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The Palladium and Platinum distribution in porphyry Cu± Mo deposits

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ABSTRACT

According to the previous studies to identify contents of PGE in porphyry Cu ± Mo deposits (Aksug, Sora, Zhireken of Russia, Erdenetiin Ovoo of Mongolia, etc.), we wanted to give short information to student who studies in the mining sector and especially for the experts who works as a miner, geologist or explorer that may this is new association to geology sector. We included 4 deposits brief introduction, contents of the PGE (Pd and Pt) in the various granitoid host rocks, main condition to form Pd and Pt in the porphyry system as well as future of the this study. Precious metal and associated element contents are reported for ore samples, sulphide concentrates, and chalcopyrite–molybdenite flotation concentrates from porphyry Cu-Mo intrusions of Russia (Sora, Aksug and Zhireken) and Mongolia (Erdenetiin-Ovoo). Average PGE contents in rocks are 17 ppb Pd and 22 ppb Pt in the Aksug deposit, 13 ppb Pd and <10 ppb (detection limit) Pt in the Sora, 14 ppb Pd and 21 ppb Pt in the Erdenetiin-Ovoo and 18 ppb Pd and 28 ppb Pt in the Zhireken deposit. In general, the precious metal distribution in the studied deposits has no direct relationship with the alteration types. The Cu–Mo ratios are highest in the Aksug and Erdenetiin-Ovoo deposits and lowest in the Sora and Zhireken deposits. According to experimental studies, significant amounts of Pd and Pt can be transported as chloride complexes by hydrothermal fluids in highly oxidized (fO_2/fS_2), salinity (30 to >75 wt% alkali chlorides) and high temperature (400°C to >700°C) within the K-silicate alteration also their deposition process is related to the composition of parent magma. Platinum group elements dissolved as chloride complexes may be deposited in response to a reduction, pH increase, dilution or temperature decrease (Grammon et al., 1992). About the temperature and other conditions are not exactly same in the other deposits such as 300-500°C temperature in Aksug deposits while Skouries deposit is formed in the 380°C-480°C etc. It is obvious that chloride complexes are the one of the most important transporter of Pt and Pd in the hydrothermal fluids from previous studies. During the past 25 years, many scientists have studied this significant study in porphyry Cu-Mo deposits in the different regions of the world. Even though we have porphyry Cu-Mo deposits such as Oyu-tolgoi, Tsagaan-suvarga, Erdenetuin-oboo, Harmagtai, Bayan-Uul, Shuteen, Saran-Uul, Ariin-Nuur etc, we've not researched this study in our porphyry Cu-Mo deposits yet except Erdenetin-ovoo research which was studied by Russian experts about decades before. Furthermore, since we have a porphyry Cu-Mo deposits, we have to do research on precious metals deeply on our deposits and determine the Pd and Pt contents. May be this study's outcome will increase our precious metals reserve.

Keywords: Palladium, Platinum, Cu-Mo-Ag, Chalcopyrite; Molybdenite; Concentrates

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1. Brief introduction of deposits

Deposits are generally located in the area of southern Siberian craton of Russian (Aksug, Sora, Zhireken) and northern Mongolia including subduction, collision, and rift-related igneous series of early Paleozoic to Mesozoic age. These deposits are all characterized by various crustal contribution to their parent magmas and the presence of explosive breccias. The Cu–Mo mineralization is associated in time and space with the porphyry stocks and dikes, hosted within granitoid plutons. The host and porphyry complexes are represented by compositionally variable mafic to felsic rocks; evolved rocks are more abundant in the porphyry complexes, as demonstrated by their rare element contents. Representative chemical analyses of the rare element contents of the major host plutons and porphyry rock types of the deposits studied are given by Berzina et al. (1999c). The porphyry intrusions are accompanied by well-developed hydrothermal alteration and disseminated or vein-stockworks of pyrite, chalcopyrite and molybdenite, with temperatures of formation varying from early potassic (700–500°C) to late sericitization, silicification and argillization (400–200°C) (Sotnikov et al., 1977). A common feature of the studied porphyry copper–molybdenum systems is the presence of explosive breccias, which are considered to be related in space and time to the porphyry stocks; furthermore, a crustal contribution to the parent magmas of the porphyry intrusions is apparent (Berzina et al., 1999a; Sotnikov et al., 1999). The

Sora, Erdenetiin-Ovoo and Aksug deposits are characterized by a dominant mantle component in their parent magma, in contrast to the Zhireken deposit, characterized by an elevated crustal component.

