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Platinum, Palladium, and Rhodium Analyses of Ultramafic and Mafic Rocks from the Stillwater Complex Montana

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ABSTRACT

Analyses by a combination fire-assay—solution—optical-emission spectrographic method of 137 rocks from the Stillwater Complex, Mont., indicate that platinum, palladium, and rhodium are preferentially concentrated in chromitite zones. The A chromitite zone (21 samples) has an average of 988.9 ppb (parts per billion, 10^{-9}) Pt, 2290.2 ppb Pd, and 245.9 ppb Rh and reaches a maximum (to date) of 8,000 ppb Pt, 11,000 ppb Pd, and 1,700 ppb Rh.

INTRODUCTION

The occurrence of minor amounts of platinum-group metals in the Basal, Banded, and Upper zones of the Stillwater Complex was first documented by Howland (1933) and Howland, Peoples, and Sampson (1936). As part of the Heavy Metals program of the U.S. Geological Survey, a study of the distribution of the platinum-group metals within the complex resulted in the discovery of platinum-bearing minerals in the Peridotite member of the Ultramafic zone (Page and Jackson, 1967). Some of the platinum-group metals occur as the minerals laurite, cooperite, and a platinum-iron alloy which are included within cumulus olivine and chromite of the G and H chromitite zones. The platinum-bearing minerals are associated with iron-nickel-copper sulfide minerals and are concentrated in chromite relative to olivine. Recently, Grimaldi and Schnepfe (1969) have proposed that most of the rhodium and some of the platinum are in chromite either as solid solution or as small inclusions.

In order to survey the other petrologic environments within the complex, large bulk rock samples were collected for Pt, Pd, and Rh assays. The results from 137 samples are given in this report (table 2).

Samples have been located relative to coordinate systems used on the maps of the complex which appear in the following reports: Peoples and Howland (1940), Howland, Garrels, and Jones (1949), Jackson, Howland, Peoples, and Jones (1954), Peoples, Howland, Jones, and Flint (1954), Howland (1955), and Jones, Peoples, and Howland (1960). Designation of geographical areas follows the usage of these reports. Stratigraphic terminology is shown in table 1 and follows that of Hess (1960), Jones, Peoples, and Howland (1960), and Jackson (1961); cumulus terminology is from Jackson (1967).

Table 1.—*Subdivisions and terminology used for the Stillwater Complex, Mont.*

Zone	Member	
Upper zone	-----	
Banded zone	-----	
Ultramafic zone	Bronzitite member	Contains about 15 cyclic units, each of which normally has a chromitite zone, labelled A through K from the base upward.
	Peridotite member	
Basal zone	-----	
Hornfels	-----	

ACKNOWLEDGMENTS

The contribution of samples taken previous to 1968 by E. D. Jackson is warmly acknowledged.

SAMPLING AND ANALYTICAL METHODS

Ten to 40 pounds of rock was collected from surface outcrops as hand-specimen samples (a single large block), as chip samples (chips at specified intervals perpendicular to the foliation over the outcrop extent), and as channel samples. The specimens were crushed to a size fine enough to pass through a 50-mesh screen and then split and put in paper containers. One-quart splits of screened material were then submitted for analysis.

The combination method of analysis of Haffty and Riley (1968) was used to obtain the values of the platinum-group metals reported in this paper. In this method, fire-assay techniques are used to collect the Pt-Pd-Rh of the sample into a gold bead; this bead is

