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The meteoric stone seen to fall in the Mangwendi native reserve, Southern Rhodesia, on March 7, 1934.

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1. *Circumstances of the fall.*[1]

THIS is the first meteorite to be recorded from either Southern or Northern Rhodesia. It fell at about 12.45 p.m. on March 7, 1934, on the right bank of the Shawanoya river in the Mangwendi native reserve, about forty miles east of Salisbury. The latitude and longitude of the spot are 17° 39′ S., 31° 36′ E.

The recovery of the meteorite was made through the efforts of the Rev. F. J. Gits, S.J., who is in charge of St. Paul's Mission. Three loud detonations were heard from a direction north-east of the Mission Station followed by a loud rushing sound. Father Gits, who was out in the open at the time, involuntarily ducked his head. His inquiries failed at first to elucidate the cause of the explosions, which were also heard at Arcturus, Macheke, and Mtoko, that is, over a radius of at least fifty miles. But on March 21 a native came and told of a 'maminimini', meaning 'something to make you gape', that had terrified the people of the district and which they feared to talk about. He said 'a sun came rushing from the sky and buried itself in the earth'. Father Gits proceeded to the spot, a distance of eight miles NNE. of the Mission Station, and saw what he assumed to be

[1] Accounts were published in the Rhodesia Herald (Salisbury) of March 30, and in several South African newspapers; also in Nature (London), 1934, vol. 134, p. 469.

a meteorite, and he at once communicated with the Meteorological Department. His letter was forwarded to the Geological Survey, and Mr. B. Lightfoot visited the place in company with Father Gits. The native, Hakata by name, was persuaded to repeat his story. He said that he was guarding his lands from baboons when the meteorite descended white-hot and with a rushing noise. It came steeply down from a southerly direction and he saw it fall. It fell through a tree, cutting off branches and striking the trunk, and then penetrating the ground, which is thickly strewn with granite boulders. It had not been disturbed when seen by Mr. Lightfoot on March 27. The hole was reminiscent of a crater produced by a 'whizz-bang', and was 3 feet in diameter and 18 inches deep, the top of the meteorite being six inches below ground level. In its fall it had cut through several tree roots and it had come to rest on a granite boulder (fig. 1).

Mr. W. Edwards, retired District Native Commissioner, recorded that a fireball travelling in a northerly direction was seen at Macheke, thirty-seven miles SSE. of the place of fall. A stone is said by the natives to have fallen at Magaya (about seventeen miles east of St. Paul's Mission Station), but this could not be found, or it may be kept secret by the natives, who indeed raised objections to the removal of the Mangwendi stone. The fact that three detonations were heard suggests that other stones fell, but although search has been made no others have been found.

2. *External characters.*

One large piece weighing 49 lb. 3 oz. and ten small pieces weighing 3 lb. 1 oz. were collected and taken to Salisbury. Several small pieces were missing, and the weight of the meteorite when it hit the ground must have been about 60 lb. The main mass of the stone, weighing 48 lb. 11 oz., has been very generously presented by the Government of Southern Rhodesia to the British Museum.[1]

[1] This fine specimen is the fifth largest stone preserved in the collection, which now includes the following single stones of over 20 kg.

	Fell.	Grams.	Lb.	B.M. Reg. no.
Parnallee, Madras	Feb. 28, 1857	60,550	133½	34792
Warbreccan, Queensland ...	found 1904	31,593	69½	1905,377
,, ,, ...	,,	29,140	64	1905,378
Kyushu, Japan	Oct. 26, 1886	28,803	63½	80031
Mangwendi, Rhodesia ...	March 7, 1934	22,084	48¾	1934,839
Wold Cottage, England ...	Dec. 13, 1795	20,638	45½	1073

The stone has the form of a roughly rectangular block measuring approximately 24 × 22 × 18 cm. Five sides are covered with a black crust with a maximum thickness of 0·8 mm. A striking feature is presented by the channelled grooves on the edges of the three crusted surfaces adjacent to the back of the stone (fig. 2). 'Thumb-mark'

FIG. 1. Meteoric stone of Mangwendi, Southern Rhodesia. Seen in situ in front of the shovel.

pittings are seen on one side (fig. 3) towards the front of the stone, and there are also a few at the back of the stone, but they are not prominent. The crust shows fine radiating stream-lines resembling the paint marks left by a brush, but there is no cascade of fused material over the back edges of the stone. Stream-lines are also seen on the back surface. Small grains of nickel-iron project through the crust in places.