1. Aksug Cu-Mo deposit, northeastern Tuva in Russia

The Aksug deposit of Northeastern Tuva, is of early Paleozoic (Devonian ((?)) age, and is located in the Tuvinian terrane. This terrane comprises an island-arc complex, including an Early Cambrian, low Na content basalt–andesite–rhyolite series, followed by Middle Cambrian collisional-related plutons of gabbro-diorite–tonalite affinity that host the porphyry Cu-bearing complex (Berzina et al., 1999b, c). The porphyries consist of diorite and tonalite, with rare granodiorite. The chemical compositions of the porphyries are similar to that of the host granitic plutons. The Aksug porphyries belong to the calc-alkaline series and represent an andesitic parental magma (Kuzmin, 1985). They are characterized by low Rb, Cs, Th, Ta, and REE contents, high K/Rb ratios (Berzina et al., 1999b,c), and low Fr/Cl in magmatic fluids compared to the deposits studied, based on the chemical composition of halogen-containing minerals, such as titanite, amphibole, biotite and apatite (Berzina and Sotnikov, 1995; Sotnikov et. al., 2000). In addition, the deposit is dominated by a mantle source component, with ($^{87}Sr/^{86}Sr$) varying from 0.70458 to 0.70496. Hydrothermal alteration is represented by early propylitizatiom and widespread quarts-sericite-metasomatism. K-silicates, in the form of quartz-K-feldspar veinlets, occur in the peripheral zones of the deposit. Sulphide mineralization occurs as veins, stockworks , and disseminated grains within the porphyries and host diorites and tonalities, consisting of chalcopyrite and pyrite with subordinate molybdenite, bornite, chalcopyrite, and trace tetrahedrite, sphalerite, and native copper.

2. Sora Mo-Cu porphyry deposit, Kuznetsk Alatau

The Mo–Cu porphyry Sora deposit of Early Devonian age, is located in the Kuznetsk Alatau terrane, an island-arc complex of Vendian–Early Cambrian age, consisting of trachyrhyolite–trachyandesite subvolcanics and monzonite–diorite-gabbro intrusions. In general, these rocks are characterized by relatively high Na contents. Collisional plutons of Cambrian–Ordovician age are represented by a monzodiorite–granosyenite–leucogranite association. Mineralization is related to subvolcanic stocks, including monzodiorite, diorite, syenite- and subalkaline granite-porphyries. The Sora porphyries have a K-calc-alkaline affinity, and although host granitoids and porphyries are similar in composition, a significant time gap of about 20–30 Ma between them is suggested by Sotnikov et al. (1995b) Strontium isotope data ($^{87}Sr/^{86}Sr$) =0.70400–0.70460 suggest that porphyry the emplacement coincided with the beginning of rift magmatism. Sora porphyries are characterized by increased REE, Nb, and Ta contents, high K/Rb (Berzina et al., 1999b, c), and elevated F/Cl in halogen-containing minerals, highest among the deposits studied (Berzina and Sotnikov, 1995; Berzina et al., 1997a; Sotnikov et. al., 2000). The Sora deposit is essentially characterized by Mo mineralization, consisting of molybdenite accompanied by pyrite, chalcopyrite and small amounts of sphalerite, galena, and tetrahedrite. The porphyry stock is characterized by potassic alteration (biotite, K-feldspar) and strong albitization (Na-Ca), with minor subsequent sericitization and silicification.

