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SUPPLEMENTARY TABLES 1-6

SOURCES OF PLATINUM-METAL DEPOSITS FROM POLAR SIBERIA AND MIDDLE URALS: EVIDENCE GROM RADIOGENIC (RE-OS, PT-OS) AND STABLE (CU, S) ISOTOPES

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Table S1. Concentrations of highly siderophile elements (ppb) in chromitite and clinopyroxenite from the Guli and Nizhny Tagil massifs

№ образца	Os	Ir	Ru	Rh	Pt	Pd	Au	Re	ΣHSE	Pt/Pd	Pt/Ir
G-40	277.8	215.9	370.6	-	1.0	0.27	n.a.	0.14	865.71	3.7	0.005
G-3	43	62	212	6.7	1.3	1.0	n.a.	0.29	326.29	1.3	0.021
G-5	94	34	56	4.6	1.1	1.0	n.a.	0.15	190.85	1.1	0.032
G-86	0.10	0.24	0.11	0.30	7.25	4.25	n.a.	0.54	12.79	2.0	31.97
NT-14	4	76	8	29	1190	16	22	n.a.	1345	74.38	15.67

Note. Samples G-40, G-3, G-5 – chromitites from the Guli massif; sample G-86 – clinopyroxenite from the Guli massif; sample NT-14 – chromitite from the Nizhny Tagil massif; «n.a.» – not analyzed.

Table S2. Chemical and Cu-isotope data for laurite and erlichmanite from the Guli massif

Analysis #	Mineral, Figure	Ru	Os	Ir	Rh	Fe	Ni	S	As	Total	Ru#	$\delta^{34}S$
1	Lr, Fig. 5б	60.02	0.74	0.13	0.26	<d.l.	<d.l.	38.84	<d.l.	99.99	99	0.6
2	Lr, Fig. 5б	32.48	32.31	2.06	0.37	<d.l.	<d.l.	32.62	<d.l.	99.84	65	
3	Lr, Fig. 5б	34.01	30.71	2.32	0.27	<d.l.	<d.l.	32.77	<d.l.	100.08	68	0.0
4	Lr, Fig. 5б	52.34	9.11	1.60	0.23	<d.l.	<d.l.	36.81	<d.l.	100.09	92	
5	Lr, Fig. 5в	26.32	36.98	4.77	0.29	<d.l.	<d.l.	31.49	<d.l.	99.85	57	1.5
6	Erl, Fig. 5в	4.75	62.99	5.87	<d.l.	<d.l.	<d.l.	26.25	<d.l.	99.86	12	1.2
7	Erl, Fig. 5в	2.56	66.33	5.49	<d.l.	<d.l.	<d.l.	25.63	<d.l.	100.01	7	1.4
8	Lr, Fig. 5в	25.56	37.55	5.19	0.33	<d.l.	<d.l.	31.18	<d.l.	99.81	56	2.1
9	Lr, Fig. 5в	40.77	21.17	3.41	0.43	<d.l.	<d.l.	34.28	<d.l.	100.06	78	
10	Erl, Fig. 5в	4.40	63.79	5.14	<d.l.	<d.l.	<d.l.	26.31	<d.l.	99.64	11	
11	Erl	0.81	65.97	4.99	<d.l.	<d.l.	<d.l.	25.83	0.26	99.20	2	1.3
12	Erl	0.84	67.03	5.37	<d.l.	1.34	<d.l.	25.21	0.56	99.55	2	2.2
13	Erl	1.26	67.11	5.34	<d.l.	0.32	<d.l.	24.55	1.12	99.96	3	2.7
14	Erl	0.79	66.84	5.35	<d.l.	0.54	<d.l.	25.16	1.24	99.69	2	0.8
15	Lr, Fig. 5г	53.79	5.77	1.45	1.22	0.58	<d.l.	37.48	<d.l.	99.71	95	-2.0
16	As-Erl, Fig. 5е	3.96	48.47	16.24	<d.l.	0.31	<d.l.	23.91	5.93	99.68	13	6.0
17	As-Erl, Fig. 5е	3.35	49.84	16.01	<d.l.	<d.l.	<d.l.	23.74	5.79	99.91	11	4.7
18	As-Erl, Fig. 5е	1.63	50.76	16.86	<d.l.	0.83	0.34	23.18	6.13	99.78	6	6.0

Note. Lr – laurite, Erl – erlichmanite, As-Erl – As-bearing erlichmanite; an. 1-14: Ru-Os sulfides of the first type (assembled with Os-Ir alloys); an. 15: laurite of type 2 (assembled with ferroan platinum and Ru-Os-Ir alloys); an. 16-18: As-bearing erlichmanite of type 3 (in association with Os-Ir alloy); «<d.l.» – below the detection limit; detection limits (wt. %) were as follows: Rh – 0.27, Fe – 0.22, Ni – 0.12, As – 0.20; $Ru\#=100*Ru_{at\ \%}/(Ru+Os)_{at\ \%}$.