The sixth surface of the block is broken and approximately flat with a slabby fracture. Parallel to this direction there are fresh cracks (shown on the back surface in fig. 2) formed by fracturing when the stone fell. A step shown on the large side surface in fig. 2 suggests that a slabby piece had broken away before the crust was formed. The most prominent 'thumb-marks' are in the angle of this step. The stone thus appears to have a slabby structure.

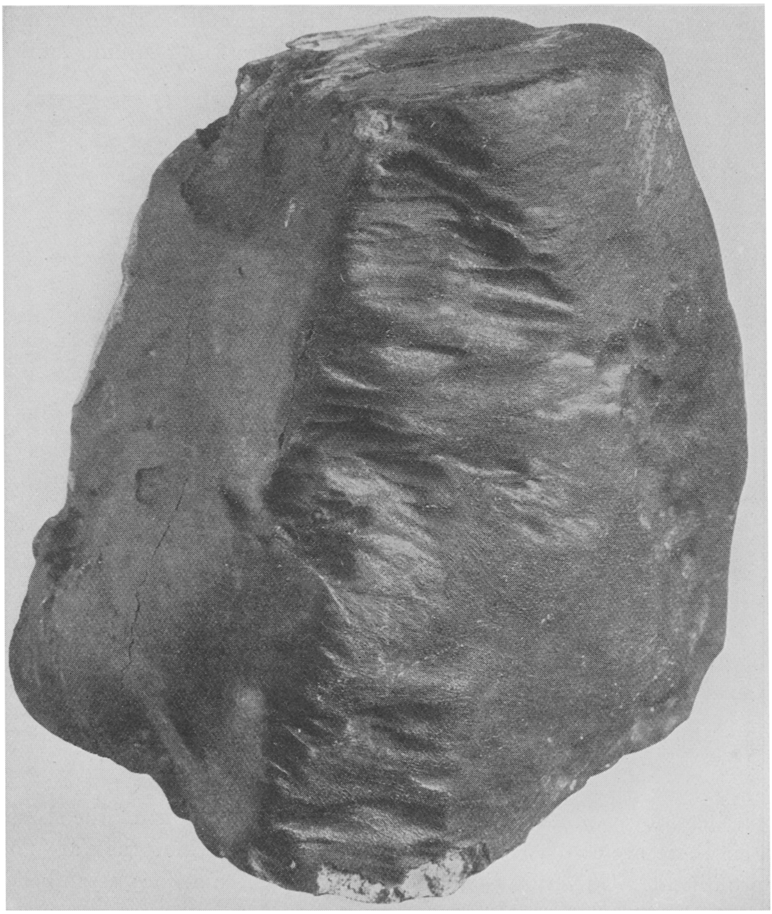

FIG. 2. Meteoric stone of Mangwendi, Southern Rhodesia. The surface to the left is the back of the stone. ½ actual size.

For the purpose of the above brief description in conjunction with figs. 2 and 3, mention has been made of the 'front' and 'back' of the stone. But it must be pointed out that there is no clear evidence for this orientation. In fact, what is now described as the 'front' has been thought by some persons to be the 'back'. The lines of flow on the surface of the crust do not radiate uniformly from one centre, and the positions of the pittings are inconclusive.

FIG. 3. Meteoric stone of Mangwendi, Southern Rhodesia. View from the front of the stone. $\frac{1}{2}$ actual size.

3. *Petrographical description* (*A.M.M.*).

The broken surface shows the stone to be fine-grained and of pale grey colour. Iron sulphide is conspicuous mainly in small veins through the stone. Specks of nickel-iron are mostly surrounded by rusty staining, due probably to the oxidation of lawrencite. The stone has a fragmental structure with angular inclusions, either lighter or darker in colour than the matrix. One of these measures 4·5 × 4·5 cm., but the majority are 1 cm. or less in diameter. Spheroidal chondrules are not conspicuous even under a hand-lens.

