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With the Author's compliments.

THREE NEW INDIAN METEORITES; KUTTIPPURAM, SHUPIYAN AND KAMSAGAR.

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(With Plates 7 to 20.)

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THE KUTTIPPURAM METEORITE.

On the 10th and 11th of April 1914, accounts of a meteorite fall appeared in various Indian newspapers. The following extract from the Calcutta "Statesman" is typical of them all. It is dated Calicut, April 10th, 1914: "On last Monday morning (April 6th), a terrible rumbling noise in the sky was heard, and it was generally believed that it was thunder which forecasted the early approach of the south-west monsoon. Reports now received go to show that meteorite stones, weighing about a hundred pounds, had fallen immediately after the noise in Ponnani, Tirur, Trurangadi, Kuttippuram, Ottapatam, and other places in South Malabar, and that they had gone about five or six feet deep into the earth. All the stones, which so fell, are reported to have been broken to pieces, owing to the extraordinary force with which they fell."

All meteorites which fall in British India are the property of the Government of India, and, as such, are added to the great collection in the Geological Museum, Calcutta. The Collector of Malabar, who is in charge of the district in which the stones fell, was requested, therefore, to obtain them, together with any available particulars of the occurrence.

Several Indian meteorites have previously been lost to science owing to the veneration bestowed on such objects by superstitious villagers, who regard the phenomena accompanying their descent as supernatural manifestations, and place the stones themselves in the temples, for public adoration, whence it is quite impossible to obtain them.

The Geological Survey Department is greatly indebted to Mr. C. A. Innes, the Officiating Collector of Malabar, for the trouble he took to secure the stones and for the completeness of the enquiries which he instituted regarding them.

In forwarding eleven fragments Mr. Innes submitted the following report which is reproduced below in his own words:—

"Careful enquiries have been made and it has now been ascertained that meteoric stones fell on the 6th April last only at the

following places in the Ponnani taluk of this district: (1) Kuttayi, (2) Triprangod, (3) Trikkanapuram and (4) Kuttippuram. These four places are practically in a straight line and you will find them all clearly marked in the Survey of India Topographical Sheets No. 49-N—13 and 58-B—1. Kuttayi is on the coast; Kuttippuram is 9 or 10 miles inland in a due easterly direction from Kuttayi. At Kuttayi four small stones are reported to have fallen within a distance of one mile. One of these stones is said to have measured $\frac{3}{4}' \times \frac{1}{2}' \times \frac{1}{2}'$, but only one small stone has been secured. One stone has been secured from Triprangod and six from Trikkanapuram. At Kuttippuram one large stone weighing it is said some 71 lbs. fell. It is now in three pieces all of which have been secured.

"I summarize below such information as I have been able to collect. Accounts vary as to the exact time at which the meteorites fell. At Kuttayi 6-30 A.M. is given as the time; at Kuttippuram 7 A.M.; while another account mentions 7-30 A.M.

"At Kuttayi there was a festival at the mosque on the morning of the 6th April, and many people who had collected at the sea shore had a good opportunity of observing the phenomenon. First they heard two loud and almost simultaneous reports which they compared to the noise made by *kadinas*. *Kadinas* are small mortars which are much in favour in Malabar and which are exploded with terrific noise at times of festival. A continuous roaring sound like that caused by a volley of musketry followed and at the same time there was a flash like a flash of lightning. (It is more probable that the flash preceded or accompanied the first two loud reports, but the account above is the one given by the Deputy Tahsildar of Tirur in whose division Kuttayi is.) The direction of the flash was from west to east and the people who saw it said that in appearance it resembled a palm tree. The stones which fell at Kuttayi penetrated only about 6 inches into the earth. They were slightly warm when picked up and there was no smell.

"At Kuttippuram the stone fell in a paddy field, which was then dry, and penetrated some feet into the ground. A cloud of dust rose into the air, and this attracted people to the spot. But they were apparently afraid to touch the stone, and it was not till some hours later that it was dug out and then it was quite cold. The people who gathered at the spot say that for some minutes

after the fall there was a smell of backwater mud in the vicinity. Backwater mud or silt is black oozy stuff which is full of rotting organic matter and its smell, which is familiar to everyone who lives in Malabar, is most unpleasant.