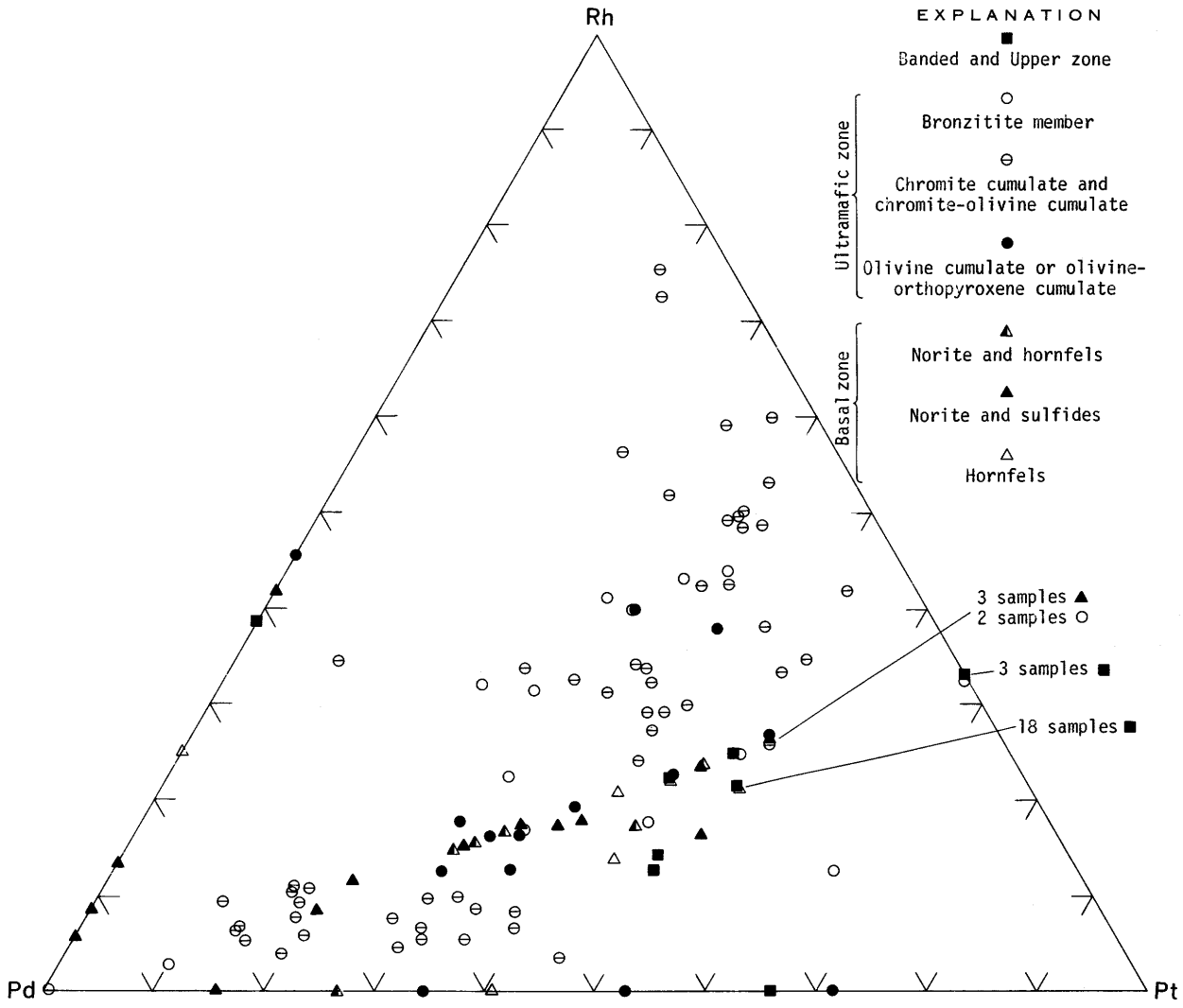

Figure 1.—Platinum, palladium, and rhodium ratios for each specimen from the Stillwater complex, Mont.

dissolved in aqua regia, and an optical-emission spectrographic analysis is made of this solution. As shown by Haffty and Riley, samples of certain types of materials and especially samples rich in chromite are more difficult to fire assay than routine gold ores. Several expedients have been used to overcome these difficulties, such as varying the flux composition, reducing the amount of sample taken (as from 15 g (gram) to 3 g), or increasing the amount of flux. Fine grinding helped on some of the chromitites. Another helpful variation for many chrome-rich samples was the addition of a small amount of molten flux to the main charge a few minutes before pouring, so that it could act as a "wash."

PT, PD, AND RH ASSAY DATA

Table 2 lists the results of the fire-assay—emission-spectrographic analyses of the rocks from the complex as values in parts per billion (10^{-9}). Included are coordinate locations of the samples, brief rock descriptions, and sample-collection types. The analyses are grouped in geographic areas from east to west in the complex and are listed, as closely as possible, within the groups in stratigraphic order from the base of the complex upward. Figure 1 is a plot of Pt, Pd, and Rh ratios for all the samples; rock types and zones are designated by symbols. Examination of figure 1 and table 2 shows that the Pt, Pd, and Rh ratios for the three main zones vary widely and that a single value or range of values is probably not representative of a particular zone, whereas the total amount of platinum metals tends to correlate well with rock type and zone. The amount of platinum metals seems to correlate with stratigraphic position, the larger amounts being found at low stratigraphic positions. The general order of concentration of platinum metals, from the

most enriched rocks to the least enriched rocks, is (1) chromitites, (2) other Ultramafic zone rocks, (3) Basal zone norites and massive sulfide pods, (4) hornfels, and (5) Banded and Upper zone rocks.