3. Erdenetiin-ovoo Cu-Mo porphyry deposit, Northern Mongolia

The Triassic Erdenetiin-Ovoo Cu–Mo deposit is located in the Orkhon-Selenge belt of northern Mongolia, formed above the subduction zone of the Mongolo-Okhotsk and Paleo-Tethys plates under the Siberian continent. Granites and andesites are the most volumetrically important rock types, with minor quartz diorites and granodiorites. Mineralization is most closely related to diorite and granodiorite porphyries with minor copper associated with the granite porphyries. The Erdenetiin-Ovoo porphyries belong to calc-alkaline series characterized by relatively high Na content, like the host granitoids, although the time gap between them is about 30 Ma (Sotnikov et al., 1995a). Isotope data suggest that, the host granitoids formed synchronously with that of early volcanism of a continental margin, whereas the ore-bearing porphyries are coeval with bimodal rift-related volcanism. The Erdenetiin-Ovoo deposit comprises strontium isotope signatures ($^{87}Sr/^{86}Sr$) value (0.70406-0.70424) for porphyry-generating magmas, which suggest a mantle source. These porphyries are characterized by high Sr and Ba content, and moderate HFSE and REE contents (Berzina et al., 1999c). Mineralization consists of chalcopyrite with pyrite, molybdenite and traces sphalerite, tetrahedrite, and hydrothermal rutile. Dominant hydrothermal alteration consists of silicification and sericitization of host rock silicates. Potassic and chloritic alteration is minor.

4. Zhireken Mo-Cu porphyry deposits, Eastern Transbaikalia

The Late Jurassic age Zhireken porphyry molybdenum–copper deposit is located in Eastern Transbaikalia. Host rocks comprise a calc-alkaline suite of normal to elevated alkalinity dominated by granodiorites, granosyenites and granites. The Zhireken subvolcanic stocks are of K-calc-alkaline affinity, mainly diorite-, granosyenite- and subalkaline granite-porphyries. Geologic and isotopic data suggest that these high REE porphyry genesis was related to the beginning of rifting during Late Jurassic–Cretaceous time. Among the other deposits discussed, the Zhireken subvolcanic stocks exhibit the highest Rb, Cs, Li, and Th contents and the lowest K/Rb ratios. Zhireken porphyry intrusions also have very high Rb/Sr ratios (Berzina et al., 1999c). Halogen-containing minerals are characterized by elevated F contents, although F/Cl ratios are generally lower than those of Sora deposit (Sotnikov et al., 2000). The most salient feature of the Zhireken deposits is elevated (87Sr/ 86Sr) values of 0.70510–0.70642 indicating a significant crustal contribution to the parent magma of these porphyries. Hydrothermal alteration consists of well-developed potassic (K-feldspar) and argillic assemblages, with ore mineral associations, including molybdenite accompanied by pyrite, chalcopyrite and traces sphalerite, rutile, tetrahedrite.

Table 1.

Characteristics of the deposits studied (Sotnikov et al./Ore Geology Reviews 18 (2001) 95-111)

Deposits, location	Average Cu/Mo in ores	Age	Age (Ma) ^{40}Ar-^{39}Ar	Age (Ma) Rb-Sr	(^{87}Sr-^{86}Sr)	Host intrusive rock	Magma type
The Aksug	40-70	Devonian (?)	400±380		0.70458–0.70496	Diorite, tonalite porphyries	calc-alkaline
The Sora	2-4	Early Devonian	402±386		0.70400–0.70460	Monzodiorite, diorite,syenite, subalkaline granite	K-calc-alkaline
The Erdenetiin-Ovoo	30-50	Triassic	225±3.5	252-220	0.70406–0.70424	Diorite, granodiorite, granite porphyries	calc-alkaline
The Zhireken	1	Late Jurassic	160-165	156±23	0.70510–0.70642	Diorite, granodiorite, subalkaline granite porphyries	K-calc-alkaline