Four microscope sections have been cut by Mr. N. E. Barlow from fragments of the stone. Owing to its rather friable nature the material was soaked in fused Canada balsam before grinding. In the slides the chondritic structure as well as the fragmental nature of the stone are evident, and chondrules are present both in the angular inclusions and in the surrounding matrix. One triangular mass about 4 mm. in length, which differs from the matrix by being darker in colour due to more abundant fine opaque matter, mainly troilite or pyrrhotine, contains one complete chondrule and the broken fragment of another. Other fragmental inclusions differ from the matrix by being either finer or coarser in grain or may be composed of single crystals of colourless hypersthene. Some have outlines suggesting the form of pyroxene crystals, but are composed of a mosaic of small crystals, suggesting recrystallization under metamorphism.

The chondrules occur as complete spheroids or as broken fragments, and vary considerably in size, in grain, and in structure; the largest exceed 2 mm. in diameter. Some resemble cloudy devitrified glass, in which shadowy crystals of pyroxene, which fade at the margins, one into another, are visible in cross-polarized light. The only iron-ore in these may be in cracks which extend into the matrix. The majority of the chondrules have a seemingly fibrous structure which is either parallel or radiating. Some may consist of a single crystal of pyroxene, clear at the margin, but containing in the interior a parallel intergrowth of another mineral which appears to be felspar with an extinction-angle of about 45° from the direction of the fibres. The majority of the radiating intergrowths cannot be resolved.

The matrix of the stone is wholly crystalline, being an aggregate of granules without recognizable crystal forms, but the felspar and pyrrhotine are usually interstitial. The grain varies as much from part to part as do the fragmental inclusions, of which it is sometimes difficult to distinguish a margin.

Olivine and pyroxene, not always easy to recognize, form the bulk of the stone. Both are optically negative and therefore relatively rich in iron, though they are quite colourless.

Two felspars can be distinguished. The most abundant shows a high relief against the balsam. It is untwinned and the cleavage is generally indistinct. It is optically negative with large axial angle.

These characters are in agreement with labradorite-bytownite as determined in the analysis. Orthoclase is scattered in interstices. An areal analysis with the Shand micrometer gave a value of 0·6 % for the latter in one slide.

Three opaque substances are recognizable in the slides. Nickel-iron forms small pellets, often rounded in shape but sometimes irregular, with partially concave outlines. In very few cases does it appear to be moulded against silicate minerals, but it may enclose chromite partially or wholly. The slides are generally stained brown near the metal, suggesting the presence of lawrencite (ferrous chloride). A sulphide of iron, troilite or pyrrhotine, is rather plentiful in the silicate portion of the rock, where it is frequently interstitial and fills small cracks. Since it is almost non-magnetic it is probably troilite.

The third opaque substance has a dark inky-blue colour. It appears to be a mixture of chromite and ilmenite with other opaque substances. While some of it, probably chromite, has crystallized very early, being enclosed in the iron, another portion, perhaps a phosphate resembling triplite, is interstitial between crystals of olivine. An areal analysis of this opaque material in two of the slides gave a volume percentage of 2·05, which compares closely with the volume percentage of hercynite, chromite, triplite, and ilmenite calculated from the analyses.

For purposes of determining the mineral composition the three analyses were treated separately.

In the insoluble portion the alumina is almost exactly equivalent to the lime and alkalis to form felspar. After deducting chromite and ilmenite, the remaining iron and the magnesia were calculated as hypersthene and enstatite on the assumption that all the olivine had been dissolved. A quantity of silica equivalent to 3·62 % of the whole stone was found to remain. Since the presence of free silica in a stone so rich in olivine would be anomalous, and moreover could not be determined in the slides, this silica was assumed to have been liberated from the soluble portion and rendered insoluble in soda by the evaporation to dryness.

In the soluble silicate, with the excess of silica mentioned above, only traces of calcium and alkalis occur. The alumina probably occurs as hercynite or Tschermak's silicate. It was calculated as the former. The P_2O_5 was reckoned as a phosphate of manganese and iron, and the remaining bases divided between olivine and pyroxene on the assumption that the pyroxene has the same composition as it has in the insoluble portion.

