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MOORE COUNTY, NORTH CAROLINA, METEORITE—A NEW EUCRITE

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Introduction

This meteorite fell April 21, 1913, at about 5:00 p.m., on the farm belonging to Mr. George C. Graves, located about 3 miles east of Carthage, Moore County, North Carolina, longitude 79° 23′ W., latitude 35° 25′ N. Mr. Graves had this specimen taken to his store in Carthage where it was displayed for several days and then it was given to his wife who has carefully preserved it and all records pertaining to the fall. The authors are indebted to Mrs. Graves for preservation of both the records of the fall and also the meteorite.

The day of the fall, April 21, 1913, was partly cloudy and partly rainy, the sun being hidden by fleecy clouds and no appreciable wind was blowing. The first warning of a meteorite was a roaring overhead to the southwest. The roar of the meteorite was heard by persons within a radius of about five or six miles from the location of the fall. The sound effect was described as rumbling and zooming with no distinct explosions.

The meteorite fell in an open freshly plowed field where Mr. Haig Cockman and two negro helpers were working a cotton crop. Looking overhead, Mr. Cockman and the negroes noted what they described as a red hot ball followed by a trail of blue-black smoke, estimated to be about 15 feet long. There were bright sparklers given off from this meteorite. The noise was heard before the meteorite was noted and became more audible as the meteorite approached, and even a slight rumbling persisted for a short interval after it struck the ground. It embedded itself in the soft plowed ground to a depth of about two feet and within a few feet of Mr. Cockman. The hole had a slight slope from the southwest, but appeared to be nearly vertical.

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PHYSICAL PROPERTIES OF MOORE COUNTY METEORITE

This meteorite is a very symmetrical individual stone weighing 4 lbs. 2 oz. and shows well developed flight markings. The maximum measurements taken in three directions, at right angles to each other, are 6″×4 3/16″×3 3/16″. The meteorite was not a rotating body in its fall through the atmosphere. Its present flattened conical shape together with radial markings on the sloping sides is considered ample evidence of the fact that certainly through the last portion of its flight, and in the most dense atmosphere, it maintained a fixed orientation.

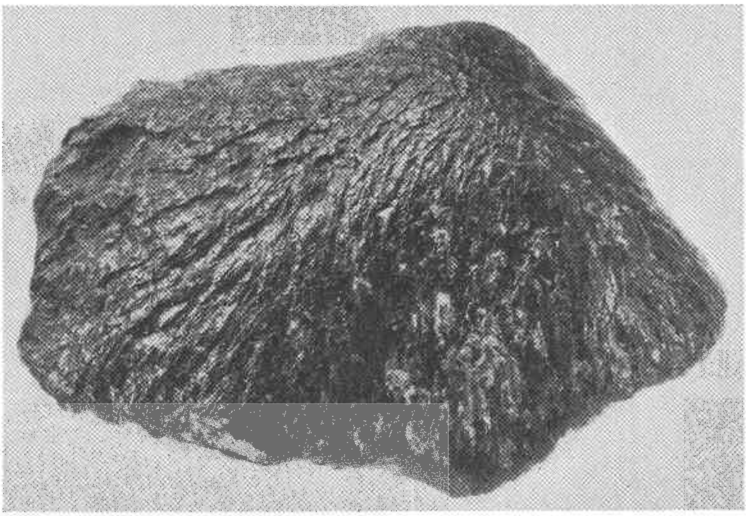

FIG. 1. Moore County, North Carolina, meteorite. The forward face showing flight markings.

The paths of meteors are generally straight, a fact which is supported both by crude visual observations and by photographic plates.[1]

The surface is covered with a dark colored glassy brown material with shallow furrows (piezoglyphs) extending from the "brustseit" to the outer edges of the face which was forward on its oriented flight. At the crown or "brustseit" the glass is pitted with rounded irregular shallow depressions but on the sloping sides the furrows become very definite, at first they are shallow but farther down the sloping sides they become wider and deeper.