2. The contents of PGE (Pd and Pt) in porphyry Cu-Mo-Au deposits

Content of platinum, palladium and gold in the ore and sulphide concentrates were determined in both X-ray Assay Laboratories (XRAL), Ontario, Canada, the National University of Athens, using ICP-MS and Atomic Absorption Spectroscopy (heated graphite atomizer). In order to determine contents of platinum, palladium and other precious metals (Ba, Cr, Cu, Mo, Ni, Pb, W, Zn), they sampled 43 ore samples from these deposits. Samples analyzed include intrusive mineralized rocks with veinlets of sulphides accompanied by quartz, and disseminated sulphides from various alteration types, sulphide concentrates from highly mineralized samples, as well as chalcopyrite and molybdenite flotation concentrates and molybdenites. Pd and Pt contents in the ore are representing that average contents of Pt and Pd are 17 ppb Pd/22 ppb Pt in the Aksug deposit, 13 ppb Pd/10 ppb Pt in the Sora, 14 ppb Pd/21 ppb Pt in the Erdenetiin-Ovoo and 18 ppb Pd/28 ppb Pt in the Zhireken deposit. The Pd and Pt contents of both chalcopyrite and molybdenite in flotation concentrates are low, varying between 9–52 ppb Pd and <10–110 ppb Pt in the Sora deposit, 17–83 ppb Pd and 29–96 ppb Pt in the Aksug deposit, 20 ppb Pd and 33 ppb Pt in the Erdenetiin ovoo deposit. The highest values recorded are 924 ppb Pd in concentrate sulphides from the Aksug deposit, and 684 ppb Pd and 299 ppb Pt in concentrate sulphides from breccia, Zhireken deposit. The high content of Pd in the sample (s-2392b) from the Aksug deposit probably reflects the presence of the PGE mineral. Distinct platinum group minerals have been identified as inclusions in chalcopyrite from several Cu-porphyry deposits (Tarkian et al., 1991; Tarkian and Stribrny,. 1999). Also the correlation matrix for selected major and trace element data on ore samples and sulphide concentrates 34 samples (Tab.2) shows that precious metals are associated with either chalcopyrite or molybdenite. The Pd and Pt occur as merenskyite in the deposits. For example, at grain boundaries of chalcopyrite and bornite of the Skouries (Tarkan et al.., 1991)

These the porphyry Cu-Mo deposits more related to the island-arc system about their geotectonic. The deposits which formed in the island-arc might contain more content of Pd and Pt than the deposits which deposited in the continental margin (Tarkian and. Stribrny, 1999). All copper–molybdenum porphyry deposits discussed are attributed to the beginning of rifting (Berzina et al., 1994, 1999B), but large plutonic intrusions that hosts porphyry systems have been known as having formed in different geodynamic environments. Ore-bearing porphyry systems apparently inherited geochemical features of preceding magmatism (Berzina et al., 1999c). For instance, the Aksug ore-bearing porphyry complex occurred within preceding collisional-related plutons associated with island-arc basalt–andesite–rhyolite series is characterized by highest Pd content and Pd/Pt ratio in sulphide concentrate as well as the highest Au contents in flotation and sulphide concentrates among the study of deposits. The Zhireken ore-bearing porphyry complex was formed with a significant crustal contribution. In the Late Triassic–Middle Jurassic period, northern parts of Eastern Transbaikalia (where the Zhireken deposit is located) was formed in continental-margin setting with subduction of oceanic crust (Zonenshain et al., 1990). The mantle source was partially changed under the influence of subduction processes. Sedimentary rocks possibly participated in these processes, which could be reflected by elevated PGE contents of the Late Jurassic ore-bearing porphyry complex. In addition, the rock of the complex which inherited many pertrochemical features of Island-arc magmatism and continental margin could be the one way to explain this PGE content of the ore.

