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GEOLOGY

The Model Re–Os Age of Platinum Group Minerals from Vilyui Placers in the Eastern Siberian Craton

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The mysterious "Vilyui" placers of fine gold and Rh-rich platinum have been known in the eastern Siberian Craton since the beginning of the 20th century, but their source rocks are still unknown. However, the large areas of their development indicate that the sources are probably characterized by high productivity and significant scales. Rhodium specialization of the Vilyui platinum was first reported by Vysotskii [1] based on the bulk composition of platinum flakes from the Vilyui River. Subsequently, we carried out detailed mineralogical investigations and revealed the typomorphic paragenetic association of platinum group minerals (PGM) of the Vilyui placers. The paragenesis is reflected in the association of Rh-rich Fe-platinum with a subordinate amount of minerals of the Ru–Ir–Os composition [2, 3]. We define this unique PGM paragenesis as an independent Rh–Pt (Vilyui) type, because this kind of mineralization is unknown in both bedrock and placer platinum deposits of the world. In the Siberian Craton, Rh–Pt placers are confined to the Vilyui syneclise and the Anabar–Olenek anteclise that are combined into the Lena platiniferous placer province. In terms of mineralogy and geochemistry, placers of the Lena province drastically differ from platiniferous placers in other regions of the Siberian Craton and its framing (Aldan–Stanovoi Shield, Baikal–Patom region, Yenisei Ridge, and northern Siberian Craton). This fact indicates that Vilyui placers have specific sources.

In order to identify the sources of PGM material accumulated in placers of the Lena province and to reveal the possible sources of this unique mineral association, we determined the initial Os isotopic composition in a number of osmium, ruthenium, rutheniridosmine, and Fe-platinum grains recovered from alluvial sediments of the Vilyui River (the Krestyakh and Kempendyai sectors) and the Chara River (Fig. 1). Negative thermal ionization mass spectrometry (NTIMS) was carried out with a Triton multichannel mass spectrometer in line with the algorithm examined in the papers of Kostoyanov et al. [5, 6].

The results of the analyses revealed the following facts. The initial Os isotopic composition ($^{187}Os/^{188}Os$ ratio) in minerals of the Os–Ir–Ru composition show a wide variation range (from 0.118324 to 0.124836). The Os isotope ratio does not depend on the composition and location of minerals (table). Only in one Fe-platinum grain (sample 33) is the ratio equal to 0.13671, which exceeds the typical value of 0.12736 ± 0.00036 in the present-day Os isotopic composition recorded for the nugget uniform reservoir (NUR) of platinum group minerals [8]. With respect to the contents of siderophile elements, such as Re and Os, as well as variations in the Os isotopic composition, the NUR composition is similar to the CHUR composition, in which the $^{187}Os/^{188}Os$ ratio is equal to 0.12863 ± 0.00046 [9]. Despite these minor discrepancies, Re–Os isotope systems of the NUR and CHUR reservoirs make it possible to define the evolution trend of the Os isotopic composition in the mantle. The available estimates indicate that the $^{187}Os/^{188}Os$ ratio in the mantle (chondrite) material increased from 0.096 to 0.12863 in the course of geological evolution. Hence, variations in the initial Os isotopic composition (0.118324–0.124836) in the PGMs from the Vilyui and Chara placers (Fig. 2) are consistent with the variation range of this parameter in the mantle (chondrite) material.

In contrast to many minerals, the PGMs are characterized by a very low content of Re (<0.05%). Therefore, variations in the Os isotopic composition in the PGMs can be provoked by in situ ^{187}Re decay due to the accumulation of placer minerals in different periods.