The soluble magnetic portion was calculated in the same way as the soluble silicate; and the insoluble magnetic portion was assumed to have the same composition as the insoluble silicate. Throughout the sulphur was calculated as troilite.

The resulting mineral composition is given in the following table:

Mineral Composition.

	Magnetic portion.	Insoluble silicates.	Soluble silicates.		
Orthoclase	—	0·69	—	0·69	
Albite	—	3·94	—	3·94	12·38 Felspar
Anorthite	—	7·75	—	7·75	
Enstatite	—	12·46	7·54	20·00	29·88 Pyroxene
Hypersthene ...	—	6·17	3·71	9·88	
Forsterite	0·64	—	27·15	27·79	47·10 Olivine
Fayalite	0·26	—	19·05	19·31	
Hercynite ($FeAl_2O_4$)	0·05	—	1·07	1·12	
Chromite	—	0·67	—	0·67	2·50 Iron-ore
Ilmenite	—	0·37	—	0·37	
Triplite ($Mn_3(PO_4)_2$)	—	—	0·34	0·34	
Troilite (FeS) ...	0·11	—	4·87	4·98	4·98 Troilite
Iron	2·09	—	—	2·03	
Nickel	0·93	—	—	0·93	3·07 Metal
Cobalt	0·11	—	—	0.11	
	4·19	32·05	63·73	99·91	

Lawrencite ($FeCl_2$) water soluble (including 0·06 % of iron determined in magnetic portion)	0·13
	100·04
Specific gravity calculated from above composition	3·51

For purposes of comparison with other meteorites the following particulars are significant:

(1) percentage of metal ... ... 3·07
(2) ratio of iron + cobalt to nickel in metal ... ... 2·30
(3) ratio of MgO to FeO in silicate by weight ... ... 1·26
or by molecular proportion ... ... 2·22
(4) dominant felspar—bytownite-labradorite.

These characters place the stone near the boundary between groups 3 and 4 of chondrites in Prior's classification,[1] the first three characters being characteristic of group 3 and the fourth of group 4. The stone seems to be generally similar to the Soko-Banja stone from Serbia, but exhibits a further stage of progressive oxidation in every respect.

4. *Chemical analysis* (*E.G.*).

The method used for analysis was that described by George P. Merrill.[2] A piece of the stone weighing 18·341 grams was crushed to pass 80-inch mesh. The larger particles of metal which would not pass the sieve were pounded flat to free them from silicate as far as possible and reserved. The powdered material was then worked over thoroughly with a hand-magnet, then again by an electromagnetic separator, the magnetic portion again subjected several times to the hand-magnet, and finally added to the metal. The whole of the remaining powder was then treated by the electromagnetic separator, the attracted portion obtained worked over several times with the hand-magnet, and added to the metal. This separation gave:

Attracted portion	0·8838
Unattracted portion	17·4558
	18·3396 grams

The attracted portion was all digested in aqua regia, evaporated to dryness, taken up in hydrochloric acid, and filtered. The undissolved portion was washed thoroughly in hot water, then digested for one hour in hot 10 % sodium carbonate solution, filtered, and the insoluble residue washed thoroughly with hot water, and then with dilute hydrochloric acid and again with hot water. The residue was weighed as insoluble silicate. This gave:

Dissolved	0·7636 = 4·163 % of whole
Insoluble	0·1202
	0·8838 gram

The alkaline and acid filtrates were combined, evaporated to dryness, and the silica separated in the usual manner. The solution was

[1] G. T. Prior, The classification of meteorites. Min. Mag., 1920, vol. 19, pp. 51–63.

[2] G. P. Merrill, Bull. U.S. Nat. Mus., 1930, no. 149, pl. 57. [M.A. 4–257.]

then made up to 500 c.c. in a calibrated flask at 25° C. and divided into aliquot portions for the various determinations.