Other than these furrows the surface is almost free from any pitting. Near the outer edges of the forward face there are a few groove shaped depressions which have been carved out by the force of the air. These are

[1] Fisher W. J., *Harvard College Observatory Circular* **385.**

considerably deeper than the furrows, the deepest of these measuring about 4 mm. The glass is very thinly spread over the forward face, in fact, so thin that the color of the component minerals of the meteorite can be seen through the glass. At all places where measurement was possible the thickness of the glass on this face is less than 1 mm. This indicates that as fast as the minerals were heated to their fusion point or to the temperature where they were slightly plastic, they were removed by the force of the rushing air. With such a high velocity, and consequent fusion, the size of this meteorite must have been rapidly reduced. Presumably most of the material is carried off in finely divided particles. Such particles trail behind to constitute the smoke train.

Fused material has cooled and collected on the rear face of this meteorite. Here it is too thick to be transparent, and it appears as a black glass. In this glass are conspicuous vesicular cavities. In the central portion of this face, where it is uniformly spread, the glass is about twice as thick as on the forward face. Near the rim of this rear face, just under the edges from the sloping front faces, there is a maximum accumulation of this glass. This maximum accumulation is an almost continuous band about 5 mm. thick and about 1.5 cm. wide.

This meteorite was cut into two almost equal parts and a slice was taken off one half to provide material for the detailed study of the minerals. Superficially this meteorite appeared to be free from fractures, but, after cutting, two rather prominent fractures were found. Both of these were completely concealed by the surface covering of glass and therefore it seems logical to assume that these fractures were in existence prior to the entrance of the meteorite into our atmosphere.

To the unaided eye there appeared to be present but three minerals: viz., white basic bytownite (near anorthite), yellow pyroxene, and a few very small and scattered inclusions of chromite. The former two constituents appeared to be present in about equal proportions. No free iron or sulphides could be seen, but subsequent chemical tests proved their presence.

General Structure of the Meteorite

The texture of the Moore County meteorite is best described as uniformly granular and unusually coarse grained for a meteorite. The minerals are uniformly distributed throughout the entire mass. There is very little bond between the component minerals. In fact the minerals can be easily separated by lightly rubbing the fingers over the surface from which the fused glassy covering has been removed. It was found to be almost impossible to make thin sections of this meteorite without causing the mineral grains to completely separate one from another.

The cleavage in the feldspar is developed far more perfectly than is normally the case and, in preparing the thin section, many of the laths of feldspar were broken into small cleavage fragments. When thin sections of terrestrial rocks are made the feldspars rarely shatter into cleavage fragments. There is also a tendency for the pyroxene minerals to separate into cleavage fragments, but to a lesser extent than the bytownite.

The development of the cleavage is a significant feature of this fall and may be connected with some of the thermal changes described later in this paper. However, the authors are not able to definitely state that this is true. The lack of bond between the mineral components may be due to the same cause which has developed the cleavages, although there is the possibility that it is more closely connected with the chemical composition of the meteorite. In the Moore County meteorite there is no excess of free silica (see Table 4) and it is very likely that quartz serves to some extent as a binder to the minerals with which it is associated in igneous rocks. Some dunites are equally as granular and friable as this meteorite and they are free from quartz.

Farrington[2] states that "all eucrites and shergottites show an ophitic structure." This Moore County meteorite can be classified as a eucrite since the feldspar is near anorthite in composition, but it certainly does not possess to any appreciable extent an ophitic texture.

The slice, used for the mineralogical study, was carefully washed with water to remove the abrasive agents used in cutting it from the meteorite. After washing it was dried in an oven at 110° for three hours to expel any absorbed moisture. The central portion was broken out, crushed and treated with heavy solutions to separate the mineral constituents. Since only the central portion was selected for study there is no possibility of including any of the fused outer portion, or minerals which may have been affected by the heating during its flight.

This meteorite, because of its coarse granular texture, afforded an excellent opportunity for a careful mineralogical study of the component minerals.