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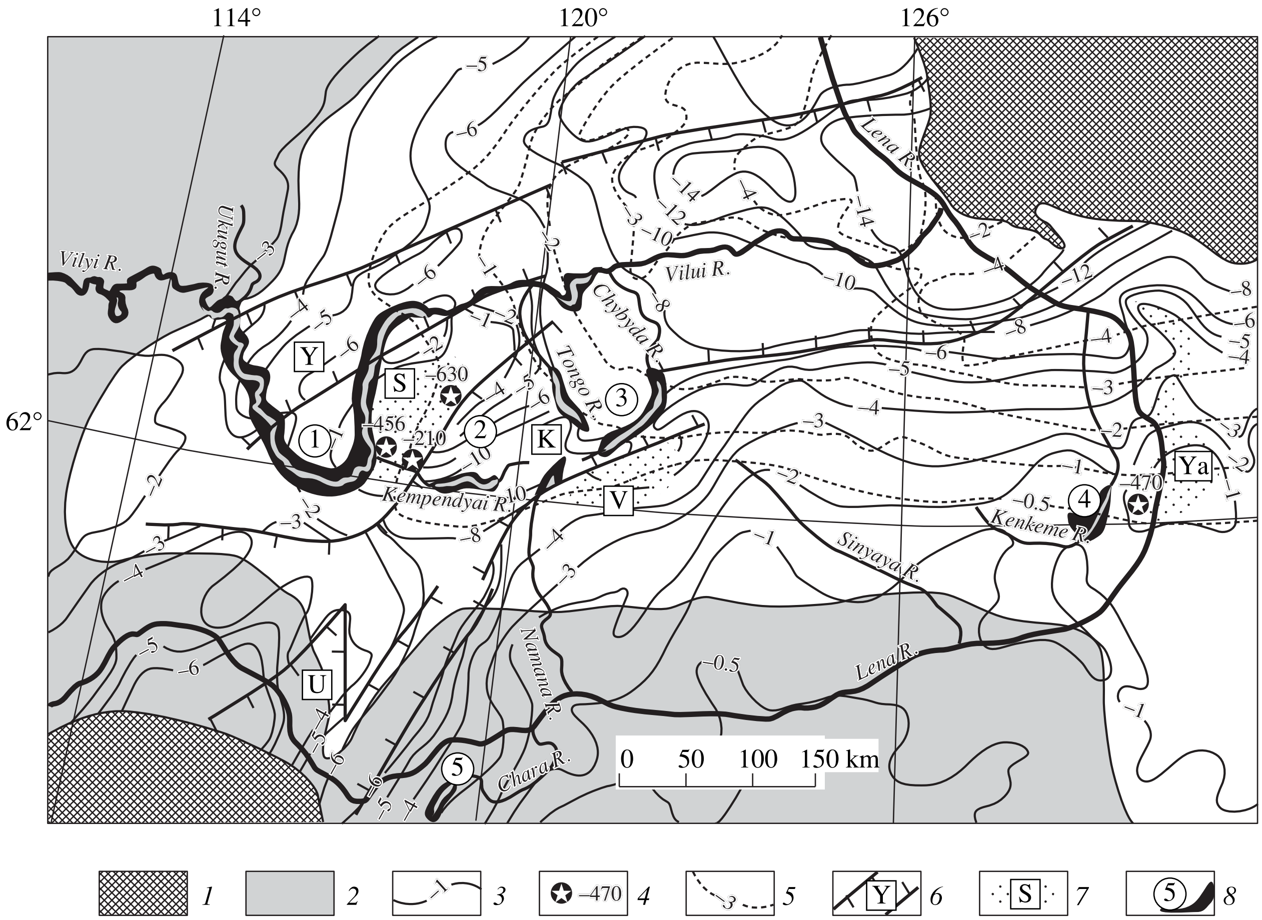

Fig. 1. Schematic location of platiniferous placers in the Vilyui syneclise. (*1*) Framing of the Siberian Craton; (*2*) Paleozoic cover rocks; (*3*) isohypses of the crystalline basement surface, km; (*4*) absolute marks of the basement surface in boreholes, m; (*5*) Mesozoic rocks with isohypses of the base; (*6*) boundaries of paleorift systems: (Y) Ygyattin, (K) Kempendyai, (U) Urin; (7) washout zones of buried basement inliers in Paleozoic and Mesozoic: (S) Suntar, (V) Verkhnesinsk, (Ya) Yakut; (8) placers: (1) at middle reaches of the Vilyui River, (2) at upper reaches of the Kempendyai River, (3) at upper reaches of the Tongo, Chybyda, and Namana rivers, (4) Kenkeme River, (5) Chara River. Tectonic scheme is based on [4].

