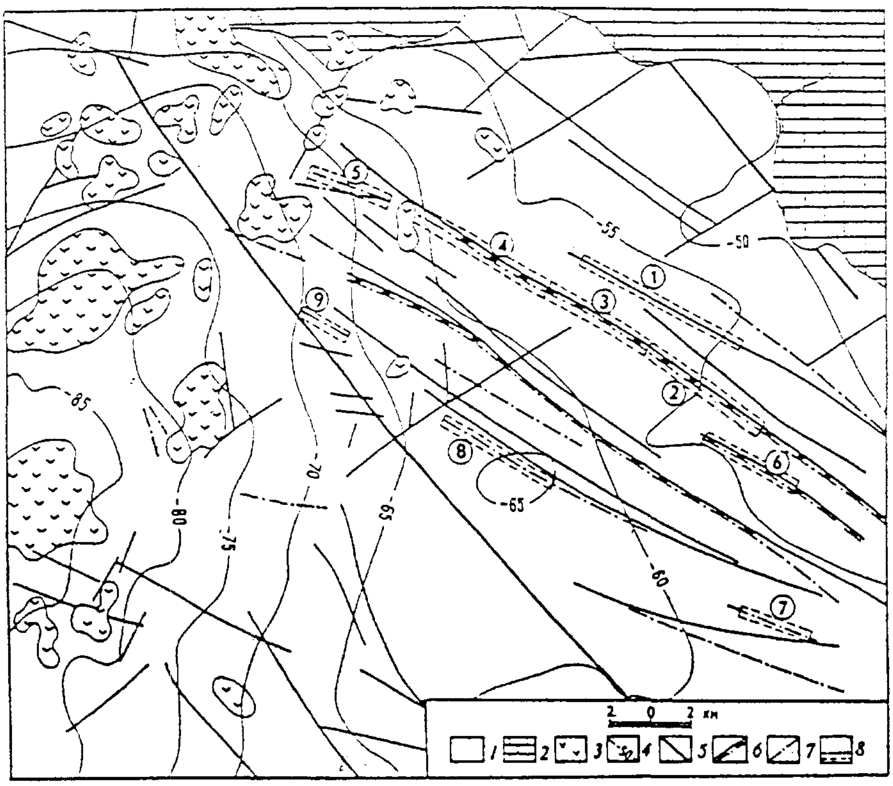

FIG. 4. Geological map of Aldansky uranium ore district (after E.V. Akhapkin).

Legend: 1) Archean crystalline basement (gneiss, granite, schists); 2) Cambrian platform mantle (limestone, dolomite); 3) Mesozoic intrusive subvolcanic complex; 4) Isoanomaly of gravitation field, m. gal; 5–7) Types of faults: 5) Ancient, 6) Ancient renewed in Mesozoic, 7) Mesozoic; 8) Ore parts of faults; Figures in circle-uranium deposits: (1) Severnoye, (2) Druzhnoye, (3) Kurung, (4) Elkonskoye Plateau, (5) Elkon, (6) Vesenneye, (7) Agdinskoye, (8) Snezhnoye, (9) Intersnoye (2–5 deposits of Yuzhnaya zone).

- Early Archean gneiss, granite, migmatite, schist compose the crystalline basement,
- Vend — Lower Cambrian platform mantle up to 700 m thickness is presented by limestone and dolomite,
- products of intensive Jurassic tectonic-magmatic activation presented by sediments and volcanics, which fill closed fault troughs, and by extrusion of laccoliths, stocks, sills of subvolcanic intrusions of alkaline complex.

Gold mineralization is typical for the district. It is presented by stratiform concentrations in the basal layers of closed fault troughs and by placers.

Uranium deposits are related to Elkonsky horst (the upstanding block of Archean granite-gneiss basement) which is intruded by Jurassic alkaline rocks and crossed by the faults of different age. These faults can be divided into three groups:
- ancient Early Proterozoic faults,
- renewed faults with overprinting of Mesozoic tectonites and metasomatites upon ancient faults,
- young Mesozoic faults, which develop within unbroken Archean rocks.

Uranium mineralization is related to young and to renewed faults.