Table 3 gives the arithmetic averages for Pt, Pd, and Rh. Average mill concentrates and tailings are included because they represent combined samples of the G and H chromitite zones. The sum of the averages of Pt, Pd, and Rh tends to decrease from the A chromitite zone to the G chromitite zone and tends to increase from the G chromitite zone to the J chromitite zone. From the A to the G zone, there is an increase in the Rh/(Rh+Pt+Pd) ratio, whereas from the G to the J zone the Rh/(Rh+Pt+Pd) ratio remains fairly constant. Examination of the other samples analyzed shows no definite trends of Pt, Pd, and Rh ratios with stratigraphic position or rock type.

Comparison of the geographic areas in which Pt, Pd, and Rh are more enriched in chromitites to the lateral variations in the thicknesses of chromitite zones and the Peridotite member (Jackson, 1963, fig. 3) indicates that the enriched areas are on the edges of basinlike structures. If the Rh/(Rh+Pt+Pd) ratios are compared with the $Fe^{+3}/(Fe^{+3}+Fe^{+2})$ ratio in chromite from the chromitite zones (Jackson, 1963, fig. 6), then it appears that low Rh/(Rh+Pt+Pd) ratios correlate with low values of oxidation ratios. Tentatively, low Fe^{+3} concentrations in the chromite, which probably reflect low partial pressures of oxygen in the differentiating magma, tend to favor the concentration of Pt and Pd with respect to Rh. This is to be expected if Pt and Pd occur as platinum-metal-iron alloys which require low partial pressures of oxygen for their formation.

Each sample was analyzed by a semiquantitative spectrographic method (R. H. Heidel, analyst). The following list of 54 elements were looked for: Al, Ag, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cu, Fe, Ga, Ge, Hf, In, Ir, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, Os, P, Pb, Pd, Pt, Re, Rh, Ru, Sb, Sc, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Yb, Zn, Zr. Preliminary examination of the spectrographic results suggests that only V has a correlation with the sum of Pt, Pd, and Rh, as determined by the quantitative fire-assay-spectrographic method; that is, increased V is associated with increases in the platinum metals. It is possible that V may be a favorable geochemical tracer for these metals within the Stillwater Complex.

CONCLUSIONS

The A chromitite zone of the Stillwater Complex is enriched in Pt, Pd, and Rh, has an average platinum-metal content of 3.5 ppm (parts per million) along the strike (Jackson, 1963, 1968), and ranges in thickness from a few inches to a couple of feet. Samples of the A chromitite zone taken in the eastern end of the West Fork area to Crescent Creek (a linear distance of about 1 1/2 miles) have an arithmetic average of 4.6 ppm platinum metals; this zone has not been sampled from Crescent Creek west to the Boulder River. This average value is comparable with averages of 8.6 ppm platinum metals from the Merensky Reef, 3.4 to 5.1 ppm from the Great Dyke, and 0.86 ppm from Sudbury (Allen, 1960).

More systematic reconnaissance and geochemical exploration is necessary to define more promising targets within the lower chromitite zones than has been reported here. The present data only suggest zones of economic interest.

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TABLES 2 and 3

Table 2.—*Platinum, palladium, and rhodium analyses of rocks from the Stillwater Complex, Mont.*