Mineralogy

A solution of methylene iodide was adjusted so as to float the bytownite and drop the pyroxene. The bytownite was twice treated in this manner and then placed in a second solution of methylene iodide, adjusted to float off any mineral of lighter specific gravity, such as quartz or a lighter feldspar. This proved useless as none was found.

[2] *Meteorites, their Structure, Composition, and Terrestrial Relations.* Published by the author, Chicago, 1915.

The pyroxene portion was again treated with pure methylene iodide to remove any minerals of lighter gravity. Naturally chromite was concentrated in the pyroxene portion by such a procedure and was later removed by hand picking. No silicate was rejected because after it was found that several different minerals were present the authors wished to get an analysis which included all of these minerals in their true proportions.

Bytownite.—When the feldspar is examined on the freshly broken surface of the meteorite two different colors and lusters are noticeable. One is white and more vitreous, similar to the bytownite of terrestrial rocks, the other has a dull luster and is slightly gray in appearance. What these two types of bytownite may signify the authors are unable to say. In thin section this difference is not noticeable and the analysis, as well as the determination of the optical properties were made upon a sample prepared as described above and containing both types of feldspars.

The bytownite contains numerous minute inclusions, most of which are without any symmetrical arrangement. Under the oil immersion objective the most common inclusion observed has a rather elongated rhombohedron shape and a brownish red color. There are a few inclusions of spherical habit, with a similar color, and some inclusions of slender, prism-like forms, rather uniform in shape, and arranged in rows along the direction of the cleavage.

The indices of refraction, determined by the immersion method using crushed fragments were found to be: $\alpha=1.571$; $\beta=1.578$; $\gamma=1.583$; B.$=.012$. Sign ($-$), extinction angle on (010) is 36°, on (001) is 32°. Dispersion moderately strong, $r<v$. 2V$=77°$ (calculated).

Bytownite, Moore County Meteorite

E. P. Henderson, *analyst*

		Ratios		
SiO_2	46.70	.7770	.7770	2+
Al_2O_3	33.20	.3256	.3356	1
Fe_2O_3	1.59	.0100		
CaO	17.42	.3106	.3301	1
MgO	0.27	.0067		
Na_2O	1.16	.0187		
K_2O	0.08	.0008		
TiO_2	0.06			
	100.48			

The norms of this bytownite are: *an.* 86.38%; *ab.* 9.78%; *or.* 0.43%; with an excess of 1.92% of silica.

Pyroxene Portion

A sample of this pyroxene aggregate was prepared by the same procedure as described under the preparation of the feldspar portion. The hand picked portion contained some unavoidable inclusions of chromite and perhaps some other opaque mineral. The specific gravity was found to be 3.67.

This portion, on first inspection, was thought to be a single homogeneous mineral, as the color was very uniform (brownish yellow), but on a careful optical study made by Miss Jewell J. Glass, it was found to consist of three components which could be distinguished from one another by their distinct optical properties. One of these minerals was hypersthene and the other two were pigeonites. It is unusual to find two modifications of a mineral whose compositions can be expressed as a mixture of different molecules of a solid solution series, in the same rock. Evidence is offered later in this paper to explain this apparent anomaly.

Pyroxenes, Moore County Meteorite

E. P. Henderson, *analyst*

		Ratios	
SiO_2	49.37	.8220	.8220
Al_2O_3	1.55	.0152	
Fe_2O_3	1.83	.0115	
FeO	26.44	.3680	
CaO	4.60	.0820	.8406 (FeO, CaO, MgO, MnO)
MgO	15.54	.3854	
MnO	0.37	.0052	
TiO_2	0.62	.0077	
	100.32		

Hypersthene.—The hypersthene has a brownish yellow to smoky yellow color, the grains are prismatic and have a good cleavage. Some show very fine twinning. The indices of refraction are: $\alpha = 1.705$; $\beta = 1.717$; $\gamma = 1.720$; B. = .015. Sign (−). $2V$ slightly variable, about 60°. Extinction parallel, dispersion weak, $r > v$. The optical plane is parallel to the elongation and also to the trace of the best cleavage. The grains are slightly pleochroic. X = pale pinkish brown, Y and Z = colorless.

