ON METEORIC CHROMITES.

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The analyses of many meteorites show small percentages of chromium, which is present, in part at least, combined as chromite. So common is the reported occurrence of this mineral in meteorites that it may be regarded as a constant constituent. The amount present is small; the stones and stony irons rarely contain as much as 3 per cent of chromite and usually less than 1 per cent, while the irons generally carry less than a hundredth of a per cent.

The small amount of chromite together with the small quantity of the meteorite usually available for chemical and mineralogical study has made it difficult in the majority of cases to do more than report the occurrence of the mineral, a condition that apparently makes it worth while to bring together the results of the several analyses of meteoric chromites obtained from certain of the meteorites belonging to the Museum collections. As a matter of convenience each chromite will be described under the name of the meteorite from which it was derived.

THE MOUNT VERNON METEORITE.

Chromite occurs quite abundantly in this pallasite in two forms—as minute rounded grains frequently occluded in the olivine, and as crystals which are to a large extent probably contained in the eutectic of the metallic portion. The crystals are occasionally of a considerable size, one of them being a millimeter in diameter. They are more or less perfect octahedrons, rarely modified by other forms, and then only by ∞ O (110) as noted in one instance. Color brilliant black with a metallic luster; nonmagnetic, specific gravity 4.49 at 18° C., and of the following percentage compositon:

Cr_2O_3	65.01
Al_2O_3	9.95
FeO	18.97
MgO	5.06

The granular form, like the crystals, is nonmagnetic and under the microscope is seen to be impregnated to a certain extent with olivine. Color brownish-black with a resinous luster.

Composition:

Cr_2O_3	64.91
Al_2O_3	9.85
FeO	17.97
MgO	4.96
SiO_2	1.38

Comparing these two analyses it is interesting to note that notwithstanding the presence in the granular form of a silicate rich in magnesia and ferrous iron, the content for both of these oxides is less than that of the crystals which are free from such a silicate.

THE ADMIRE METEORITE.

The first lot of chromite separated from this pallasite was as small nonmagnetic, jet-black grains having a brilliant luster. No crystals were noticed, although under the microscope occasional grains would show planes which may have been either crystal or anhedral faces. The chromite as analyzed gave:

Cr_2O_3	65.49
FeO	33.00
MgO	0.40
SiO_2	0.50

A characteristic of the Admire is the interesting association of the metallic alloys which may briefly be described as consisting of a broad white outer band of nickeliferous iron surrounding a dark gray area made up of a more or less spongy iron containing iron sulphide, phosphide, chloride, etc. Acid treatment of these metallic portions, which are practically free from silicates, yielded very minute dust-like particles in relative abundance. These particles were magnetic; had a bluish-brown color with a dull luster. An analysis gave:

Cr_2O_3	56.49
Fe_2O_3	10.20
FeO	29.92
Al_2O_3	Trace.
MgO	Trace.

While this analysis in itself is poor, a comparison with the one preceding makes it evident that there are two different members of the chromite group present in this meteorite and which may have had different periods and conditions of formation.

THE MARJALAHTI METEORITE.

Through the kindness of the late H. A. Ward several fragments of this pallasite were secured for use in making separations. In these fragments chromite occurred sparingly in crystals of quite a large size most of them being a millimeter or more in diameter. No rounded grains or minute particles were noted. The crystals were commonly in distorted and occasionally twinned octahedrons. These twins were usually simple, once only were striations noted which would lead to the belief that polysynthetic twinning had occurred. Color, blue-black; luster, brilliant; nonmagnetic. Composition:

Cr_2O_3	61.39
Al_2O_3	1.96
FeO	30.46
MgO	6.70

THE HENDERSONVILLE METEORITE.

Chromite occurs very sparingly in portions of the stone as disseminated dust-like, nonmagnetic particles. The mineral showed no evidences of crystallization and was blackish-brown in color with a dull resinous luster. Composition:

Cr_2O_3	56.73
Al_2O_3	2.98
FeO	29.64
MgO	2.42

THE PERSIMMON CREEK METEORITE.