"Triprangod is about 3 miles from Kuttayi; Trikkanapuram about 5 miles from Triprangod and Kuttippuram about 2 miles from Trikkanapuram.

"The noise of the first two loud reports is said to have been heard at various places in Malabar. The Tahsildar heard it distinctly at Ponnani which is 4½ miles south of Kuttayi. A gentleman who lives close to my own bungalow at Calicut (30 miles north of Kuttayi), also says he heard the noise; while another enthusiastic gentleman claims (I believe) to have heard it at Cannanore which is 60 miles north of Calicut.

"I am sorry I cannot give you more definite information on the points referred to in your letter, but such information as my officers have been able to get has been gathered from villagers who are not exact observers of physical phenomena."

The following list gives the weights of the fragments and the names of the places in which they were picked up:—

259 A	18,236 gms.	
259 B	10,989 „	
259 C	3,374 „	
259 D	3,993 „	
259 E	738 „	
259 F	427 „	
259 G	221 „	
259 H	206 „	
259 I	121 „	
259 J	63 „	
259 K	60 „	
259 L	9 „	(Small fragments and dust.)

259 is the number which the meteorite bears in the Geological Survey register of meteoric stones. In the new catalogue its number is 194[1].

[1] The new catalogue of the meteorite collection is now in the press and will shortly be published.

A, B and C, which are parts of the same large stone and easily fit together, fell in Kuttippuram. D, E, F, G, H and I fell in Trikkanapuram, J in Triprangod and K in Kuttayi. The map (Plate 20) shows the exact position of each of these villages, all of which are situated in the Ponnani taluk of the Malabar District in the Madras Presidency. Kuttayi is on the coast in Lat. 10° 51′ : Long. 75° 54½′. Triprangod in Lat. 10° 50½′ : Long. 75° 57′, is 3¼ miles further inland in a line 2° south of east. Trikkanapuram is 7½ miles from Kuttayi in a line 9° south of east and is situated in Lat. 10° 49½′ : Long. 76° 1′, while Kuttippuram where the largest stone fell is in Lat. 10° 50½′ : Long. 76° 2′, 8¾ miles from the coast at Kuttayi, in a line 2° south of east.

It would appear therefore that a large meteor, travelling with a low trajectory, approached the Malabar Coast from the Arabian Sea, in a direction a few degrees south of east, and bursting into fragments, scattered portions of itself over the villages mentioned, for the greater momentum of the larger stones would carry them further than the small ones. Confirmatory evidence is supplied by the Deputy Tahsildar of Tirur who reported that the direction of the flash which accompanied the fall was from west to east at Kuttayi. From the small size of the Kuttayi fragments, and the large dimensions of the mass which fell in Kuttippuram, it seems to me that little if any of the material was lost by falling into the sea.

Description of the Kuttippuram Stone.

This large stone is broken into three pieces and part of the front and lateral surfaces are missing. These injuries may have been caused by its impact on reaching the ground, or they may have been inflicted later by inquisitive persons. For this reason it is impossible to describe exactly its original shape, but the larger portions which remain give a very good idea of what that shape was. Standing on the broken area and looked at from the end the meteorite has the appearance shown in Pl. 7, from which it seems to be somewhat prismatic. On the whole it is perhaps best to describe it as a very irregular tetrahedron, with one corner replaced by the flat face seen in Pl. 7, and modified of course by the broken and missing pieces. In this position it measures 28 cms. (11 inches) in height, at the end shown in Pl. 7, which is believed to be the rear face, decreasing to 18 cms. (7 inches) at the front face or "brustseite," which is smashed. Its length is 32 cms.

(12½ inches), and its greatest breadth in a line approximately perpendicular to this is 31·5 cms. (12⅜ inches). It weighs 32,599 gms. The specific gravity of this large mass has not been taken, but that of the smaller piece 259 H is 3·558. As will be seen later, the various fragments which comprise this fall are of a very uniform composition, and there is no reason to believe that the specific gravity of the large mass differs very much from that of the smaller piece.