Inclusions of both a transparent and opaque nature are numerous. There are some transparent inclusions arranged in a series of parallel interrupted rows, which might be mistaken for twinning lamellae. This apparent twinning structure in transmitted light gives a ridge and trough-like effect due to the difference in the index of refraction between the included bands and the host mineral. Other transparent inclusions show a flag- or figure "7"-like pattern arranged symmetrically either parallel to the cleavage, or in rows inclined 25 to 30 degrees to the cleavage. The opaque included mineral has a rhomb-like form and no symmetrical arrangement in the hypersthene. Some of these opaque inclusions certainly are chromite and since there is some ferric iron present in the composite analysis, there may be some hematite present. Brookite of reddish color and of modified rhombic form, as well as titaniferous iron in rhombic forms have been reported in hypersthene.[3]

Pigeonite.—There are present two distinct compounds which can be recognized and distinguished from one another, both having optical properties which fall within the range included in the pigeonite series.

Pigeonite "A."—This modification of pigeonite is a far more abundant and important constituent than that described under pigeonite "B." The grains are prismatic with a vitreous luster, having two perfect cleavages and a good parting in a direction transverse to the best cleavage. Contact twinning is common and frequently an indistinct polysynthetic twinning occurs. The following table contains three separate sets of indices of this pigeonite which are listed for comparative purposes.

TABLE 1

Refractive Indices of Pigeonite "A" in Moore County, North Carolina, meteorite, determined by Jewell J. Glass.

α	1.706	1.705	1.705
β	1.708	1.707	1.708
γ	1.730	1.732	1.730

Sign (+). $2V=0°–15°$. Pleochroism distinct. X=pinkish brown, Y=pale pinkish brown, Z=faintly greenish (nearly colorless). Extinction $Z \wedge c=31°$. Dispersion is strong, $r>v$. The dispersion phenomenon in this mineral is distinctive. The grey blue bands cover the entire area of the two opposite quadrants, and when the gypsum plate is interposed the other two quadrants are a deep rose reddish orange.

The direction of the optical plane is not easily determined; pieces which show centered figures are invariably irregular in outline and show no directional features. Optical figures are easily obtained, however, and the fragments which give a perfectly centered figure are distinctive, having a blue grey color in one position and a rose brown at 90° to this.

The inclusions in the pigeonite are limited to opaque ones of rhombic habit and in general are haphazardly arranged. There is a suggestion of definite arrangement of the tiny rectangular inclusions parallel and at right angles to a cleavage. The pattern found resembles those which have been noted in "Schiller structures."

[3] Kosmann, *Jarb. Min.*, p. 532, **1869**; p. 501, **1871**.

The uniaxial augite, pigeonite, from the Island of Mull[4] has the following indices: $\omega = 1.714$; $\epsilon = 1.744$; B. = .030. According to Bowen and Schairer[5] "in optical properties it shows a close approach to a pyroxene of the pure Mg-Fe clino series having $MgSiO_3$ (40%), $FeSiO_3$ (60%)." Since the optical properties of this modification of meteoric pigeonite agree with those of the pigeonite from the Island of Mull, it is evident that the composition is close to that given by the above authors for the latter locality. Comparing the optics of the pigeonite, here described, with Tomita's[6] diagram, the same relative composition was obtained.

Table 2

	Clino-hypersthene	Pigeonite "B"
	Bluff, New Zealand	Moore County, N.C., meteorite
Observer	Harold Service	Jewell J. Glass
Twinning	Fine lamellar twinning on (100) frequent	Polysynthetic twinning, also contact twinning
Birefringence	.023	.029
Indices of Refraction	Mean index 1.72	$\alpha = 1.693$; $\beta = 1.696$; $\gamma = 1.722$
Sign	−	+
Optic plane	Parallel to traces upon (001) of (100) twins	Normal to cleavage
Pleochroism	$X = Y$ = pale rose pink; Z = pale apple green	X = pinkish brown; Y and Z = pale tan to brownish
Miscellaneous	$2V = 30° \pm 3$	$2V = 30°–40°$ $Z \wedge c = 38°$ Dispersion moderate

Bowen and Schairer[7] further comment on the Island of Mull pigeonite by saying: "There can be little doubt that the stable condition of the substance of this uniaxial augite at low temperatures would be an orthorhombic pyroxene with a small admixture of lime rich monoclinic pyroxene and the suggestion is that these crystals formed at a high temperature."