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Table S3. **Chemical and Cu-isotope data for Pt-Fe minerals from clinopyroxenite-dunite massifs**

Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sample	60-1	70-3	60-4	NL-104	NL-107	248	258	K2-1	K2-2	K1-3	K1-5	K2-7	K2-8	K2-9
Wt. %														
Fe	12.28	11.44	9.75	11.77	10.46	12.55	12.95	8.40	8.74	8.15	7.98	8.71	8.40	8.46
Ni	0.58	0.33	0.35	0.91	0.34	0.42	1.02	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.
Cu	0.51	0.53	0.99	0.42	0.22	0.76	0.71	0.57	0.59	0.71	0.87	0.40	0.50	0.64
Ru	0.64	<d.l.	0.32	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.	<d.l.
Rh	1.81	1.04	2.53	0.94	0.80	0.67	0.84	0.62	0.78	0.58	0.53	0.36	0.44	0.97
Pd	<d.l.	3.54	<d.l.	0.52	0.41	<d.l.	<d.l.	<d.l.	0.30	0.30	0.34	0.39	<d.l.	<d.l.
Os	0.53	<d.l.	0.22	0.63	0.24	0.21	0.27	2.73	0.13	0.29	0.22	0.25	0.24	0.26
Ir	5.62	1.51	4.57	3.11	2.03	4.22	4.49	2.80	0.76	1.40	2.09	1.01	2.45	2.31
Pt	78.28	82.11	81.20	81.75	85.39	81.09	79.66	84.83	88.83	88.61	88.13	88.94	87.82	87.14
Total	100.25	100.50	99.93	100.05	99.89	99.92	99.94	99.95	100.13	100.04	100.16	100.06	99.85	99.78
Ат. %														
Fe	31.64	29.65	26.25	30.75	28.48	32.61	33.05	23.91	24.60	23.22	22.73	24.68	24.00	24.01
Ni	1.42	0.81	0.90	2.26	0.88	1.04	2.48	-	-	-	-	-	-	-
Cu	1.16	1.22	2.35	0.96	0.53	1.73	1.58	1.43	1.47	1.77	2.18	1.00	1.25	1.59
Ru	0.91	-	0.48	-	-	-	-	-	-	-	-	-	-	-
Rh	2.53	1.46	3.69	1.34	1.18	0.94	1.16	0.96	1.19	0.90	0.82	0.55	0.68	1.49
Pd	0.00	4.81	-	0.71	0.59	-	-	-	0.44	0.45	0.51	0.58	-	-
Os	0.40	-	0.17	0.48	0.19	0.16	0.20	2.28	0.11	0.24	0.18	0.21	0.20	0.22
Ir	4.21	1.14	3.58	2.36	1.60	3.19	3.33	2.31	0.62	1.16	1.73	0.83	2.03	1.90
Pt	57.73	60.91	62.58	61.14	66.55	60.33	58.20	69.11	71.57	72.26	71.85	72.15	71.84	70.79
Total of PGE	65.78	68.31	70.50	66.03	70.12	64.62	62.89	74.66	73.94	75.01	75.1	74.32	74.75	74.40
Fe+Cu+Ni	34.22	31.68	29.50	33.97	29.88	35.38	37.11	25.34	26.06	24.99	24.90	25.68	25.25	25.60
δ^{65}Cu, ‰	0.27	0.31	-0.02	-0.12	-0.38	-0.34	-0.19	-0.09	0.06	-0.24	0.25	-0.04	-0.04	-0.31

Note. Ferroan platinum from Quaternary deposits of the Gule River (an. 1-3) within the Guli massif, Novy Log Creek (an. 4 and 5) and chromitites (an. 6 and 7) of the Nizhny Tagil massif; isoferroplatinum from chromitite of the Svetly Bor massif (an. 8-14); <d.l. – below the detection limit; detection limits (wt. %) were as follows: Os – 0.13, Ru – 0.28, Rh – 0.27, Pd – 0.22, Ni – 0.12.