3. Factor controller of PGE (Pd and Pt) in the porphyry system

The formation of Pd and Pt, several features are apparent as mentioned above. The studies have suggested that both Mineralogical and geochemical data, coupled with textural relations between base-metal sulphides indicate that the main Pd and Pt-bearing mineral merenskyite is associated with vein-type chalcopyrite and bornite, and was deposited during the major vein stage of Cu deposition. Also, they concluded that in the earlier stage of porphyry copper systems fluids are fully capable of transporting at least 10 ppb Pd if the source for PGE are available. The low and high content of these porphyry Cu-Mo deposits have a reason to explain. First the low content of Pd and Pt are probably connected with available of source material and composition of parent magma. Secondly the high content of those elements in the Zhireken molybdenites associated with breccia may be caused by assimilation of crust rocks and the magma fractionation (volatile component). Finally different contents of Pd and Pt in that deposits depend on their variable deposit conditions of geodynamic. A limited variation of the Pd/Pt ratio, seems to be characteristic of the studied porphyry Cu–Mo deposits.

The greater Pd and Pt contents in sulphide concentrates from the Aksug and Zhireken deposits may be related to their Na-and high-K-calc-alkaline parent magmas, respectively. Molybdenite concentrate from the Zhireken (deposit 24 wt.% Mo and 2.7 wt.% Cu) shows high contents of Pd (684 ppb) and (Pt 299 ppb), (sample s-0508g). Molybdenites from this system exhibit a significant enrichment in both Pt and Pd, especially in breccia-hosted samples. However, molybdenites and molybdenum flotation concentrate from the Sora deposit, which is related to high-K and elevated F calc-alkaline magmatism, show low Pt and Pd contents. This difference between the Zhireken and Sora molybdenites seems to be consistent with the higher values of the Sr isotope data in the former than in the latter, suggesting a major contribution of crustal rocks at depth prior the final emplacement. Another important feature to form Pd and Pt is the high temperature of the magmatic-hydrothermal fluids in porphyry Cu-Mo deposits. Every deposit has different temperatures even though should have been between 400°C to 700°C. For example 300°C-500°C In Aksug deposit, 380°C to 480°C in Skouries, porphyry Cu-Au deposit of Greece , 300°C to 400°C in Sungun, Cu deposits of Iran etc. Study indicates a small correlation between Cu and Mo ($r=0.42$) a strong positive correlation ($r=+0.98$) between Pd and Cu, and Pt–Mo (Table2). The lack of a strong Cu–Mo correlation may confirm the precipitation of the molybdenite and chalcopyrite during different stages, and that the bulk Mo mineralization has probably taken place from fluids undersaturated with respect to chalcopyrite, at relatively higher temperature (Hezarkhani et al., 1999). All previous studies suggest decisively that chloride complex is the main transporter. For instance Ore-forming fluids of the Aksug deposit were enriched in chlorides (Sotnikov et al., 2003). The presence of sulfates (anhydrite and, less often, barite and celestine) in metasomatites of the deep deposit horizons and results of gas chromatography of porphyritic-rock leucosome ($(CO + CH_4)/CO_2 = 0.05–0.02$) indicate that the oxygen fugacity was relatively high in the early stages of the porphyry system evolution (Berzina et al., 2005). Such conditions favored the transport of Pt and Pd as chloride complexes. Maybe because of it, Aksug deposit has high contents of Pd and Pt also study of Fengshan porphyry Cu-Mo deposit, Hubai Province, Eastern China has noted that the variation of mineralized fluid caused various transport forms in the Fengshan deposit. In the high temperature, fO_2, hypersaline fluid of the major mineralization stage, Pt and Pd were transported in chloride complex.