This assumption is also supported by the following facts. Variations in the $^{187}Os/^{188}Os$ ratio in the PGMs from the Chara and Vilyui alluvium are consistent with variations recorded for platiniferous placers in the Kozhim and Timan (Polar Urals) [6], Amur [10], and other regions of Russia (Fig. 2). Moreover, the $^{187}Os/^{188}Os$ ratio varies not only within platinum placers, but also in the PGM-bearing bedrocks [11].

The common pattern of $^{187}Os/^{188}Os$ variation in minerals from different regions is consistent with the concept of the existence of global stages of mantle-related PGM ore genesis [6] and alkaline metasomatism [12]. In other words, processes of PGM accumulation in the mantle substrate were periodically reactivated in the Earth's interior. The Os-rich material with a heterogeneous isotopic composition was subsequently accumulated as platinum placers at the crustal level. Findings of PGM grains with a $^{187}Os/^{188}Os$ ratio higher than the typical NUR value (0.12736) do not contradict the proposed mechanism of the formation of isotopically heterogeneous PGMs in placers. However, the PGMs in such placers were probably derived from a Re-rich source rather than chondrites. The universal PGM source was characterized by a relatively constant Re/Os ratio, but the differentiation of source material could be accompanied by the Re–Os fractionation and the appearance of zones enriched (or depleted) in the PGMs. Moreover, as in the coaly and enstatite meteorites, the Re–Os fractionation could be promoted by redox processes.

Since variation ranges of the $^{187}Os/^{188}Os$ ratio in platinum placers of the Vilyui and Chara areas usually correspond to the mantle (chondrite) values, one can calculate the model Re–Os age for individual PGM grains based on the method discussed in [5]. Results of the calculation show that the age of PGM grains in placers of the Lena province ranges from 1320 to 370 Ma, i.e., from the Middle Riphean to the Middle Devonian (Table 1). The Re–Os age estimates differ from the model dates (200–405 Ma) obtained for minerals from

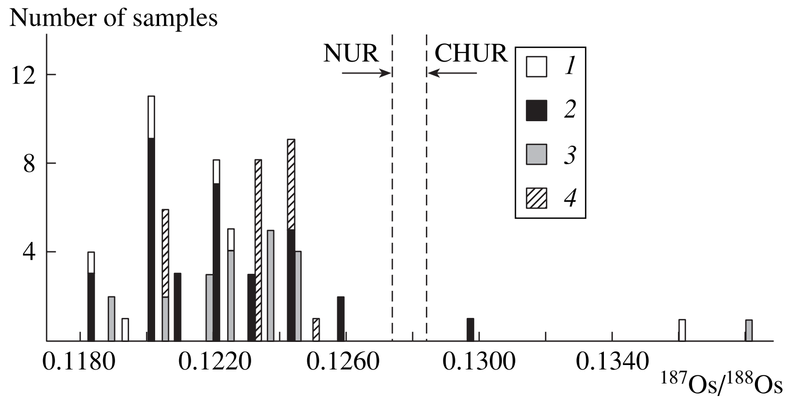

Fig. 2. Variations in the Os isotopic composition in PGMs from placers in different regions of Russia. (1) Vilyui and Chara rivers; (2) Middle Timan; (3) Kozhim River (Polar Urals); (4) Amur region.

placers associated with the Guli, Konder, and Inagli alkaline–ultrabasic rock massifs [13]. This fact testifies to a specific nature of the Vilyui platinum: it is related neither to the Middle Paleozoic or Late Paleozoic–Early Mesozoic basic (trap) magmatism nor to the alkaline–ultrabasic magmatism of the Siberian Craton.