Table S4. **Chemical and S-isotope data for laurite and Ir-Rh sulfides from the Svetly Bor and Nizhny Tagil massifs**

Analysis, Figure	PGM	Wt. %						At. %					Ru #	$\delta^{34}S$, ‰
		Ru	Os	Ir	Rh	S	Total	Ru	Os	Ir	Rh	S		
1	Lr	44.89	12.76	5.35	1.17	35.81	99.98	26.64	4.02	1.67	0.68	66.99	87	0.1
2	Lr	47.98	8.98	5.24	1.13	36.34	99.67	28.03	2.79	1.61	0.65	66.92	91	-0.4
3	Lr	44.80	12.98	5.26	1.17	35.76	99.97	26.61	4.10	1.64	0.68	66.97	87	0.0
4, Fig. 5ж	Lr	47.19	9.62	5.91	1.20	35.68	99.60	27.91	3.02	1.84	0.70	66.53	90	-0.6
5	Lr	44.97	12.96	4.94	1.21	35.59	99.67	26.79	4.10	1.55	0.71	66.85	87	0.2
6	Lr	44.35	13.84	4.73	0.89	35.90	99.71	26.36	4.37	1.48	0.52	67.27	86	0.0
7	Lr	43.15	15.81	4.68	0.88	35.30	99.82	25.97	5.06	1.48	0.52	66.97	84	-1.1
8	Lr	44.10	13.90	5.18	0.93	35.75	99.86	26.28	4.40	1.62	0.54	67.16	86	-0.1
9	Lr	46.88	10.78	4.82	1.05	36.05	99.58	27.61	3.37	1.49	0.61	66.92	89	-0.7
10	Lr	45.48	12.98	4.72	1.07	35.74	99.99	26.98	4.09	1.47	0.62	66.84	87	-0.2
11	Lr	50.65	5.56	5.67	1.19	37.01	100.08	29.04	1.69	1.71	0.67	66.89	94	0.0
Mean (n=11)														-0.3±0.4
12	Ka	<d.l.	<d.l.	50.07	24.80	25.07	99.94	-	-	20.29	18.78	60.93	-	-0.2
13	Ka	<d.l.	<d.l.	49.96	24.85	25.02	99.83	-	-	2028	18,84	60.88	-	-0.8
14	Ka	<d.l.	<d.l.	50.77	23.92	25.04	99.73	-	-	20.67	18.20	61.13	-	-0.3
15	Ka	<d.l.	<d.l.	67.97	9.56	22.27	99.80	-	-	30.99	8.14	60.87	-	1.4
16	Ka	<d.l.	<d.l.	60.83	15.82	22.96	99.61	-	-	26.67	12.96	60.37	-	-0.1
17	Ka	<d.l.	<d.l.	51.21	23.79	24.75	99.75	-	-	20.98	18.21	60.81	-	-0.5
18	Ka	<d.l.	<d.l.	52.95	22.96	23.99	99.90	-	-	22.09	17.90	60.01	-	0.4
19	Ka	<d.l.	<d.l.	52.13	23.59	24.17	99.89	-	-	21.62	18.28	60.10	-	0.1
20	Bo	<d.l.	<d.l.	42.46	31.42	26.07	99.95	-	-	16.49	22.80	60.71	-	-0.5
21, Fig. 5з	Ka	<d.l.	<d.l.	57.22	18.99	24.17	100.38	-	-	24.57	15.23	60.20	-	0.7
22	Ka	<d.l.	<d.l.	57.75	18.05	23.51	99.31	-	-	24.85	14.50	60.65	-	-0.3
Mean(n=11)														0.0±0.6
23, Fig. 5и	Lr	56.24	2.73	2.43	0.31	37.99	99.70	31.41	0.81	0.71	0.17	66.90	97	1.7

Note. Lr – laurite, Ka – kashinite, Bo – bowieite. Svetly Bor: an. 1-11 – laurite from alluvial deposits; an. 12-22 – PGM from chromitite; Nizhny Tagil: an. 23 – laurite from chromitite; $Ru\#=100*Ru_{at\ \%}/(Ru+Os)_{at\ \%}$; <d.l. – below the detection limit; detection limits (wt. %) were as follows: Os – 0.13, Ru – 0.28, Rh – 0.27, Pd – 0.22, Ni – 0.12.