4. Future of this study

Recently PGE has been taking attention for both economic and scientific interest since two decades before. During the last 25 years this study has been done on the porphyry Cu-Mo and Cu-Au deposits in

Table 2.
Precious metals and associated trace element content in rocks from porphyry Cu-Mo deposits (Sotnikov et al/Ore Geology Reviews 18 (2001) 95-111)

	Concentration (pmm; ppb)												Pt/Pd	Cu/Mo
Sample	Ag	Au	Ba	Cr	Cu	Mo	Ni	Pb	Pd	Pt	W	Zn		
Aksug Russia														
s-0463b	<0.2	30	1360	34	1550	8	3	<2	11	17	73	8	0.65	194
s-0464	0.3	51	660	23	2090	10	4	<2	9	17	<10	22	0.53	209
s-0468	<0.2	47	430	3	950	55	3	<2	12	21	88	78	0.57	17
s-0474	0.5	204	400	11	2400	55	4	<2	12	21	88	78	0.57	44
s-0486	0.3	72	830	10	1010	72	4	<2	20	34	170	17	0.59	14
s-0487	0.2	26	1100	27	350	43	3	<2	23	20	36	58	1.15	8
s-0488	<0.2	24	1250	28	154	128	4	<2	31	21	30	13	1.48	1
s-0497a	0.3	36	660	11	3800	<1	5	<2	12	24	<10	26	0.5	>1800
Sora, Russia														
K-64a	0.8	21	1410	151	490	56	3	5	18	<10	30	100	>1.8	9
K-64b	<0.2	17	1070	9	15	4	5	<2	12	<10	88	67	>1.2	4
K-65a	2.1	16	880	61	1880	5400	20	<2	17	<10	120	880	>1.7	0.4
K-70a	3.7	19	1300	36	133	3	4	5	13	<10	68	81	<1.3	44
K-79	6.9	16	1280	15	240	14	7	5	10	<10	<10	61	>1.0	17
K-95e	<0.2	12	800	23	14	<1	3	5	9	<10	<10	44	>0.9	>14
Erdenetiin-Ovoo, Mongolia														
s-0404	10	18	400	21	2250	9	4	124	12	28	144	140	0.43	250
s-0404a	<0.2	19	1320	19	2040	21	4	<2	16	25	168	16	0.64	97
s-0413	`0.6	37	800	25	1740	21	10	5	17	32	177	36	0.53	83
s-0414	0.6	21	940	33	4050	23	14	43	12	16	156	42	0.88	176
s-0424	0.5	20	2340	46	2690	2	30	18	11	22	<10	113	0,5	1345
s-0424a	0.3	17	1250	12	1110	10	6	627	7	<10	68	130	>0.7	111
s-0873	<0.2	17	960	40	490	18	6	<2	11	18	80	46	0.61	27
s-0923d	<0.2	17	780	43	43	5	12	23	11	28	42	59	0.39	9
s-0943v	<0.2	21	830	28	125	3	8	<2	13	20	100	36	0.67	42
s-0946g	<.0.2	23	1500	19	100	755	5	<2	23	15	74	32	1.53	0.1
Zhireken, Russia														
s-0508a	<0.2	26	790	24	36	1530	5	2	26	27	110	15	0.96	0.02
s-0511b	<0.2	32	500	18	1000	210	7	<2	14	28	156	44	0.5	4.8
s-0511d	<0.2	23	720	32	147	225	7	4	16	21	106	24	0.76	0.6
s-0515	`<0.2	29	420	26	113	1220	3	53	21	37	182	9	0.57	0.1
s-0515a	0.2	60	350	5	27	136	3	20	13	32	61	6	0.41	0.2
s-0516b	<0.2	19	760	30	53	3	6	17	11	31	153	19	0.36	18
K-11	<0.2	21	900	60	174	573	8	10	24	22	156	60	1.1	0.3

Table 3.
Correlation matrix for selected major and trace elements from porphyry Cu–Mo deposits (Sotnikov et al./Ore Geology Reviews 18 (2001) 95-111)