The results of analysis of the *attracted portion* were as follows:

	Grams.		4·163 % of whole.
Soluble silicate:			
SiO_2	0·0648		0·353
Al_2O_3	0·0055		0·030
TiO_2	nil		nil
FeO	0·0340		0·185
CaO	trace		trace
MgO	0·0675		0·368
MnO	0·0005		0·003
		0·1723	
Pyrrhotine (Fe_7S_8):			
Fe	0·0113		0·062
S	0·0074		0·040
		0·0187	
Metal:			
Fe	0·3878		2·114
Ni	0·1697		0·925
Co	0·0206		0·112
Cu	nil		nil
P	0·0002		0·001
		0·5783	
		0·7693	4·193

Metal found = 3·15 % of whole meteorite.

Net composition of metallic portion:

Iron, Fe	67·059
Nickel, Ni	29·345
Cobalt, Co	3·562
Phosphorus, P	0·034
Platinum metals, Pt, &c.	0·0001 (by assay 0·60 dwt. per ton)
Gold, Au	nil

Duplicate assays for 'platinoids', made by Mr. G. W. Gibbings, of the Metallurgical Department, Southern Rhodesia, gave 0·60 dwt. per short ton, corresponding with 0·0001 %. No gold was found.

The soluble silicate portion.

For the analysis of the soluble silicate triplicate portions of 2·00 grams of the finely crushed unattracted powder were taken and treated in the same manner as the preceding attracted portion. The average of the results were :

Dissolved	1·2564 grams
Insoluble	0·7436

After the separation of silica, the acid portions were made up to 250 c.c. in a calibrated flask at 25° C. and divided into aliquot portions for the various determinations. The average of the results obtained is as follows :

SiO_2	0·4157 grams
Al_2O_3	0·0131
TiO_2	nil
FeO	0·3371
CaO	trace
MgO	0·3900
MnO	0·0028
P_2O_5	0·0041
Fe	0·0571
S	0·0373
NiO*	0·0071
CoO	trace
	1·2643

* Probably present as Ni in the incompletely separated metallic portion.

The insoluble silicate portion.

From the last treatment the clean acid-washed insoluble silicate portion was taken. One gram of this was weighed out, fused with sodium carbonate, and analysed by standard methods. The chromite was decomposed by the addition of a little potassium nitrate to the carbonate. The analysis gave the following results :

	Per cent.	Grams.
SiO_2	57·02	0·4240
Al_2O_3	10·35	0·0770
TiO_2	0·53	0·0039
FeO	10·37	0·0771
CaO	4·36	0·0324
MgO	13·89	0·1033
NiO	nil	nil
P_2O_5	nil	nil
Cr_2O_3	1·27	0·0094
Na_2O	1·31	0·0097
K_2O	0·32	0·0024
	99·42	0·7392

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Bulk composition of the portion of the meteorite ground for analysis (Lab. No. G475).

	Attracted %	Unattracted %	Bulk Grams.	Bulk %
SiO_2	8·486	41·985	7·4440	40·590
Al_2O_3	0·720	4·505	0·7973	4·347
TiO_2	nil	0·195	0·0343	0·187
FeO	4·452	20·710	3·6740	20·033
CaO	trace	1·620	0·2847	1·553
MgO	8·840	24·665	4·4026	24·006
MnO	0·065	0·140	0·0251	0·137
P_2O_5	—	0·205	0·0360	0·196
Cr_2O_3	—	0·470	0·0726	0·450
Na_2O	—	0·485	0·0852	0·465
K_2O	—	0·120	0·0210	0·115
P	0·026	—	0·0002	0·001
NiO	—	0·355	0·0624	0·340
CoO	—	trace	trace	trace
Fe	52·265	2·855	0·9009	4·912
Ni	22·223	—	0·1697	0·925
Co	2·697	—	0·0206	0·112
Cu	nil	—	nil	nil
S	0·969	1·865	0·3352	1·827
Pt	—	—	trace	trace
Totals	100·743	100·175	18·3658	100·196
SrO	—	—	—	trace
H_2O+	—	—	—	nil
H_2O-	—	—	—	0·110
Water-soluble chlorine	—	—	—	0·071

ZrO_2, CO_2, SO_3, V_2O_3, BaO sought but not found.
Sp. gr. 3·517