Mesozoic activation led to intensive pre-ore pyrite- carbonate- feldspar metasomatic alteration extending along faults for tens of metres into the gneiss wall. Subsequent repeated crush and brecciation of potassic metasomatites inside faults precede uranium ore formation. Such tectonic sutures make up the complex of sub-parallel linear vein-like stockworks 500–700 m long and commonly up to 10m thick. The thickness of separate sutures is several centimetres. Uranium mineralization is presented by brannerite, which is usually transformed in amorphous aggregate of U-Ti dioxide phases. Ore textures — brecciated, knotty, cancellated with uranium mineralization in the cement. Molybdenum and gold are regarded as by-products. The absolute age of ores is 150–130 mln.y., the temperature of their formation 200–230°C.

Most uranium deposits are localized within Yuzhnaya zone, which is presented by 30 km long ancient tectonic suture, which have been renewed in Mesozoic (Fig. 4). Its central part can be considered as one gigantic deposit, consisting of deposits Druzhnoye, Kurung, Elkon, Elkonskoye Plateau with numerous echelon-like linear stockworks. The upper borderline of ores is situated commonly at the depths of 200–500 m but the most productive ore chimneys predominate at a depth more than 1 km. The average U grade is 0.15%. The resources belong to 80–130 $/kg U cost category. Deposits Kurung, Druzhnoye, Elkonskoye Plateau have been explored by underground mines, the rest — only by bore holes from the surface.

Complicated economic, geographical, mining and technical conditions and rather low quality of ores makes the development of this district unprofitable in the nearest future but it could be of future interest due to the considerable gold resources.

Other reserve districts include mainly small and middle size deposits of vein, volcanic and sandstone types with low U grades. They are not yet considered to be the sources of uranium production.

5.2. Central Transbaikalsky district

Central Transbaikalsky districts include 16 deposits of three principal types [1,4,12] (Fig. 5). Their genesis is connected to the Mesozoic and Cenozoic tectonic-magmatic activation, which occurred in various geological situations. Their resources could be considered as the potential addition to the base of Priargunsky Production Centre.

Volcanic type is presented by 5 U- Mo deposits in caldera composed by Upper Jurassic–Lower Cretaceous volcanic rocks (similar to some stratiform deposits of Streltsovsky district).