Placers of the Lena province are mainly confined to fields of Mesozoic platformal terrigenous rocks in buried inliers of the crystalline basement. Rh–Pt placers are absent at exposures of the crystalline basement in the Aldan and Anabar shields. We also do not see any geological signs of the link between the Vilyui placers and bedrock sources within the Phanerozoic platformal cover. These facts suggest that primary platiniferous rocks of the Lena province are associated with a buried Proterozoic–Riphean megacomplex.

According to Trushkov et al. [14], commercial Pt concentrations in the Vilyui River are confined to boundaries of the Suntar Uplift in the Precambrian basement. Therefore, we can suppose that the Vilyui PGMs are related to sources located within the Suntar Uplift that underwent the final stage of erosion in the Early Jurassic. This assumption is supported by rare findings of platinum grains associated with gold in Lower Jurassic basal conglomerates in the study region. Based on drilling data, Precambrian basement rocks are located here at a depth of 210–630 m beneath the Lower Jurassic rocks. The Suntar Uplift is 6 and 8 km higher

Chemical composition (wt %) and model Re–Os age of PGMs from placers of the Lena platiniferous province

Analysis no.	Location	Pt	Ir	Os	Ru	Rh	Pd	Fe	Ni	Cu	Total	$^{187}Os/^{188}Os$*	$T_{Re–Os\ modal}$, ka**
23	Kempendyai River	2.32	37.83	48.01	11.85	0.26	0.01	0.25	0.03	0.10	100.66	0.118324 ± 0.000022	1320
19		1.76	36.17	37.86	23.48	0.00	0.00	0.26	0.04	0.09	99.66	0.119300 ± 0.000029	1175
60	Vilyui River	2.35	34.56	42.58	18.94	0.65	0.11	0.49	0.09	0.06	99.83	0.120230 ± 0.000018	1040
95	Chara River	7.94	27.51	30.57	31.85	1.52	0.20	0.22	0.01	0.11	99.93	0.11993 ± 0.00018***	1080
112		4.06	43.13	29.80	22.49	0.40	0.16	0.30	0.07	0.15	100.56	0.121968 ± 0.000022	785
70	Vilyui River	1.29	32.00	34.05	32.50	0.00	0.00	0.17	0.04	0.07	100.12	0.122653 ± 0.000017	685
26	Kempendyai River	10.23	32.37	38.22	16.11	0.30	0.00	1.75	0.22	0.38	99.58	0.12449 ± 0.00018***	420
22		1.62	37.23	57.25	3.28	0.26	0.03	0.22	0.01	0.12	100.02	0.12473 ± 0.00023***	380
27		4.34	33.24	42.05	19.78	0.28	0.04	0.39	0.05	0.13	100.30	0.12479 ± 0.00017***	375
8		1.02	43.00	43.63	12.01	0.02	0.02	0.53	0.16	0.14	100.53	0.12479 ± 0.00022***	375
25		2.95	37.89	41.56	17.35	0.26	0.00	0.33	0.05	0.06	100.45	0.124836 ± 0.000009	370
33		80.20	1.25	1.33	4.87	2.22	2.22	9.63	0.13	0.78	102.63	0.13671 ± 0.00035***	–

Note: (*) Normalized to $^{190}Os/^{188}Os$ = 1.98379 [7]; (**) calculated according to [5] (dynamic measurement regime). The PGM composition was determined with a Camebax-Micro microprobe at the Institute of the Geology of Diamond and Noble Metals, Yakutsk (N.V. Leskova, analyst).

than the Ygyattin and Kempendyai depressions, respectively [15]. The schematic map (Fig. 1), which is based on isohypses of the basement surface and Mesozoic rock base, shows the inferred erosion areas of basement inliers beneath the Suntar and Yakut uplifts in the Mesozoic. Some PGMs could also be delivered from the intermediate (Riphean, Cambrian, Devonian, Carboniferous, and Permian) metalliferous sediments (collectors); i.e., the washout zone could be wider.