[4] Hallimond, A. F., *Mineral. Mag.*, vol. **17**, p. 97, 1914.
[5] Bowen, N. L., and Schairer, J. F., *Am. Jour. Sci.*, vol. **29**, p. 202, 1935.
[6] Tomita, T., *Jour. Shanghai Sci. Inst.*, sec. **V. 1**, p. 41, 1934.
[7] *Idem.*

Pigeonite "B."—It is estimated that this modification of pigeonite makes up slightly less than 5% of the total pyroxenes of this meteorite. It has a yellowish brown to smoky greenish color, vitreous luster and the grains of this variety are rounded. The fracture is irregular and cleavages are not as common as in the hypersthene. Twinning surfaces are observed, but less commonly than in the other pyroxenes present.

In the following table a comparison is made between the optical properties of clino-hypersthene from Bluff, New Zealand,[8] and this modification of pigeonite in the Moore County, North Carolina, meteorite.

Interpolating the indices of refraction for this meteoric pigeonite in Tomita's diagrams[9] the composition was found to be about 35% $FeSiO_3$ and 65% $MgSiO_3$.

There is little variation in the observed indices of refraction for the subordinate pigeonite and the following table permits a comparison of the range of variations.

TABLE 3

Indices of Refraction of Pigeonite "B" in Moore County, North Carolina, meteorite. Determined by Jewell J. Glass.

α	1.693	1.692	1.692	1.692
β	1.696	1.694	1.695	1.696
γ	1.722	1.720	1.722	1.720

These two tables, Pigeonite "A" and Pigeonite "B", showing the variations in refractive indices of the two pigeonites are given not only to show the limits of variation but also to show that the results obtained are easily duplicated. Such careful work was thought to be necessary because it has been rare to find two such distinct modifications of pigeonite in terrestrial rocks. This feature leads to important deductions concerning the natural history of this meteorite.

In the andesite from Hakone volcano, Japan, Kuno[10] describes a pigeonite occurring as phenocrysts, the core of each crystal is homogeneous but with a narrow marginal zone, with a larger optical angle and a slightly larger extinction angle than the central core. Kuno states "The narrow rim around each augite phenocryst (pigeonite) is richer in $MgSiO_3$ than, and nearly equal in $CaSiO_3$ content, to the core . . . judging from its lower refraction. From these facts and other marginal zones surrounding the hypersthene, plagioclase and augite, it may be interpreted that the phenocrysts in the rock are in reality xenocrysts that were enclosed just before extrusion by a magma more basic in composi-

[8] Service, Harold, *Royal Soc. New Zealand*, vol. **64**, p. 147, 1934.

[9] *Idem.*

[10] Kuno, Hisashi, *Jour. Geol., Soc. of Japan*, vol. **42**, no. 496, p. 39, 1935.

tion than that with which they had been in equilibrium in the deeper portion, and that the narrow marginal zones around the phenocrysts, which were characterized in the above, are products of their reaction with this basic magma." The authors do not believe that Kuno's explanation of the two pigeonites in the Hakone lavas applies to the pigeonites in the Moore County meteorite.

Relationship of the Pyroxenic Minerals

It is evident from a study of the stony meteorites that they have not been through many recrystallizations or magmatic alterations and that the minerals in meteorites have not reached chemical equilibrium, so perhaps one might expect to find these two forms of pigeonite occurring together. We favor, however, the possibility that the complex assemblage of pyroxenic minerals found in this meteorite may be the result of a transformation resulting from a second reheating. There is abundant evidence from laboratory studies that transformations such as are recorded in this meteorite can easily take place.