Chromite occurs sparingly associated with carbon and olivine in certain troilite areas. No crystals were noted, the mineral occurring in dull black nonmagnetic grains. Not enough material was secured for quantitative work and its identity was established by the blow pipe.

CASAS GRANDES METEORITE.

Chromite occurs very sparingly in this iron as minute rounded grains, which under the microscope were decidedly greenish blue in color. The material was strongly magnetic. Because of the very small amount separated it was not possible to do more than prove the presence of chromium by the bead test.

CANYON DIABLO METEORITE.

Out of the numerous fragments examined but two contained minerals of the chromite group. In one case it was associated with troilite and silicon compounds in areas rich in carbon. Here the chromite occurred as rounded grains having a blue-black color and a dull luster. It was strongly magnetic and had the following composition:

Cr_2O_3	5.20
Fe_2O_3	65.25
FeO	30.05

Nothing can be said about the associations of the other occurrence of chromite as only one small octahedral crystal was found among the residues derived from the treatment of many fragments. Unlike the mineral described above, it was nonmagnetic, with a jet black color and a brilliant luster. Its identity was established with the blowpipe.

Another occurrence, probably belonging to the Canyon Diablo, but whose meteoric origin has not as yet been established beyond dispute, though all the evidence at hand points to such an origin, is the chromite found in the borings of hole 16 [a] made at the Meteor Crater of Canyon Diablo. This mineral was jet black in color; had a brilliant luster; was nonmagnetic; and occurred in small octahedral crystals and rounded grains. An analysis, after deducting 1.20 per cent of silica and recalculating, gave:

Cr_2O_3	63.40
Al_2O_3	5.30
FeO	26.30
MgO	5.00

THE ALLEGAN METEORITE.

Doctor Stokes [b] found in his chemical work on this stone a small amount of chromite which contained titanium. The results of his analysis are:

Cr_2O_3	50.31
Al_2O_3	9.67
FeO	28.71
MgO	2.76
TiO_2	1.20

Separations made on a fairly large amount of the débris of this stone afforded me quite a quantity of chromite which was nonmagnetic and had a blackish-brown color. The results of my analysis were:

Cr_2O_3	56.70
Al_2O_3	12.38
FeO	27.60
MgO	4.00
TiO_2	Trace.

The mineral was never in crystals but always in grains which under the microscope had the appearance of having been shattered. A condition that may be explained by the following statement of Doctor Merrill: [c] "The general structure of the Allegan stone can, I believe, be accounted for only by regarding it as an agglomerate of chon-

[a] G. P. Merrill, Smithsonian Misc. Coll., Quart., L, 1908, p. 447.

[b] Proc. Wash. Acad. Sci., II, 1900, p. 48.

[c] Idem., II, 1900, p. 54.

drules embedded in a fragmental groundmass or matrix, the materials for which were derived from the trituration of other chondrules."

Of the ten chromites here analyzed, one only approximates the typical compound FeO. Cr_2O_3. Eight contain alumina and magnesia. Two contain ferric oxide and are free from alumina and magnesia. One is so rich in ferric oxide that it may be regarded as a chromiferous magnetite. Two of these chromites, from different parts of the same fall, have widely differing compositions.

Tabulating, for comparison, these analyses with such others as were available, thus:

Chemical composition of various meteorites.

Name.	Cr_2O_3.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	SiO_2.	TiO_2.
Admire	65.49			33.00	0.40	0.50	
Mount Vernon	65.01	9.95		18.97	5.06		
Do	64.91	9.85		17.97	4.96	1.38	
Canyon Diablo	63.40	5.30		26.30	5.00		
Coahuila [a]	62.71			33.83			
Bjurböle [b]	62.00		41.00				
Marjalahti	61.39	1.96		30.46	6.70		
Klein-Wenden [c]	59.85			27.93	12.22		
Shalka [d]	56.82	11.36		26.14	5.68		
Hendersonville	56.73	2.98		29.64	2.42		
Allegan	56.70	12.38		27.60	4.00		Trace.
Admire	56.49	Trace.	10.20	29.92	Trace.		
L'Aigle [e]	52.13	10.25		37.68			
Allegan [f]	50.31	9.67		28.71	2.76		1.20
Sewrukof [g]	39.40	28.50		31.50	0.60		
Lodran [h]	24.60		54.50		20.90		
Canyon Diablo	5.20		65.25	30.05			