[Analysts: Joseph Haffty, W. D. Goss, and O. M. Parker. Samples were analyzed by a combination fire-assay–optical-emission spectrographic method.
System: ACM, based on SE corner of NE1/4 sec. 21, T. 55 S., R. 15 E., as 50,000 N.–50,000 E. (Peoples and others, 1954). BM, based on section corner common to secs. 25, 36 of R. 15 E. and secs. 30, 31 of R. 16 E., T. 5 S., as 120,000 N.–120,000 E. (Jackson and others, 1954). NB, based on SE corner of NE1/4 sec. 21, T. 55 S., R. 15 E., as 50,000 N.–50,000 E. (Jackson and others, 1954). MS, Montana (South) rectangular coordinate system, Mount Douglas and Mount Wood 15-minute quadrangles. WF, based on W1 at east end of West Fork base line assumed as 20,000 N.–20,000 E. (Howland, 1955). GM, based on F1 at north end of Boulder River base line assumed as 20,000 N.–20,000 E. (Howland and others, 1949).
Rock type: Cr, chromite; ol, olivine; br, bronzite or orthopyroxene; cpx, clinopyroxene; pc, plagioclase.
Sample type: H, hand-specimen samples; CH–10',1.5', chip sample; first number is the width of outcrop, second number, the chip interval; C–10', channel sample for distance specified, width and depth of channel varies to yield enough rock for analysis; var., varying interval.
Limits of determination: <10 ppb Pt, <4 ppb Pd, <5 ppb Rh. tr indicates element is present but below limits of determination and too low to assign a value, all values based on a 15g sample weight]

Coordinates			Rock type	Sample type	Parts per billion		
Northerly	Easterly	System			Pt	Pd	Rh
			BASAL ZONE				
			BENBOW AREA				
119,245	117,880	BM	Chill norite	H	11	12	<5
119,245	117,880	BM	Hornfels	H	tr	15	<5
117,645	121,017	BM	Gossan	C-3'	<10	17	<5
117,595	121,036	BM	Norite, sulfide, hornfels	H	tr	88	<5
117,512	121,162	BM	Diabase dike	H	<10	<4	<5
119,433	117,645	BM	Gossan	H	10	30	<5
121,413	116,470	BM	Gossan in norite	H	<10	14	<5
119,704	117,965	BM	Br cumulate	H	<10	tr	<5
			NYE LIP AREA				
48,000	54,395	NB	Norite	H	<10	15	<5
47,740	54,570	NB	Chill norite	H	13	11	<5
			MOUNTAIN VIEW AREA				
47,822	44,193	ACM	Quartz monzonite	H	<10	<4	<5
47,817	44,190	ACM	Hornfels	H	<10	7	<5
47,842	44,115	ACM	Massive sulfides	CH-40',4'	<10	55	tr
"A" tunnel mine dump			Massive sulfides	H	24	84	10
"A" tunnel mine dump			Norite with sulfides	H	tr	56	<5
47,886	43,919	ACM	Norite	CH-30',2'	<10	18	<5
47,892	43,815	ACM	Hornfels	CH-20',1'	16	15	<5
48,040	43,622	ACM	Norite		<10	<4	<5
509,780	1,898,130	MS	Norite and hornfels	CH-50',5'	<10	19	<5
47,060	49,409	ACM	Norite	H	10	16	<5
42,755	49,409	ACM	Norite	H	tr	33	<5

Table 2.—*Platinum, palladium, and rhodium analyses of rocks from the Stillwater Complex, Mont.*—Continued

Coordinates			Rock	Sample	Parts per billion		
Northerly	Easterly	System	type	type	Pt	Pd	Rh
			BASAL ZONE—Continued				
			BLUEBIRD PEAK AREA				
505,020	1,880,380	MS	Hornfels	H	<10	9	<5
			WEST FORK AREA				
21,070	15,500	WF	Hornfels	H	13	15	<5
			GISH AREA				
542,300	1,814,440	MS	Hornfels	H	17	25	tr
542,440	1,814,450	MS	Norite	H	tr	7	<5
			ULTRAMAFIC ZONE				
			BENBOW AREA				
			Peridotite Member				
119,582	118,615	BM	Chromitite, A zone	C-0.83'	26	180	21
120,485	117,663	BM	Chromitite, B zone	H	71	67	63
117,665	121,260	BM	Chromitite, B zone	H	82	51	67
117,755	121,450	BM	Ol-br cumulate, B zone	CH-20',1'	<10	tr	<5
120,387	118,025	BM	Chromitite, C zone	C-2'	45	36	42
118,443	121,485	BM	Chromitite, E zone	C-4'	10	5	11
119,020	121,340	BM	Chromitite, G zone	C-6'	42	9	65
Benbow mill site			Chromite concentrate	H	42	5	34
Benbow tailings pond			Mill tailings	H	53	17	69
121,734	118,967	BM	Chromitite, H zone	H	180	81	12
119,427	121,525	BM	Gabbro-pegmatite, J zone	CH-9',1'	32	45	15
119,410	121,520	BM	Chromitite, J zone	CH-2'	330	270	190
119,450	121,545	BM	Ol-br cumulate, J zone	CH-20',0.5'	<10	14	11
119,695	121,597	BM	Chromitite, K zone	C-3"	<10	<4	37
119,710	121,586	BM	Ol cumulate, K zone	CH-8',0.5'	<10	<4	6
119,830	121,580	BM	Br cumulate, K zone	CH-20',1'	<10	9	tr
			Bronzitite Member				
~500,000	~1,995,000	MS	Br cumulate	CH-1700',60'	38	16	9
123,203	120,408	BM	Br-cr cumulate	C-2.5'	17	16	23
			NYE LIP AREA				
			Peridotite Member				
48,736	55,612	NB	Chromitite, A zone	H	20	89	100

