On the chemical composition of the Meteorites Amana (= Homestead) and Eagle Station.[1]

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Amana.

The Amana meteorite, known also as Iowa County, Homestead, and West Liberty, is fully described in O. C. Farrington's 'Catalogue of the Meteorites of North America'.[2] After the appearance of a brilliant meteor which on the night of February 12, 1875, passed with loud detonations from S.W. to N.E. over northern Missouri and southern Iowa, about 100 meteoric stones, weighing altogether some 500 lb., were found scattered over an elliptic area of about eighteen square miles from Amana in Amana township to Boltonville in Iowa township, both in Iowa Co., Iowa. In the same year three analyses were made of the meteorite by G. D. Hinrichs[3] and J. Lawrence Smith[4] in the United States, and by C. W. Gümbel and A. Schwager[5] in Germany. All three analyses, the results of which are given on p. 175, agree in making both olivine and pyroxene rich in ferrous oxide. To accord with the idea of a genetic relationship of meteorites advanced by the author in a previous paper,[6] this low ratio of MgO to FeO in the ferro-magnesian silicates should be associated with a small amount (less than 6 per cent.)

[1] Communicated by permission of the Trustees of the British Museum.
[2] O. C. Farrington, Mem. National Acad. Sci. Washington, 1915, vol. xiii, p. 227.
[3] G. D. Hinrichs, Compt. Rend. Acad. Sci. Paris, 1875, vol. lxxx, p. 1175.
[4] J. L. Smith, Amer. Journ. Sci., 1875, 3 ser., vol. x, p. 357.
[5] C. W. Gümbel and A. Schwager, Sitzungsber. München. Akad. Wiss., 1875, vol. v, p. 313.
[6] G. T. Prior, On the genetic relationship and classification of meteorites. Mineralogical Magazine, 1916, vol. xviii, p. 26.

of nickel-iron, in which the ratio of Fe to Ni is also low (less than 6). As Gümbel and Schwager's analysis was the only one to satisfy the latter condition, it was assumed to be the most accurate, and the excessive amount of the nickel-iron was attributed to its unequal distribution through the mass. Accordingly the meteorite was doubtfully referred to the Soko-Banja type (Group C 4) of chondritic stones.

In order to settle this point, however, a new analysis of this well-known meteorite seemed desirable, especially as Gümbel and Schwager's analysis was made on such a small amount of material (about $1\frac{1}{2}$ gram). The British Museum Collection contains two specimens of Amana, one (48474), a large complete stone weighing 3,800 grams which was obtained by exchange from Prof. Hinrichs in June, 1875, the other (50803) a portion, now weighing 127 grams, of a stone acquired by exchange with J. Lawrence Smith in 1876. A piece of the latter specimen weighing about 12 grams was taken for analysis. The crushed material was separated by the magnetic comb into an attracted portion weighing 1·7429 grams and an unattracted portion weighing 10·2125 grams. The results of the analyses are as follows:

	Attracted.	Unattracted.	Bulk-analysis.
Fe	61·79	0·80	9·71
Ni	7·52	0·10	1·19
Co	0·61	—	0·09
Fe	0·88	4·39	3·97
S	0·51	2·52	2·28
SiO_2	5·10	44·01	39·27
Al_2O_3	—	2·40	2·10
Cr_2O_3	—	0·37	0·32
Fe_2O_3	—	0·46	0·40
FeO	2·84	13·31	12·06
MnO	—	0·09	0·08
CaO	0·63	1·92	1·78
MgO	5·66	27·47	24·88
Na_2O	—	1·03	0·92
K_2O	—	0·15	0·13
H_2O	—	0·54	0·47
P_2O_5	—	0·30	0·26
Insoluble	14·51	—	—
	100·05	99·86	99·91

The numbers given under the unattracted are the combined result of separate analyses of the soluble and insoluble portions in hydrochloric acid, the individual numbers for which are as follows:

	Soluble.	Molecular ratios.	Insoluble.	Molecular ratios.
SiO_2	16·58	0·276	27·43	0·457
Al_2O_3	—	—	2·40	0·024
Cr_2O_3	—	—	0·37*	—
Fe_2O_3	0·46*	—	—	—
FeO	8·76	0·121	4·55	0·063
MnO	0·05	—	0·04†	—
CaO	0·42	0·007	1·50	0·027
MgO	17·46	0·436	10·01	0·250
Na_2O	—	—	1·03	0·021
K_2O	—	—	0·15	0·002
P_2O_5	0·30*		47·48	
H_2O	0·54*			
{ Fe	0·80			
{ Ni	0·10			
{ Fe	4·39			
{ S	2·52*			
	52·38			

In the following table are given for the new and the three previous analyses the percentages of nickel-iron and troilite in the meteorite, and the percentage chemical compositions of the nickel-iron and of the soluble and insoluble silicates:

	1 (Hinrichs).	2 (Lawrence Smith).	3 (Gümbel and Schwager).	4 (Prior).
Percentages of nickel-iron and troilite:				
Nickel-iron	7·5	12·54	12·32	10·99
Troilite	1·8	5·82	5·25	6·25
Composition of nickel-iron:				
Fe	88	89·07	83·38	88·37
Ni	12	10·35	16·62	10·76
Co	—	0·58	—	0·87

* These determinations were made on separate portions of the total unattracted.

† Probably under-estimated, as the separation from iron was by ammonia and not sodium acetate.

	1 (Hinrichs).	2 (Lawrence Smith).	3 (Gümbel and Schwager).	4 (Prior).
Composition of soluble silicates :				
SiO_2	37·05	36·18	38·39	38·34
Al_2O_3	—	0·72	1·01	—
FeO	28·78	27·63	28·58	20·24
MnO	—	—	0·53	0·10
CaO	1·14	—	trace	0·97
MgO	33·08	33·99	31·49	40·35
Na_2O	—	1·48	—	—
Composition of insoluble silicates :				
SiO_2	53·90	55·92	54·19	57·76
Al_2O_3	—	0·85	2·01	5·05
Cr_2O_3	—	—	1·42	0·78
FeO	19·60	27·85	25·30	9·58
MnO	—	—	trace	0·08
CaO	4·90	—	4·05	3·16
MgO	21·60	13·34	8·96	21·08
Na_2O	—	2·04	2·40	2·19
K_2O	—	—	1·67	0·32

Comparison of the results given in this table shows that the new analysis as regards the amount and chemical composition of the nickel-iron is in fairly close agreement with that of Lawrence Smith. With respect to the composition of the silicates, however, it is nearer to that of Hinrichs, for in the insoluble of analysis 1 the percentage of MgO is practically the same as in 4, and the excess of FeO is partly accounted for by its including undetermined Al_2O_3 and Cr_2O_3; while in the soluble the excess of ferrous oxide is perhaps to be attributed to included troilite and nickel-iron, the amounts of which constituents in the meteorite Hinrichs appears to have under-estimated.

The results of the new analysis show that in the nickel-iron the ratio of Fe to Ni is about 8, and that the composition of the olivine corresponds approximately to the formula $3\frac{1}{2}\,Mg_2SiO_4 . Fe_2SiO_4$ and that of the pyroxene to $4\frac{1}{2}\,MgSiO_3 . FeSiO_3 . \frac{1}{2}\,CaSiO_3$.

The meteorite thus occupies an intermediate position between the type-meteorites[1] Baroti and Cronstad of groups C 2 and C 3, as seen in the following table:

[1] G. T. Prior, loc. cit., pp. 28, 30.

	Percentage of nickel-iron.	Ratio of Fe to Ni in nickel-iron.	Ratio of MgO to FeO in Mg-silicates.
Cronstad (Group C 2)	18½	11	4½
Amana	11	8	4
Baroti (Group C 3)...	9	6½	3½

Within the errors of analysis it would be difficult to decide from the ratio of MgO to FeO to which group the meteorite belongs, but the amount of nickel-iron and its composition are in favour of referring it to group 2.

