INVESTIGATION OF THE ESTES PARK "METEORITE"

By

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Investigation of the Estes Park Meteorite

Introduction.

At a point about two and a half miles west of the village of Estes Park are found fragments of material, which are said by the inhabitants of the region to be pieces of a meteorite. The fragments are limited to a small area and occur both on the surface and in the soil, which is a coarse sand resulting from decomposition of the granite.

When washed free from adhering soil, the pieces are black, smooth, somewhat shiny, deeply and irregularly pitted and rather heavy. When broken, the black mineral has a sub-metallic luster and granular structure. There are, in this black substance, irregular patches of white mineral, which vary in size from one to ten millimeters in diameter. Under the hand lens these show a radiating structure. By carefully cleaning the pitted surface some of the white mineral is found at the bottom of the pits. The pits in broken fragments are found to terminate frequently in the white mineral.

Attempts to obtain accurate historical data concerning this meteorite have not met with much success. Apparently no one knows when it fell and it is possible that the material was identified as a meteorite on account of its color, pitted surface and high specific gravity. There is a legend that the fall was observed by Indians sometime between 1850 and 1870.

Meteorites are classified into three groups which pass more or less gradually into one another: meteoric stones, or aerolites, stony iron meteorites, or siderolites and nickel iron meteorites, or siderites. The aerolites consist largely of silicate minerals with small amounts of metallic alloys and sulphides. The siderolites consist of a variable mixture of silicate minerals in a network of nickel iron. The siderites consist largely of nickel iron with iron sulphide and phosphide and usually graphite or other forms of carbon. Examination of a number of analyses indicates that iron and nickel are almost universally present in some form.

The Estes Park meteorite does not fall into any of these groups, since it contains only a small amount of silicate mineral and no metallic alloys.

The analysis of the substance was undertaken to determine the exact composition of a local meteorite in order to see if it was unusual in any way, and also to add a bit to the rather large mass of data concerning the composition of meteorites.

Qualitative Analysis.

Qualitative analysis in the wet way, according to the usual procedure, of a one gram sample showed the presence of a small amount of silica, large quantities of iron and rather small quantities of aluminum and titanium. The flame test showed traces of sodium.

Certain difficulties encountered in the quantitative analysis indicated that there were present traces of elements other than those found in the analysis of a small sample. In order to detect these traces, if present, a two hundred gram sample was digested with concentrated HCl for several days until all soluble material was in solution. The solution was carefully decanted and then evaporated down until a crop of crystals was formed. Since the iron was present in large excess, ferrous and ferric chlorides crystallized out and were removed by filtration. This process was repeated until only a small volume of mother liquor remained. Some titanium separated out with the iron chlorides as a result of hydrolysis. Those elements occurring in small quantities were concentrated in the mother liquor. Iron, as ferric chloride, was further removed by extraction with ether and it was found necessary to remove most of the titanium by hydrolysis, since it would not remain in solution at the acid concentrations required in the scheme of analysis. The resulting solution, when subjected to the analytical procedure of Noyes and Bray, showed the presence of small amounts of copper, vanadium, zinc, manganese, magnesium, zirconium, sodium and potassium and the absence of all other metallic elements. In comparison with the size of sample, these elements were present only as traces.

Quantitative Analysis.

Determination of silica

Samples of about one gram were digested with concentrated HCl and the insoluble portion filtered out and fused with anhydrous sodium carbonate. This fusion was dissolved in dilute HCl and added to the main solution. The solution was then evaporated to dryness and baked for an hour at 110° - 115° C. taken up with HCl and water and the silica filtered out. This process was repeated a second time to remove silica as completely as possible. The insoluble residue, which consisted largely of silica was ignited in a platnium crucible, cooled, weighed and treated with H_2SO_4 and HF to volatilize silica as SiF_4. The loss in weight is the weight of silica.

Weight of Sample	Weight of SiO_2	Per cent SiO_2
1.0010	.0082	.82
.9994	.0076	.76
1.0080	.0082	.81
1.0060	.0084	.83

Average per cent
.81

The residue remaining in the crucible was fused with sodium carbonate, dissolved in dilute HCl and added to the filtrate.

Determination of titanium.