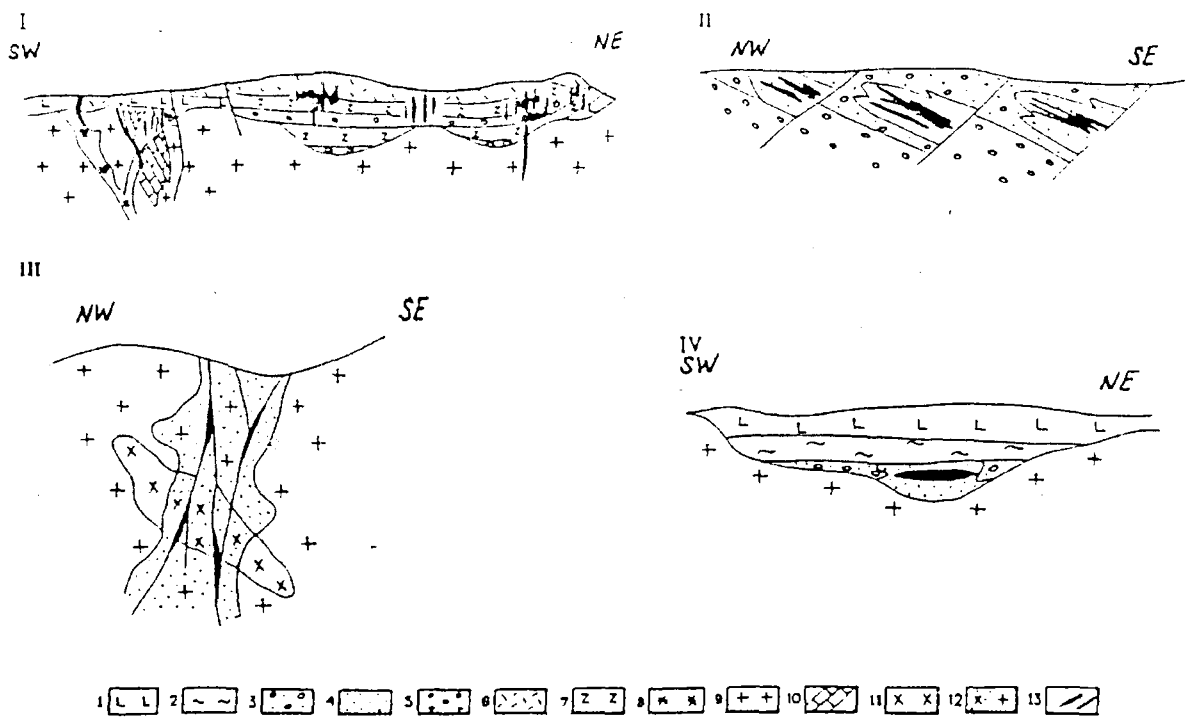

FIG. 5. Schematic sections of uranium deposits of Transbaikal region (after M.D. Pelmenev). I) Streltsovskoye ore field, II) Imskoye deposit, III) Gornoye deposit, IV) Khiagdinskoye deposit.

Legend: 1) Basal; 2) Siltstone-sandstone strata; 3) Red gravel and conglomerate; 4) Grey gravel and conglomerate; 5) Conglomerate; 6) Rhyolite; 7) Dacite; 8) Syenite-porphyry; 9) Granite; 10) Dolomite; 11) Diorite; 12) Clay-ceolite alteration, 13) Uranium ore bodies.

Olovskoye deposit is the biggest of the volcanic type. Mineralization occur in tabular stratiform bodies along interbeded contacts in volcanics and sediments of Upper Jurassic-Lower Cretaceous age. They are presented (from below to up) by conglomerate, gravel, sandstone, siltstone, rhyolite, tuff (Fig. 6) [13]. Biotitic granite and granodiorite constitute the basement. Vertical range of ore mineralization is from 10 to 120 m. Deposit consist of 90 ore bodies in 24 ore strata. Its length is 9 km, width to 600 m (average 200–250 m). More than a half of total resources are localised in lenses (to 20 m thick, first hundred meters long, first ten meters wide) in terrigene sediments and a third part of resources in ribbon-like bodies (first meters thick, more than 1 km long, 100–300 m wide) in the top and bottom of rhyolite and dacite tuff. Uranium mineralization is represented by pitchblende, coffinite in association with pyrite, native arsenic, carbonates, clay minerals. The age of ores is 102–110 mln.y.

Imskoye deposit is the example of 5 stratiform sandstone type U deposits in step faulted grabens, filled with molasse-like Cretaceous sediments [14]. The sediments are presented by the strata of conglomerate and gravel of proluvial facies, sandstone and siltstone of alluvial, limnetic and boggy facies. Their thickness is up to 1500 m. Proterozoic and Paleozoic granite and metamorphite constitute the basement of the graben (Fig. 7). Ore bodies of stratiform tabular and lens form are situated mainly in gravel with granite pebble and to a minor extend in sandstone. Host sediments are enriched with lignite, plant detritus and pyrite. The productive horizon is overlaid by 50–350 m cover. Uranium mineralization is represented by thin disseminated uranium oxides and sooty pitchblende in association with carbon substance and sulphides.