Table 2.—*Platinum, palladium, and rhodium analyses of rocks from the Stillwater Complex, Mont.*—Continued

Coordinates Northerly	Coordinates Easterly	System	Rock type	Sample type	Parts per billion Pt	Pd	Rh
			ULTRAMAFIC ZONE—Continued				
			NYE LIP AREA—Continued				
			Peridotite Member—Continued				
49,014	55,555	NB	Chromitite, B zone	C-3'	33	49	42
48,588	53,205	NB	Chromitite, G zone	C-4.3'	45	9	61
48,722	53,295	NB	Chromitite, H zone	C-3'	35	12	29
48,792	53,338	NB	Chromitite, I(?) zone	C-0.83'	52	40	38
49,063	57,030	NB	Chromitite, K zone	C-1.3'	110	72	50
			MOUNTAIN VIEW AREA				
			Peridotite Member				
48,236	39,578	ACM	Gossan	H	220	330	160
48,236	39,578	ACM	Sulfide box work	H	32	79	34
48,172	39,538	ACM	Chromitite, A zone	C-2.3'	450	2300	160
49,200	42,925	ACM	Ol cumulate, serpentinite	H	<10	14	<5
48,124	42,890	ACM	Chromitite, A zone	C-.75'	85	360	50
49,823	40,801	ACM	Ol cumulate	H	tr	6	5
49,838	40,785	ACM	Ol-br cumulate	H	tr	4	tr
49,878	40,720	ACM	Br cumulate	H	42	20	38
50,235	40,428	ACM	Gabbro pegmatite, G zone	H	<10	<4	<5
50,236	40,222	ACM	Chromitite, G zone	C-10'	36	<4	60
50,240	40,418	ACM	Chromitite, G zone	C-3'	11	<4	46
50,314	40,406	ACM	Ol cumulate, G zone	CH-30',2'	<10	<4	tr
50,527	40,214	ACM	Chromitite, H zone	C-5'	46	52	48
Mouat chrome stockpile			Chromite concentrate	CH	31	8	37
Mouat Mill Tailings pond			Mill tailings	CH	51	21	53
			Bronzitite Member				
512,540	1,896,540	MS	Br cumulate	CH-220',3'	<10	8	12
512,700	1,896,700	MS	Br cumulate	CH-205',5'	16	9	19
512,760	1,896,900	MS	Br cumulate	CH-190',3'	41	14	8
			INITIAL AREA				
			Peridotite Member				
505,140	1,887,650	MS	Chromitite, A zone	C-3'	93	25	170

Table 2.—*Platinum, palladium, and rhodium analyses of rocks from the Stillwater Complex, Mont.*—Continued