An aliquot part of the filtrate from the silica determination was used. The solution was neutralized and made weakly acid with acetic acid (10 cc. of acetic acid to 300 cc. of solution). Sodium thiosulphate was added to prevent the precipitation of iron. The solution was then boiled. Titanium dioxide was precipitated, due to hydrolysis, along with sulphur and small amounts of iron and aluminum. The solution was filtered through a hardened filter. Paper pulp was used to prevent the fine precipitate from passing through the paper. The precipitate of TiO_2 was then ignited at a low temperature for half an hour and then fused with sodium carbonate. The fusion was disintegrated with water and the solution filtered. The filtrate which contained aluminum was added to the main solution containing aluminum. The residue was digested with 1 - 1 HCl, the filter paper filtered out and the titanium dioxide precipitated as before by neutralizing with NH_4OH and adding acetic acid and sodium thiosulphate and boiling. The precipitate was ignited and weighed as TiO_2

Weight of Sample	Weight of TiO_2	Per cent of TiO_2	
.3003	.0148	4.93	
.2998	.0148	4.94	
.4032	.0196	4.87	
.4024	.0198	4.92	Average per 4.92

Determination of aluminum

The filtrate from the titanium determination was used for the determination of aluminum. The solution was made weakly acid with HCl. Sodium ammonium phosphate, ammonium acetate and acetic acid were added. The solution was then boiled. Aluminum was precipitated as aluminum phosphate along with some sulphur. The precipitate of aluminum phosphate was dissolved in 1 - 1 HCl, the paper and sulphur filtered out and the aluminum precipitated out as phosphate by neutralizing the solution with NH_4OH, adding sodium thiosulphate, ammonium acetate and acetic acid. The precipitate was filtered off and heated at a low temperature in a porcelain crucible until the paper was burned, then ignited at a high temperature and weighed as aluminum phosphate.

Weight of Sample	Weight of $AlPO_4$	Per cent of Al_2O_3	
.4032	.0672	6.97	
.4024	.0672	6.99	
.2000	.0336	7.03	
.2000	.0338	7.07	Average per cen 7.02

$AlPO_4$ x .4184 x 100 = Per cent Al_2O_3

Determination of iron.

A sample of about .4 grams was fused with potassium bisulphate. The melt was dissolved in dilute hydrochloric acid.

Iron, aluminum, titanium, etc. were precipitated by adding an excess of ammonium hydroxide. The precipitate was dissolved in hydrochloric acid of such strength that the resulting solution would contain 22 - 23 per cent HCl. The solution was then extracted several times with ether in order to separate iron from the other elements present. Since about 99 per cent of the iron is extracted by ether from a solution of the above acid concentration, three extractions should effect practically complete separation of the iron. Dilute sulphuric acid was added to the ether extract, ether was allowed to evaporate spontaneously and the solution was evaporated to fumes of sulphur trioxide to remove hydrochloric acid. The solution was then diluted, reduced with zinc, and titrated with standard potassium permanganate solution.

Weight of sample	c.c. permanganate	Per cent Fe	
.3996	46.85	63.1	
.4019	47.20	63.0	Average per cent 63.05

1 c.c. $KMnO_4$ $\approx$ .00536 gm. Fe

Iron was also determined according to the following procedure. The sample was dissolved by means of the potassium bisulphate fusion as before. Iron, aluminum, titanium, etc. were precipitated by ammonium hydroxide in the presence of hydrogen peroxide. The precipitate was dissolved in hydrochloric acid, sulphuric acid was added and the solution evaporated to fumes of sulphur trioxide to remove hydrochloric acid. The solution was then diluted and the iron reduced by means of hydrogen sulphide in acid solution. The precipitated sulphur was filtered off and the excess of hydrogen sulphide removed by boiling while carbon dioxide was bubbling through the solution. The solution was rapidly cooled and titrated with standard potassium permanganate solution.

Weight of Sample	c.c. $KMnO_4$	Per cent Fe
.3988	46.95	63.2
.3973	46.70	63.2 Average per cent 63.2

63.12 per cent Fe = 87.23 per cent Fe_3O_4

Mineral analysis

No attempt was made to determine all the minerals present since a mineral analysis is somewhat outside the scope of this investigation. Some of the minerals were determined, however. The black mineral which makes up a large part of the material is titaniferous magnetite. Attempts to grind a thin section from which the transparent minerals could be determined optically, did not meet with success on account of the fact that the white material ground away much faster than the magnetite.

A handful of small pieces of the material were digested with hydrochloric acid until the more readily soluble portion had dissolved. The remaining material was washed, dried and examined. Plates of white and dark mica were found--probably muscovite and biotite and also several small octohedra which proved to be franklinite. The bulk of the mineral in the white patches is an anhydrous aluminum silicate possibly sillimanite, but was not definitely identified.

The presence of enstatite was determined by optical examination of some of the crushed material

Summary.

SiO_2	.81	Na	Trace
TiO_2	4.92	Cu	"
Al_2O_3	7.02	V	"
Fe_3O_4	87.23	Zn	"
	99.98	Mn	"
		Mg	"
		Zr	"
		K	"

Ferrous iron was not determined quantitatively because the material was only soluble by fusion. Fe_3O_4 was calculated from the per cent of iron assuming that all the iron was in the form of magnetite.

The following minerals were found: titaniferous magnetite, franklinite, enstatite. Biotite and muscovite are probably present and sillimanite is possibly present.

The complete absence of nickel is unusual and it is to be noted that the composition of this meteorite is such that it does not correspond to any one of the three groups into which meteorites are classified, nor to any intermediate position.

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