The approximate mineral composition of Amana, as deduced from the new analysis, is as follows:

$Na_2O \cdot Al_2O_3 \cdot 6\,SiO_2$ ...	7·73		
$K_2O \cdot Al_2O_3 \cdot 6\,SiO_2$ ...	0·89	... 9·76	... Felspar.
$CaO \cdot Al_2O_3 \cdot 2\,SiO_2$ ...	1·14		
$3\,Ca_3P_2O_8 \cdot CaO$ ...	...	... 0·22	... Apatite.
$FeO \cdot Cr_2O_3$ ...	...	... 0·44	... Chromite.
Fe_2O_3 ...	...	... 0·40	
$CaSiO_3$ ...	2·51		
$FeSiO_3$ ...	7·06	... 30·75	... Bronzite
$MgSiO_3$ ...	21·18		(in which MgO : FeO = 4½).
Fe_2SiO_4 ...	11·50	... 40·15	... Olivine
Mg_2SiO_4 ...	28·65		(in which MgO : FeO = 3½).
Fe ...	9·71		
Ni ...	1·19	... 10·99	... Nickel-iron
Co ...	0·09		(in which Fe : Ni = 8).
Fe ...	3·97	... 6·25	... Troilite.
S ...	2·28		
H_2O ...	...	... 0·47	... Water.
		99·43	

Eagle Station.

This meteorite, of which a mass weighing about 80 lb. was found in 1880 about $\frac{3}{4}$ mile from Eagle Station, Carroll Co., Kentucky, differs in various respects from other pallasites. As pointed out in a previous paper (loc. cit., pp. 34–35), according to an analysis by J. B. Mackintosh [1], it is exceptional in chemical composition in having the nickel-iron richer in nickel and the olivine correspondingly richer in ferrous oxide. In view of the unsatisfactory character of many of the older analyses of meteorites, a new one of this pallasite seemed desirable in order to test the above result. Material for the analysis was taken from a slice (64407) in the British Museum Collection, now weighing 701 grams, which was obtained from J. Böhm of Vienna in October, 1889. The weight of material separated by the magnet used in the analysis was 2·1885 grams, that of the olivine 0·6955 gram. The results of the analyses are as follows:

	Attracted.
Fe	79·74
Ni	13·98
Co	1·04
SiO_2	1·42
MgO	1·74
FeO*	0·77
P, S, &c.	(1·31)
	100·00

	Olivine.	Molecular ratios.
SiO_2	39·22	0·650
FeO	18·83	0·262
MgO	42·31	1·050
	100·36	

The analyses, on the whole, confirm those of Mackintosh. In the iron the ratio of Fe to Ni is about 6, instead of over 10 as in most other pallasites; and in the olivine the ratio of MgO to FeO is about 4 instead of about 7.

This exceptional character is probably connected with other distinctive features which serve to differentiate this meteorite from other pallasites. As described by A. Brezina and E. Cohen,[2] the character of the iron distinguishes Eagle Station from all other pallasites except Bitburg (Albacher Mühle), for whereas in most pallasites the structure of the iron, as revealed by etching, presents the same orientation throughout

[1] J. B. Mackintosh, Amer. Journ. Sci., 1887, ser. 3, vol. xxxiii, p. 232.

* Calculated from the composition of the olivine.

[2] A. Brezina and E. Cohen, 'Die Structur und Zusammensetzung der Meteoreisen,' Stuttgart, 1886–1906, vol. i, Taf. xxviii.

the mass, and thus indicates a mobility of the metal through the mass during solidification, in the case of Eagle Station and Bitburg the orientation is different in different parts, as if the iron had solidified independently about different centres.

From the author's point of view of a genetic relationship of meteorites, it may be pointed out that, although this meteorite does not fit into group A 2 so well as other pallasites, the variations from the normal are consistent with the theory in as much as the greater richness in nickel of the nickel-iron is accompanied by a corresponding greater richness in ferrous oxide of the olivine. In the classification suggested in the previous paper (loc. cit., p. 42), this meteorite may perhaps be referred to the vacant space under group A 3.