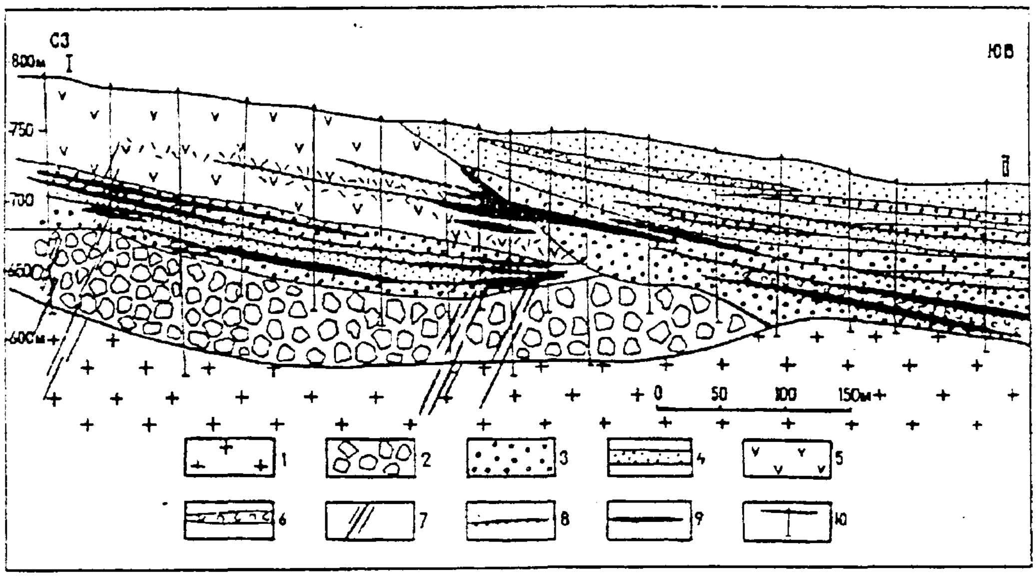

FIG. 6. Geologic cross-section of Olovskoye uranium deposit (after V.E. Vishnyakov).

Legend: 1) Granitoid and Metamorphites of the basement (lower structural stage); 2–6) Volcanics and sediments of upper structural stage): 2) Rubbly-clumpy conglomerate, 3) Heteropebbled conglomerate, gravel, 4) Sandstone, siltstone, 5) Rhyolite ignimbrite, 6) Rhyolite-dacite tuff; 7) Subvertical faults and jointing zones; 8) Gently pitching conformable interlayer faults; 9) Ore bodies; 10) Bore holes.

Gornoye deposit is a typical example of 6 vein deposits in highly radioactive Jurassic granite (Fig. 5) [15]. Ore bodies are located in 10 fault zones of north-north-east trend, which are developed in a tectonic fault wedge between two regional faults of meridian and north-east trend. Their length is usually first km, and thickness is to ten meters. Host rocks within these zones are intensively broken down and altered by quarts-clay-zeolite metasomatites. Separate veins-like ore bodies usually have a length up to first hundreds m and thickness to first m. Uranium grade is about 0.2%, sometimes to several %. The lower boundary of ores is at the depth 700m. Uranium mineralization is represented mainly by zeolite-beta-uranotil association. The age of ores is 40–14 mln.y.

5.3. Yeniseisky district

Resources of Yeniseisky district are presented mainly by two middle-size sandstone type stratiform deposits Primorskoye and Ust-Uyuk in Upper Devonian sediments of Minusinsky basin.

The section of *Primorskoye* deposit is formed in alluvial-lake Upper Devonian sandstone, siltstone, claystone [16]. Ores host is in thin (first metres) layers of grey sediments with the large amount of organic carbon (0. n-n%). The lateral extension of the ores is from 1 km^2 to 15 km^2. There are two types of ore bodies — irregular tabular and lens form in plan in essentially clay limnetic facies and ribbon-like form in the sand-clay sediments of channel complexes. Uranium grade is relatively high, from 0.05 to 2% (average 0.2%). Ore mineralization is represented mainly by thin-disseminated coffinite, with minor pitchblende. The absolute age of ore is 340–370 mln.y. Ore bodies of *Ust-Uyuk* deposit differs by ribbon and roll-like form and lower U grades.