Coordinates			Rock	Sample	Parts per billion		
Northerly	Easterly	System	type	type	Pt	Pd	Rh
			ULTRAMAFIC ZONE—Continued				
			INITIAL AREA—Continued				
			Peridotite Member—Continued				
506,110	1,883,120	MS	Chromitite, B zone	H	140	23	86
			BLUEBIRD PEAK AREA				
			Peridotite Member				
505,940	1,880,980	MS	Chromitite, B zone	H	460	120	310
			WEST FORK AREA				
			Peridotite Member				
21,284	17,684	WF	Ol cumulate	CH-10',0.6'	11	17	tr
20,415	15,350	WF	Chromite, A zone, lower	H	1100	1300	110
21,286	17,686	WF	Chromitite, A zone, lower	H	400	810	130
21,773	14,288	WF	Chromite, A zone, lower	H	350	1900	150
21,285	17,684	WF	Chromitite, A zone, lower	C-1'	520	860	130
21,285	17,684	WF	Ol cumulate	CH-10',0.6'	98	190	40
20,480	15,350	WF	Chromitite, A zone, lower	H	110	440	56
21,284	17,684	WF	Chromitite, A zone,upper	C-0.75'	1900	5000	480
21,284	17,684	WF	Chromitite, A zone, upper	C-0.75'	2100	5400	430
21,284	17,685	WF	Chromitite, A zone, upper	C-9"	2300	8200	640
21,284	17,685	WF	Ol-cr cumulate, A zone upper	C- 4"	1100	4300	220
21,284	17,685	WF	Chromitite, A zone, upper	C- 1"	150	840	64
21,850	14,388	WF	Chromitite, A zone, upper	H	52	220	32
21,284	17,684	WF	Ol cumulate	CH-10',0.6'	18	160	5
21,323	15,665	WF	Chromitite, A zone, upper	H	8000	11000	1700
21,320	15,670	WF	Ol cumulate	H	<10	11	5
21,633	14,776	WF	Chromitite, A zone, lower	C-3'	710	1200	110
21,776	14,720	WF	Chromitite, A zone, upper	C-1'	490	1900	200
d1,979	15,228	WF	Br cumulate	H	<10	8	12
22,439	14,745	WF	Ol cumulate	H	<10	<4	<5
22,439	14,745	WF	Chromitite, G zone	C-0.92'	45	14	59
22,439	14,745	WF	Ol cumulate	H	24	45	15
21,738	15,938	WF	Chromitite, G zone	H	32	18	54

Table 2.—*Platinum, palladium, and rhodium analyses of rocks from the Stillwater Complex, Mont.*—Continued

Coordinates Northerly	Coordinates Easterly	System	Rock type	Sample type	Parts per billion Pt	Pd	Rh
			ULTRAMAFIC ZONE—Continued				
			WEST FORK AREA—Continued				
			Peridotite Member—Continued				
21,737	15,937	WF	Chromitite, G zone	H	62	48	59
21,802	16,000	WF	Chromitite, H(?) zone	C-0.13'	110	36	73
21,882	16,026	WF	Chromitite, I(?) zone	C-0.67'	<10	8	23
			Bronzitite Member				
22,432	15,803	WF	Br cumulate	H	15	9	14
			CRESCENT CREEK AREA				
			Peridotite Member				
506,460	1,865,740	MS	Chromitite, A zone	C-2"	640	1500	170
506,780	1,865,970	MS	Chromitite, B(?)zone	CH-15',var.	79	140	24
			IRON MOUNTAIN AREA				
			Peridotite Member				
511,260	1,857, 850	MS	Chromitite, A(?)B(?)	C-0.75'	71	270	40
			CHROME MOUNTAIN AREA				
			Peridotite Member				
526,520	1,839,100	MS	Chromitite, G zone	C-1.67'	25	9	33
524,130	1,838,180	MS	Mafic dike	H	<10	<4	<5
			GISH MEMBER				
			Peridotite Member				
16,958	21,635	GM	Ol-br cumulate	H	<10	16	<5
17,109	21,710	GM	Intrusive dunite	H	<10	9	tr
17,078	21,688	GM	Br cumulate	H	<10	<4	11
16,595	22,378	GM	Br cumulate	H	<10	<4	<5
17,380	21,782	GM	Chromitite, G zone	C-16'	40	28	28
16,705	22,375	GM	Chromitite, G zone	C-5'	290	400	48
17,200	22,058	GM	Ol cumulate	H	20	14	10
16,918	22,675	GM	Chromitite, H(?) zone	H	210	68	260
			BANDED AND UPPER ZONE				
			BENBOW AREA				
499,080	1,923,880	MS	Br-pc cumulate	H	23	12	tr
501,540	1,925,570	MS	Br-pc cumulate	H	<10	tr	<5
501,280	1,925,870	MS	Pc cumulate	H	<10	<4	<5
501,760	1,926,950	MS	Pc cumulate with sulfides	C-7'	<10	<4	<5