It is now well established that both enstatite and hypersthene can be transformed from an orthorhombic to a monoclinic form. Allen, Wright and Clement[11] found that when the enstatite from the Bishopville meteorite was heated to 1450° the enstatite with its parallel extinction disappeared completely and was replaced by the twinned monoclinic lamellae. The latter still preserved the original prismatic direction of the enstatite and also apparently the cleavage, the size of the grain of the two phases being about the same and the original outline of the enstatite fragments being still preserved after the paramorphic change.

These same investigators[12] were able to reproduce parallel growths of enstatite and monoclinic pyroxenes by cooling rapidly a molten mass of pure magnesium silicate. They state: "The slower the cooling the more the monoclinic form is obtained; hence, we (Allen, Wright and Clement) conclude that the Bishopville meteorite was probably cooled rather rapidly from a high initial temperature."

Bowen and Schairer[13] have described in detail the changes from orthorhombic to monoclinic forms in the MgO-FeO-SiO_2 system and many references will be quoted from their publication.

It has been proposed that quick cooling such as occurs in meteorites and artificial melts gives coarse twinning which is visible under the microscope, whereas slow cooling gives submicroscopic twinning. Bowen[14]

[11] *Am. Jour. Sci.*, vol. **22**, p. 403, 1906.
[12] *Idem.*
[13] *Am. Jour. Sci.*, vol. **29**, p. 164, 1935.
[14] *Am. Jour. Sci.*, vol. **38**, p. 255, 1914.

found that "quick and slow cooling have precisely the opposite effects for pyroxenes." "When crystals form instantaneously from undercooled liquid the twinning is very fine; when they are grown by holding for a couple of hours in contact with liquid the twinning bands are broad."

If the different pyroxene minerals present in this (Moore County) meteorite represent a transition of one form to another by reheating, which seems to be the best explanation of their presence, it is more likely the reheating was done at the place of origin rather than in the course of its flight.

From the results of researches of Bowen and Schairer[15] on the system MgO-FeO-SiO_2, it appears that the original composition of this meteorite was bytownite and a homogeneous pyroxene mineral. The latter on cooling probably unmixed to give the orthorhombic pyroxene, hypersthene and pigeonite. The rock mass was at some later date reheated and a portion of the hypersthene was then transformed into the second modification of pigeonite present in subordinate amounts.

The following discussion is introduced to give some quantitative data concerning the temperatures necessary to effect these changes, and also to prove that such temperatures are more likely to be brought about by geological agencies in the meteorite's original environment than by friction with the atmosphere during its flight.

These same authors[16] found that at somewhat higher temperatures than needed for the formation of orthorhombic pyroxenes, the monoclinic pyroxenes exist in equilibrium and correspond to the clino-enstatite, clino-hypersthene series. The inversion temperature of the $MgSiO_3$ end member is 1140° and the temperature of inversion falls off rapidly as the iron ratio is increased until the inversion of the iron rich member is approximately at 955°.

In their investigations, Bowen and Schairer used natural pyroxenes and also synthetic materials. They state: "We have found it impossible to induce any synthetic metasilicate mixture of the system to crystallize completely in the orthorhombic form." These authors used the enstatite from the Bishopville meteorite and found that when it was heated at 1150° for four hours partial transformation is readily discerned, recognizable under the microscope as twinned lamellae of the monoclinic form on the edges and corners of the grains, "at times small grains are transformed through and through to the twinned form." The twinning was found to be coarse and the extinction angle against the twinning is 22°.

It was also found that when enstatite was heated for 125 hours at

[15] *Am. Jour. Sci.*, vol. **29**, p. 151, 1935.

[16] *Loc. cit.*

1140° not a trace of the monoclinic form was found. These authors suggest that all indications are that enstatite is stable up to about 1145° and will persist indefinitely at any temperatures below that. It will change at a measurable rate at a temperature even a few degrees above 1145°. It was also found that the inversion point for hypersthene from Mt. Dore[17] was about 1090°.