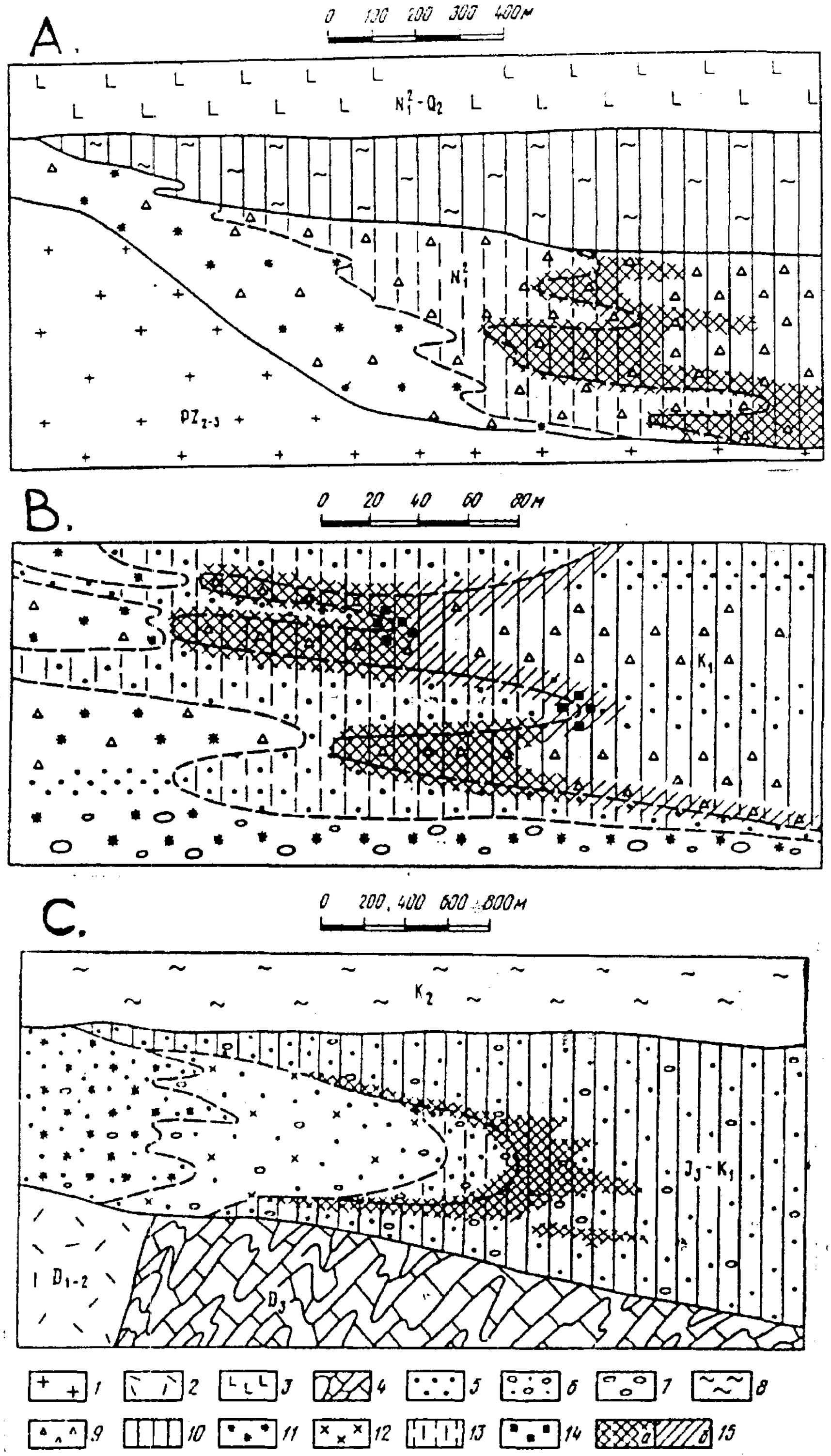

FIG. 7. Schematic geologic sections of deposits: A) Imskoye (Central Transbaikalsky distr.), B) Khiagdinskoye (Vitimsky distr.), C) Bobrovolnoye (Zauralksy distri.);

Legend: 1) Granite of the basement; 2) Persilic effusives; 3) Basalt sheet; 4) Limestone; 5) Sandstone; 6) Gravel-sand alluvial sediments; 7) Granite-pebble conglomerate; 8) Red clay sediments; 9) Pattum; 10) Primary grey sediments; 11) Mottled oxidized sediments; 12) Zone of redeposited Fe oxide; 13) Bleached sediments; 14) Accumulations of Neogenic Fe sulphides; 15) Uranium ores: a) high grade, b) low grade.

5.4. Yergeninsky district

The district is located within Kalmytskaya Autonomic Republic of Russia with the town Elista in the centre of it [17]. Its size is about 70 × 90 km. The district is situated in the northern part of Skifskaya platform within Karpinsky ridge. It has a cosidementational geological history of marine basin, which was more definitely displayed in Paleogene. Deposits consist of uraniferous fossil fish bones mineralization hosted in pyritic clays. They are also classified as organic phosphorous type. Tabular ore bodies with low U grades (0.05–0.07%) are localised within various "fish strata" of Upper Oligocene, which are similar to deposits of Prikaspysky district in Kazakstan [1]. Their dimensions are from hundreds meters to tens km long. Thirteen deposits, 37 ore occurrences and more than 30 mineralization manifestations are divided into 6 ore fields.