Table S5. Os-isotope LA MC-ICP-MS data and calculated γ^{187}Os(T) values of PGM from placer deposits of the Guli massif

Sample #, Mineral*, Figure	Atomic Proportions	^{187}Re/^{188}Os	^{187}Os/^{188}Os	^{187}Os/^{188}Os(T)	γ^{187}Os(T)
Gule River					
H3-1, Os	$Os_{1.0}$	0.000019±8	0.12451±2	0.12451	-0.66±1
H3-2, Os	$Os_{1.0}$	0.000032±9	0.12450±3	0.12450	-0.67±2
H5-1, Os	$Os_{0.93}$ $Ir_{0.04}Ru_{0.03}$	0.000073±9	0.12439±3	0.12439	-0.76±2
H6-1, Os	$Os_{0.90}$ $Ir_{0.07}Ru_{0.03}$	0.00011±1	0.12446±2	0.12446	-0.70±1
H7-1, Os	$Os_{0.92}$ $Ir_{0.05}Ru_{0.03}$	0.000039±9	0.12449±3	0.12449	-0.68±2
G1.5-1, (Os,Ir), Fig. 5г	$(Os_{0.37}Ir_{0.30}Ru_{0.29}Pt_{0.03})$	0.000005±4	0.12414±5	0.12414	-0.95±4
G1.5-2, Lr, Fig. 5г	$(Ru_{0.30}$ $Os_{0.02}Rh_{0.01})(S_{0.67})$	0.000002±1	0.12409±3	0.12409	-1,00±2
7028-1, Lr, Fig. 5д	$(Ru_{0.32}Os_{0.01})S_{0.67}$	0.00015±19	0.12433±19	0.12433	-0.81±15
7028-2, Lr, Fig. 5д	$Ru_{0.33}S_{0.67}$	0.00002±4	0.12432±7	0.12432	-0.81±6
Ingaringda River					
6021-1, Os	$Os_{1.0}$	0.00002±1	0.12445±3	0.12445	-0.70±2
6021-2, Os	$Os_{1.0}$	0.000016±9	0.12449±3	0.12449	-0.68±2
6027, Os	$Os_{0.87}Ir_{0.09}$ $Ru_{0.04}$	0.000139±7	0.12440±3	0.12440	-0.75±3
23-1, Os, Fig. 5e	$Os_{0.66}Ir_{0.24}Ru_{0.11}$	0.00048±1	0.12446±3	0.12446	-0.70±1
23-2, As-Erl, Fig. 5e	$(Os_{0.22}Ir_{0.07}Ru_{0.03}Fe_{0.01})(S_{0.61}As_{0.06})$	0.000041±6	0.12444±1	0.12444	-0.72±2
Mean (n=14)				0.12439	-0.76
2SD (n=14)				0.00013	0.10

*PGM abbreviations: Os – native osmium, (Os,Ir) – Ir-bearing osmium, Lr – laurite, As-Erl – As-bearing erlichmanite. The initial ^{187}Os/^{188}Os and γ^{187}Os(T) values were calculated for the time of formation of the Os-rich alloys at 250 Ma using the parameters specified in the text. The uncertainty on the measured ^{187}Re/^{188}Os and ^{187}Os/^{188}Os is 2SE of the mean in the last decimal place; SD – standard deviation.

Table S6. Re-Os and Pt-Os isotopic N-TIMS data for chromitite and native osmium from the Guli massif

Sample #, Figure	^{187}Re/^{188}Os	^{187}Os/^{188}Os	^{187}Os/^{188}Os(T)	γ^{187}Os(T)	^{190}Pt/^{188}Os	^{186}Os/^{188}Os	^{186}Os/^{188}Os(T)	μ^{186}Os(T)
G-40, Fig. 4e	0.000250±12	0.1244256±7	0.12442	-0.7280±6	0.0000034±2	0.1198378±7	0.1198377	-2±6
67, Fig. 4a	0.00006±28	0.1246370±5	0.12464	-0.5585±4	0.0000044±0	0.1198397±5	0.1198397	+14±4
7-71, Fig. 4б	0.00006±28	0.1244995±5	0.12450	-0.6682±4	0.0000041±0	0.1198403±5	0.1198403	+19±4

Note. Sample G-40 – chromitite, samples 67 and 7-71 – native osmium ($Os_{87}Ir_8Ru_5$ and $Os_{94}Ir_3Ru_3$, respectively). The uncertainties on the isotopic ratios and the initial Os isotopic composition are quoted at 2SD based on the long-term reproducibility of the Johnson-Matthey Os standard at IGL [Puchtel et al., 2020]. The initial μ^{186}Os(T) and γ^{187}Os(T) values were calculated for the time of formation of chromitite and native osmium at 250 Ma using the parameters specified in the text. The uncertainty on the measured ^{187}Re/^{188}Os, ^{187}Os/^{188}Os, ^{190}Pt/^{188}Os, ^{186}Os/^{188}Os is 2SE of the mean in the last decimal place.