Since the indices of the Mt. Dore hypersthene agree very closely with those given above for the hypersthene in this meteorite, it is logical to assume that the inversion point for the meteoric hypersthene would be similar to the hypersthene from Mt. Dore. Thus, when the meteorite was reheated, a temperature of 1090° must have been reached.

The following quotations from Bowen and Schairer give temperature ranges for the separation of the orthorhombic Mg-Fe pyroxenes.

"When Mg-Fe metasilicates crystallize from magmas it almost invariably assumes the orthorhombic form, stable at temperatures below 1140° at the magnesian end and below 955° at the other extreme. It is safe to conclude that crystallization of orthorhombic pyroxene took place below the temperature mentioned and since orthorhombic pyroxene is one of the earliest of minerals in these rocks in which it occurs the indications of low temperature crystallization of these rocks are clear."

"It is *not* safe to assume that the monoclinic Mg-Fe pyroxene must form only at high temperatures. It is a common observation that crystalline phases stable only at high temperatures may form metastably at low temperatures especially if rapidly formed."

It is not likely that this meteorite was heated high enough in its flight through the atmosphere to cause the inversion of the orthorhombic form into the monoclinic modifications. C. C. Wylie[18] after some theoretical considerations concerning the size and limiting velocity of a falling body says: "At these low velocities the resistance of the atmosphere would generate such a small amount of heat that it would be rapidly radiated and conducted away. If a body of 500 pounds reached the earth with a speed of 400 feet per second the rate at which the atmospheric resistance would be doing work would be less than sufficient to raise its temperature one degree per second if it had a specific heat of unity. These calculations agree with the observed fact that no meteorites have been seen to fall as balls of fire and where definite observations are available they indicate that the ball of fire appearance ended at a height of several miles."

It is a well known fact that the heat caused by the friction with the atmosphere only penetrates a very short distance into iron meteorites.

[17] Des Cloizeaux, *Min.*, II, vol. **18**, 1874.

[18] *Popular Astronomy*, vol. **42**, p. 59, 1934.

Thus it was shown by Merrill[19] that if the etched slice of the Toluca meteorite was heated for a few hours below red heat the original octahedral pattern assumed a granular structure. On continued heating the octahedral structure will disappear entirely.

That this meteorite under discussion may have passed close to our sun and at that time received enough heat to cause the pyroxene inversions is very unlikely. To be close enough to receive such heat would probably be so near that it would be drawn into our sun. Wherever and in whatever manner this meteorite was reheated the temperature must have been lower than the fusion point of bytownite.

Merrill[20] shows that feldspar can refuse and recrystallize without the formation of maskelynite. This observation is supported by researches on the melting points of feldspars.[21] There is no detectable quantity of isotropic feldspar in this meteorite. There are a few spherical inclusions in the bytownite whose mineralogical nature is not understood, but it is difficult to see how these could be maskelynite.

Its presence is questioned because the very high temperature needed to melt this bytownite cannot be shown to have been reached in this meteorite. The norms of this bytownite are 9.78% albite, 0.4% orthoclase and 86.38% anorthite. Such a feldspar would melt at a temperature far above that needed to produce the inversion of orthorhombic pyroxenes into monoclinic forms. The melting point of this bytownite[22] would be about $1510° \pm 10$.

Conclusions on the Relationship of the Pyroxenic Minerals

From the properties described and the researches quoted above it appears that the original composition of this meteorite was bytownite and a single homogeneous pyroxene mineral which on cooling probably unmixed to give hypersthene and pigeonite. At some later date the mass was reheated and a portion of the hypersthene was transformed into a second and subordinate modification of pigeonite. The temperature attained in the second reheating was somewhere between 1090°, the temperature necessary to transform such a MgO-FeO hypersthene into the monoclinic form, and 1510° the fusion point of bytownite of the same composition as in this meteorite. The temperature was probably never much above that needed for the transformation.

The Glass.—The material taken for this study was carefully picked from the rear face of the meteorite where the thickest accumulation

[19] *U. S. National Museum, Bull.* **149,** plate 26.

[20] *U. S. National Museum, Bull.* **149,** plate 2, figure 2.