Stepnovskoye deposit with 20.000 mt U resources is the biggest in the district. It is located in the S-W part of the district at the depth 170–700 m and is characterised by following dimensions: 11 km length, 0.4–2.5 km width, 3–6 m thickness. The geological setting is very much similar to well-known Kasakstanian deposit Melovoye [1]. There are high contents of pyrite in the ores the average is 16% to as high as 25% in some strata. Other mineralization is characterized by plant relicts, phosphorites, dolomite, ankerite, barite.

A low thickness of ore strata (to 1 m) is typical for most deposits of the district, except Stepnovskoye (3–6m). The composition of the ores is presented in Table II.

5.5. Onezhsky district

Onezhsky district include some small metasomatite type deposits in the area of the Baltic shield, north-west part of the Russian Federation. They are considered to be unique due to considerable vanadium resources of high quality (av.grade –2.9%) [18]. Mineralization is polymetallic with high concentrations of gold, palladium, platinum, copper and molybdenum, which are regarded as by-products [19]. The deposits are localised within Onega epicratonnal trough filled with volcanic rocks, sediments and metamorphites of Lower Proterozoic (schungite, siltstone, slate, sandstone, dolomite, tuffites) in the zones of fold-faulted dislocations. Ore bodies are located within steeply dipping faults filled by cataclasites. Ore mineralization is situated in the zonal metasomatites aureoles upon host rocks (from periphery to the centre): pre-ore albitites, glimmerites, syn-ore mica-carbonate metasomatites. The latter are connected with the main U-V resources. Uranium mineralization is resented mainly by pitchblende and vanadium by vanadian flogopite, which are related to the aureoles of mica-carbonate metasomatites upon albitized slates, siltstone and sometimes dolomite. The age of ores is 1740 ± 40 mln.y. Primarily these deposits were related to unconformity type but according to some recent data their genesis could be regarded as infiltrational (similar to sandstone roll type deposits) in the areas of ancient weathering crusts [20].

5.6. Ladozhsky district

After the discovery of Canadian and Australian unconformity-contact deposits the exploration aimed on evaluation of unconformable contact of altered by lateritic weathering Archean basement and overlying Proterozoic sediments took place in the Russian Federation within the Baltic shield. The discovery of *Karhu* deposit in the Ladozhsky district, which is related to unconformity type in the basal layers of Riphean mantle, was the first result of these activities. Uranium mineralization is located mainly in the surface of arkose stratum upon the weathering crust of Archean basement rocks and to a minor extend in the basement rocks and in the upper basal sandstone. The principal uranium mineral is pitchblende in association with Fe, Zn, Mo, Cu sulphides. Syn-uranium alteration is presented by chloritization, carbonatization. Average uranium grade is 0.1% but could reach as high as 0.5% at 7 m thickness and even 8%. Dimensions of ore bodies are 300–500 m, thickness 2–7 m.

TABLE II. COMPOSITION OF THE ORES OF ERGENINSKY DISTRICT DEPOSITS (AFTER STOLYAROV A.S. [17])

Ore field/number of deposits	Average content, %							
	P_2O_5	**S.pyr.**	**Al_2O_3**	**U**	**ΣTR_2O_3**	**Sc***	**Re***	**Mo**
Stepnovskoye/1 dep.	4.8	16.0	7.5	0.05	0.23	18	1–4	0.024
Shargadykskoye/2 dep.	5.7–13.6	15.4–16.	5.3–6.9	0.03–0.05	0.2–0.38	17–19	0.2–1.4	0.013
Bagaburulskoye/4 dep.	15.–17.8	7.7–9.0	3.5–8.0	0.08–0.16	0.52–0.7	21–23	0.2–1.7	0.01
Centralnoye/2 dep.	3.9–6.6	5.–12.8	8.1–8.8	0.03–0.06	0.15–0.33	13–20	0.2–2.2	0.022
Kharabulukskoye/1 dep.	10.6	6.3	8.6	0.08	0.45	25	0.2–1.0	0.06
Yashkulskoye/2 dep.	6.7–7.0	12.5	8.2–10.	0.03	0.18–0.32	14–16	0.2–1.1	—

*Content in n × 10–4

The geological position of this district is considered to be favourable for new deposits discovery, including the deposits of unconformity type in Pre-Riphean structures and of exogenetic-epygenetic (sandstone) type in Vend- Paleozoic sedimentary complexes.