Table 2.--*Platinum, palladium, and rhodium analyses of rocks from the Stillwater Complex, Mont.*—Continued

Coordinates Northerly	Coordinates Easterly	System	Rock type	Sample type	Parts per billion Pt	Pd	Rh
			BANDED AND UPPER ZONE—Continued				
			BENBOW AREA—Continued				
501,840	1.927,020	MS	Pc cumulate with sulfides	H	<10	<4	<5
501,720	1,926,900	MS	Pc-cpx cumulate	H	<10	<4	<5
			MOUNTAIN VIEW AREA				
512,840	1,897,020	MS	Pc-br cumulate	H	17	13	<5
512,000	1,899,400	MS	Pc-br cumulate	CH-45',2'	19	15	<5
512,000	1,899,580	MS	Pc-br cumulate	H	tr	8	<5
513,260	1,899,890	MS	Pc cumulate	CH-10'1'	<10	<4	<5
513,550	1,900,000	MS	Pc cumulate	CH-7', 1'			
513,560	1,900,000	MS	Pc-br-cpx cumulate	H	<10	<4	<5
513,830	1,900,480	MS	Pc-br-cpx cumulate	CH-60'5'	<10	<4	<5
514,510	1,900,940	MS	Pc-br-cpx cumulate	CH-8',0.5'	<10	tr	<5
514,510	1,900,940	MS	Pc-br-cpx cumulate	H	<10	<4	<5
514,550	1,900,990	MS	Pc-ol cumulate	CH-15',0.5'	<10	tr	<5
514,540	1,900,990	MS	Pc-ol cumulate	H	<10	<4	<5
514,550	1,900,990	MS	Pc-ol cumulate, altered	H	<10	<4	<5
514,560	1,900,990	MS	Pc-ol cumulate	H	<10	<4	<5
514,560	1,900,990	MS	Pc-ol cumulate	H	<10	<4	<5
514,590	1,901,030	MS	Pc cumulate	CH-84',1'	<10	<4	<5
514,590	1,901,030	MS	Pc cumulate	H	<10	<4	<5
514,590	1,901,030	MS	Pc cumulate with sulfides	C-30"	<10	5	<5
514,600	1,901,030	MS	Pc cumulate, shear zone	H	<10	<4	<5
514,750	1,901,020	MS	Pc-br-cpx cumulate	CH-40',3'	<10	<4	<5
514,600	1,901,980	MS	Pc-br-cpx cumulate	H	<10	<4	<5
			PICKET PIN PEAK AREA				
531,200	1,859,800	MS	Pc cumulate with sulfides	CH-15',0.5'	<10	<4	<5
			GISH AREA				
541,260	1,820,920	MS	Br-pc cumulate	H	<10	7	<5

Table 3.—*Arithmetic averages of Pt, Pd, and Rh, in parts per billion, for zones, members, and rock types of the Stillwater Complex, Mont.*

Zone or rock type	Number of samples	Arithmetic average			Sum of averages	Range of
		Pt	Pd	Rh	Pt+Pd+Rh	Σ(Pt+Pd+Rh)
Basal zone	25	9.4	22.9	4.8	37.1	12—118
Ultramafic zone	85	286.6	601.5	91.2	979.3	4—20,700
Peridotite member	79	306.8	646.3	97.0	1,050.1	4—20,700
A chromitite	21	988.9	2,290.2	245.9	3,525.0	227—20,700
B chromitite	6	144.2	75.0	98.7	317.9	124—890
C chromitite	1	45	36	42	123	----
E chromitite	1	10	5	11	26	----
G chromitite	9	62.9	55.0	50.4	168.3	61—738
H chromitite	5	116.2	41.5	70.3	228.0	76—538
Mill concentrates	2	36.5	6.5	35.5	78.5	76—81
Mill tailings	2	52	19	61	132	125—139
I chromitite	2	31	24	30.5	85.5	41—130
J chromitite	1	330	270	190	790	----
K chromitite	2	60	38	43.5	141.5	51—232
Average chromitite	52	452.4	956.3	137.6	1,546.3	41—20,700
Other cumulus rocks	27	26.4	49.2	18.9	94.5	4—328
Bronzitite member	6	21.2	12.0	14.2	47.4	30—63
Banded and Upper zone	27	10.7	4.9	4.8	20.4	19—39

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