The contrast differentiation of platformal cover in the eastern Siberian Craton (alternation of narrow linear subsidence zones and distinct uplifts) and the abundance of basic, alkaline–ultrabasic, kimberlitic, and other rocks of different ages are related to intense processes of rifting in the Late Precambrian and Middle Paleozoic [4]. These age boundaries are in good agreement with variations in the model age of PGMs in the placers.

Thus, the mineralogical–geochemical characteristics and Os isotopic compositions of the PGMs suggest the following conclusion. The Vilyui platinum of the Lena province (eastern Siberian Craton) was derived from unconventional platiniferous sources confined to rock blocks beneath the platformal cover. Periodic uplifts and subsidences of the Earth's crust in the course of the Riphean and Middle Paleozoic rifting fostered the multiple washout of platinum from the intermediate collectors. Subsequently, the fine-grained fraction of the well-sorted platinum was transferred from the primary sources and dispersed as placers over a large area of Mesozoic–Cenozoic terrigenous sediments.

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REFERENCES

1. N. K. Vysotskii, *Platinum and Its Mining Areas* (Akad. Nauk SSSR, Leningrad, 1933), Part 5 [in Russian].
2. A. V. Okrugin, A. A. Kim, E. D. Izbekov, et al., in *Platinum of Russia* (Geoinformmark, Moscow, 1999), Vol. 3, pp. 319–333 [in Russian].
3. A. V. Okrugin, Int. Geol. Rev., No. 8, 677 (1998).
4. *Tectonics, Geodynamics, and Metallogeny of the Republic of Sakha (Yakutia)*, Ed. by L.M. Parfenov and M.I. Kuz'min (Nauka/Interperiodica, Moscow, 2001) [in Russian].
5. A. I. Kostoyanov, Geol. Ore Deposits, No. 6, 485 (1998) [Geol. Rudn. Mestorozhd., No. 6, 545 (1998)].
6. A. I. Kostoyanov, D. Yu. Ivanov, and V. V. Manoilov, Geochem. Int., No. 6, 534 (2003) [Geokhimiya, No. 6, 595 (2003)].
7. D. Tuttas, Appl. News, No. 1, 15 (1992).
8. Q. Yin, E. Jagoutz, H. Palme, and H. Wanke, in Abstracts of Papers. XXVII Lunar and Planetary Science Conference (Texas, 1996), Part 3, pp. 1475–1476.
9. J. H. Chen, D. A. Papanastassiou, and G. J. Wasserburg, Geochim. Cosmochim. Acta **62**, 3379 (1998).
10. V. G. Moiseenko, V. A. Stepanov, and A. I. Kostoyanov, Dokl. Earth Sci. **376**, 468 (2001) [Dokl. Akad. Nauk **376**, 794 (2001)].
11. K. Malitch, S. Junk, O. Thalhammer, Can. Mineral. **41**, 331 (2003).
12. L. N. Kogarko, Petrology, No. 3, 230 (1998) [Petrologiya, No. 3, 251 (1998)].
13. K. N. Malitch and A. I. Kostoyanov, Geol. Ore Deposits, No. 2, 126 (1999) [Geol. Rudn. Mestorozhd., No. 2, 143 (1999)].
14. Yu. N. Trushkov, E. D. Izbekov, A. I. Tomskaya, and V. I. Timofeev, *Gold Potential of the Vilyui Syneclise and Its Framing* (Nauka, Novosibirsk, 1975) [in Russian].
15. K. B. Mokshantsev, D. K. Gornshtein, G. S. Gusev, et al., *Tectonic Setting of the Yakutian ASSR* (Nauka, Moscow, 1964) [in Russian].