5.7. Bureinsky district

Bureinsky district includes 5 small deposits of volcanic type in Cretaceous rhyolite and felsite, which are similar to deposits of Streltsovsky district, and 4 small deposits of vein type in Upper Paleozoic rocks altered by albitization and pyrite-chlorite-hydromica metasomatites.

5.8. Khankaisky district

Khankaisky district includes 3 small deposits of vein type with low U grades (<0.1%): *Sinegorskoye and Fenix* deposits are located in Devonian rhyolite with quartz-sericite-hydromica alteration adjacent to leucogranite; ore bodies of Lipovskoye deposit are located within albitized cataclasm zones (up to 50 m thickness) in skarned Cambrian carbonate-terrigene rocks adjacent to Devonian granite.

Rakovskoye deposit belong to sandstone basal channel type. Ribbon-like ore bodies (to 1 km in length, to 100 m wide and 5–10 m in thickness) are located in lignite-bearing basal sandstone above granite basement. Mineralization is represented by coffinite and sooty pitchblende.

5.9. Volgo-Uralsky district

Volgo-Uralsky district includes six small deposits and numerous occurrences of exogenetic type in lignite, terrigene and carbonate sediments in south-eastern part of the Russian platform [21].

Sandstone type deposits in paleovalleys, filled with Upper Permian sediments, are represented by syngenetic *Cherepanovskoye deposit* with low grades (<0.03%) ores in black clay, and by epigenetic *Vinogradovskoye deposit* in permeable sands with relatively high grade ores (0.2%). Uranium ores contain Mo(0.005–0.5%), Sc(10–100 g/t), Ag(1–80 g/t). Ore bearing sediments contain organic substance and disseminated pyrite. Ore bodies with >0.01% grades are of tabular and ribbon-like form, up to 3 m thick, 100–200m wide, and hundreds of meters in length. The principal mineral is coffinite, which is usually disseminated in organic substance and in pyrite.

A lot of *Repyovskoye* occurrences and deposits of U-bitumen type are discovered in limestone and dolomite of Upper Carbonaceous age, covered by Middle Jurassic clay sediments. Ore lenses form roll-like bodies. Uranium grades are 0.01–0.4% (average 0.32%). The uranium mineralization is represented by pitchblende, coffinite, nyngioite associated with bitumen substance (asphaltite, kerite). Bitumen genesis is considered to be from oil and uranium syngenetic with bitumen [21,22]. The admixtures of V(0.01–0.6%), Ni, Mo(to 0.05%), Se(to 0.09%) are noted in the ores. Mining of this deposit by underground method is not presently profitable and by ISL is not effective due to carbonaceous host rocks.

The third group includes occurrences and two deposits *(Babaevskoye, Mayachnoye)*, which are associated with lignite-bearing formation and recent peat. Low U grade (0.01%) and small resources (<1000 t) are typical of them.

These examples confirm the potential favourability of the the Russian platform for uranium deposits.

5.10. Chukotsky district

This part is located in the north-eastern part of the Russian Federation and includes some small separate deposits of volcanic type in Mesozoic volcanites and in lignite-terrigene Jurassic sediments. The level of their exploration is very small and the prospects of mastering are almost impossible.

6. CONCLUSION

Numerous uranium ore districts of the Russian Federation include only one uranium producing centre on the basis of Streltsovsky district deposits. Most of the above-mentioned districts relates to reserve category and are unprofitable for exploration and production in the immediate future. However, taking into account trend of the growth of world uranium prices, the complex grading of the ores of some districts, as well as the possibility of new progressive mining and processing methods using (including in situ leaching), the prospects of the commercial exploration of new districts appear more optimistic.

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