[21] Bowen, N. L., *Am. Jour. Sci.*, vol. **35,** p. 577, 1913.

[22] *Idem.*, p. 591.

was found. The glass is vesicular and contains small quantities of partly absorbed or incompletely fused minerals. The sample was crushed and all pieces containing any appreciable quantities of mineral inclusions were rejected, however, it was impossible to prepare a sample which was perfectly free from these inclusions.

In transmitted light the color of the glass is dark brownish olive green, its index of refraction is 1.632.

Although little information of any mineralogical character was expected to result from such an incomplete study of the glass it did seem worth while to make some chemical tests upon it. Since the sample was quite bulky, because of the gas cavities, it would have required the sacrifice of most of the glass attached to the meteorite to have prepared a pure sample in sufficient quantities to make a complete analysis. The prepared sample of glass weighed less than .5 gram and with such a small quantity it seemed advisable to spend it in determining the ferrous and ferric iron contents and the alkalies.

Analysis of Glass, Moore County, Meteorite

E. P. Henderson, *analyst*

FeO	8.96
Fe_2O_3	7.53
Na_2O	0.68
K_2O	0.15

In the following table are arranged the analyses of bytownite, of the pyroxene portion, the average of these two analyses and the analysis of the complete stone. This table shows a striking agreement between the analysis of the complete meteorite and the average composition, and proves that the bytownite and pyroxene are present in equal proportions. Since the description of the separate component minerals is quite complete, there is nothing to add about the nature of the entire meteorite which would not be a duplication of what has gone before.

This meteorite is called eucrite, but this classification is not absolutely correct according to the classification of Rose-Tschermak-Brezina. Eucrites by their definition consist of augite with anorthite, while in the Moore County meteorite the pyroxene and bytownite constituents are present in equal quantities. However, it seems that the augites in their definition of eucrite can be taken to mean pyroxene minerals, including pigeonite of compositions similar to augites. Also the bytownite is very close to anorthite in composition.

It has been suggested that the granular structures of certain iron meteorites are due to reheating, but prior to this description there has been no evidence so convincing that stony meteorites also have been reheated. The Moore County meteorite offers very definite evidence of reheating.

TABLE 4

SUMMARY OF ANALYSES, MOORE COUNTY, METEORITE

E. P. Henderson, *analyst*

	Bytownite	Pyroxene	Average of two mineral portions	Complete meteorite
SiO_2	46.70	49.36	48.03	48.16
Al_2O_3	33.20	1.55	17.32	15.57
Fe_2O_3	1.59	1.83	1.71	1.90
Cr_2O_3	—	—	—	0.44
FeO	—	26.44	13.22	13.98
MnO	—	0.37	—	0.31
CaO	17.42	4.60	11.01	11.08
MgO	0.27	15.54	7.90	8.41
Na_2O	1.16	—	—	0.45
K_2O	0.08	—	—	0.09
TiO_2	—	0.62	—	0.32
S	—	—	—	0.30
	100.48	100.32		100.54

The Moore County meteorite is now about equally divided between the U. S. National Museum at Washington, D. C., and the North Carolina State Museum at Raleigh, North Carolina. This meteorite fell near the town of Carthage, North Carolina, and would have taken that name had there not been one already described and named as the Carthage from Smith County, Tennessee. Thus to avoid confusion the geographic name of the county in which it fell in North Carolina was selected.

SUMMARY

A 4 pound, 2 ounce stony meteorite, eucrite, is described which fell at about 5 P.M., April 21, 1913, near Carthage, North Carolina.

The unusual coarse texture permitted a mineralogical study, which revealed the presence of three distinct pyroxene components-hypersthene and two pigeonites. The presence of the three members of this group can best be explained by assuming the meteorite had been reheated prior to its entrance into the earth's atmosphere. A temperature above 1090°C. is necessary to produce the mineralogical relationships found in this meteorite.

Chemical analyses are given of the bytownite, composite pyroxene components, and for the entire meteorite. Optical properties are given for bytownite, hypersthene, two pigeonites and the glass.