[a] Am. Jour. Sci., (3), XXI, 1881, p. 462.
[b] Bul. Comm. Geol. De Finlande, 1902, No. 12, p. 13.
[c] Ber. König. preuss. Akad. Berlin, 1844, p. 245.
[d] Ann. k. k. Nat-hist. Hofmus., III, 1888, p. 199.
[e] Sitzber. k. bayrischen Akad. Munchen, VIII, 1878, pp. 39–40.
[f] Proc. Wash. Acad. Sci., II, 1900, p. 48.
[g] Arch. f. d. Natur. Lib. Ehst. Kurl., IX, 1882, p. 137.
[h] Abh. k. Akad. Wissen, Berlin, 1870, p. 93.

In the above table the chromic oxide has a maximum percentage of 65.49 and a minimum of 5.20. Disregarding this last which may be regarded as a chromiferous magnetite, the next lowest is 24.60. Ferrous oxide ranges from a maximum of 37.68 to a minimum of 17.79. Arranging the values found for ferrous and chromic oxides in the order of their ferrous oxide contents and placing below this value the chromic oxide found, thus:

FeO	37.68	33.83	33.00	31.50	30.46	26.30	26.14	18.97	17.97
Cr_2O_3	52.13	62.71	65.49	39.40	61.39	63.40	56.82	65.01	64.91

It becomes apparent that there is no exact relation existing between the proportions of the two oxides. A low ferrous oxide content does not necessarily imply a high chromic oxide value.

The percentages of alumina are: 28.50. 12.38, 11.36, 10.25, 9.95, 9.85, 9.67, 5.30, 2.98, and 1.96. Eight of the ten chromites carrying alumina have more than 5 per cent of this oxide; one has 28.5 and but two contain less than 3 per cent. The average percentage of alumina for the ten is 10.22, and for the entire sixteen it becomes 6.38 per cent.

Since the majority of these chromites have a fairly large percentage of alumina (an oxide that is generally reported in small amounts only in the analyses of meteorites), the question suggests itself. Will not the alumina present in the chromite account in a large part for the alumina reported in analyses of the feldspar—free meteorites? This is certainly suggested in the case of the Allegan stone, in which no feldspars were recognized in thin section [a]; yet its analysis [b] shows 3.04 per cent of alumina. This meteorite contains 1.3 [b] per cent of a chromite having 9.67 per cent of alumina according to the analysis made by Stokes, and 2.63 per cent of a chromite carrying 12.38 per cent of alumina in the far greater amount of material worked up by me.

The percentages of magnesia show a maximum of 20.90 and a minimum of 0.40. Twelve of the sixteen chromites contain this oxide, the per cents present being: 20.90, 12.22, 6.70, 5.68, 5.06, 5.00, 4.96, 4.00, 2.76, 2.42, 0.60, and 0.40. The average for the twelve being 4.3 per cent. There is an apparent relation between the magnesia and the alumina in that nearly all of those chromites which contain magnesia also contain alumina. There is, however, no relation between the amount of one oxide as compared with the amount of the other oxide. One chromite, for example, has 2.76 per cent of magnesia with 9.76 per cent of alumina while another with nearly the same amount of magnesia, 2.42 per cent, has but 2.98 per cent of alumina.

Ferric oxide is present in four cases only. In two of them the total iron was determined as this oxide. One of the two remaining is so high in ferric oxide, 65.25 per cent, that it may be regarded as a magnetite; the other contains 10.20 per cent. Neither of the two last contain alumina or magnesia.

From the data here given it appears that the majority of meteoric chromites contain magnesia and alumina. That there is little if any relation existing between the amounts of the constituent oxides. One only approximates a compound of the formula $FeO.Cr_2O_3$. The majority are of the type $RO.R_2O_3$ in which RO is ferrous oxide and magnesium oxide and R_2O_3 is commonly chromic oxide with alumina less commonly ferric oxide.

[a] Proc. Wash. Acad. Sci., II, 1900, p. 46.

[b] Idem., II, 1900, p. 48.