	Ag	Au	Cu	Mo	Pd	Pt	W
Ag	1						
Au	0.57	1					
Cu	-0.47	0.91	1				
Mo	-0.07	0.06	0.42	1			
Pd	0.44	0.84	0.98	0.58	1		
Pt	-0.08	0.08	0.43	0.98	0.58	1	
W	-0.07	0.07	0.41	0.94	0.56	0.95	1

the world. But as we mentioned before, we haven't done yet this study on our porphyry deposits such as Oyu-Tolgoi(Cu, Au, Mo, Ag), Harmagtai, Tsagaan Suvarga, Erdenetiin Ovoo, Bayan-Uul, Shuteen, Saran-Uul, Ariin-Nuur etc. while we were studying this paper work, we tried to find information from these porphyry Cu-Au-Mo deposits and wanted to do comparative studies but we couldn't. It may because of a shortage of information and other things. Now we knew and know that we have plenty of porphyry deposits to do this study. In particularly, this study should start from Oyu-tolgoi by using that technologies which experts used their studies. Because the deposit has been working since 2009 and one the biggest mining company in our country. Then should go on other mentioned deposits. This study has a bright future because Erdenetiin Ovoo's study showed that various contents of PGE. Oyu-Tolgoi is much greater than Erdenetiin Ovoo's deposit about the contents of Cu, Mo. Copper reserve of Oyu-tolgoi is almost 7 times greater than Erdenetiin-Ovoo, as well as molybdenite. Also content of Pt will be greater than Pd because of the correlation between Cu-Pd and Mo-Pt. Therefore, we need to start with Oyu-tolgoi deposit.

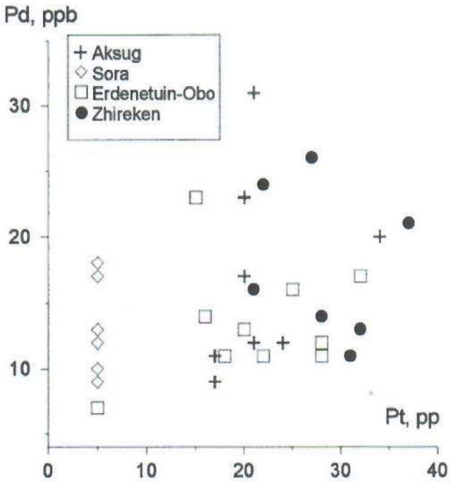

Fig.1. Correlation between Pd and Pt contents flotation and in ore data from (Tab.1)

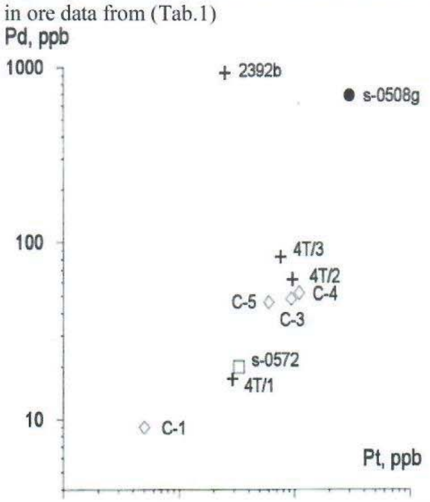

Fig. 2. Correlation between Pd and Pt contents in sulphide concentrates data from (Tab. 1). (V.I.Sotnikov et al./Ore Geology Reviews 18 (2001) 95-111)

5. Conclusion

1.We included four porphyry Cu-Mo-Au deposits which are located Siberian craton and North Mongolian in our study. In addition, we used Skouries deposit of Cu-Au in Greece in order to compare our key deposits and others (Sungun in Iran). All deposits which are studied in this work have almost same assumptions about the formation of PGE (Pd and Pt) even though every single deposits have different contents of Pd and Pt.

2.According to the studies main factor controllers of PGE could be crustal contribution to the parent magma, high temperature of hydrothermal fluids, chloride complex, oxidize (fO_2/fS_2), salinity (30 to > 75wt.% alkali chlorides) and less relation to alteration (potassic).

3. All this study proved that porphyry Cu-Au-Mo deposits have various content of Pd and Pt which means may we have other plenty resource of PGE and opportunity to raise our PGE reserve. All we need to do is do research deeply and determine content whether high or low in our porphyry deposits.

4.After we determine the contents (Pd and Pt), if the contents are valuable, we need to consider for the technology of concentration because Erdenetiin-Ovoo noted that we can't catch the PGE during the concentration of flotation

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