The peculiar form of the stone is due partly to fracturing, and partly to the atmospheric erosion to which it has been subjected during its passage through the air. Apart from the fact that the edge which struck the earth first is marked by a thick deposit of hardened, sandy soil, the general shape of the stone, its differences of curvature, the rounding of its edges, the variation in the thickness and structures of its crust and the distribution of the pittings on its surface, all tend to prove that this edge was the front one during the trans-atmospheric existence of the meteorite.

In Pl. 11, this front edge commences at the rounded corner in the lower right half of the photograph where it is covered with the brown, sandy earth, already referred to, and continues up to the crack which divides the face into two pieces, and by means of which the portion marked A in the tracing has split off along a slickenside plane. [Plate 11, see tracing, for positions of A and B.] The remainder of the front edge and face has been broken away after the fashion indicated in Pl. 8. After photographs had been taken, part of the adherent earth was removed, and it was found to be not entirely underlain by crust, some of which must have been scaled off at a comparatively late period of the trans-atmospheric flight. Near the corner, the edge flattens into a minor area 3 or 4 cms. across.

The greater part of the stone is covered with crust, the exceptions being the broken end shown in Pl. 8, the missing portion which comes between A and B in Pl. 11, the medial portion of B in Pl. 11, and the left hand lower corner in the same figure. In addition to these, there are smaller patches where the crust has been removed, usually in the vicinity of the cracks which separate the three pieces.

The edge shown in Pl. 11, and also those made by the rear with the other faces are comparatively sharp, the others are more rounded. The sharp edge of the rear face in Pl. 7, and the flatness of its plane, indicate an early fracture along this surface.

The greater portion of the crust is corrugated with deep pits or piezoglyphs, furrows and channels, caused by the differential fusion of the upper layers of the stone and not by the combustion of included sulphide nodules. On the rear face they are only faintly traceable and on the top of the stone they are absent. (See the top line in Pls. 8, 9 and 11.) They attain their maximum development on the face illustrated in Pl. 11, though they are also present on the lateral faces seen in Pl. 8, and in the lower part of Pl. 10.

The pits seen in Pl. 11 have a circular, polygonal or irregular outline, and are either broad and shallow, with low rounded edges, sloping gently off into a more or less flattened base, or deeper, with steeper sides, making short sharp ridges between them. They do not possess any definite arrangement, except in the lower portion immediately above the adherent earth, where a long, funnel-shaped depression, with its mouth pointing towards the rear surface, seems to have been produced by the fusion of the ridges of several pits, the remains of which are still visible as low prominences. Elongated depressions of approximately elliptical outline, produced by two confluent pits, are also present. The average diameter of the better-marked pits is about 2 cms. The minute lines of crustal drift in the pits themselves show no particular distribution in the great majority of cases, but occasionally they are seen to radiate from the centre. Below the adherent earth in the lower right hand corner of Pl. 9, there are two long furrows, one much deeper than the other. The larger is 4 cms. in length, 1 cm. in breadth, and over 1 cm. in depth at the centre. In a general way both of them point from the front to the rear of the stone, showing the direction of the air currents by which they were produced.

The pits which are visible on the face seen in the lower left hand portion of Pl. 11, and in the lower right hand part of Pl. 10, are not so well developed as those just described. Instead of the deep pits, broad shallow ones occur, with diameters up to 4 cms. across and circular or elliptical outlines. These are made up of smaller depressions with badly defined edges. The minute irregular network of the crustal drift is more in evidence on this side than on the former one, but it does not exhibit any particular distribution. The crust itself is thicker and has scaled off a slight prominence. All these phenomena point to a diminished air resistance on this face.

The opposite lateral face is seen in Pl. 8. The part which lies in shadow on the upper left hand corner of the print contains several shallow elongated depressions, the long axes of which point towards the rear end. The rest of the upper portion of this face consists of a broad triangular area, next to the shadowed portion just described, a rounded and smoothed surface above this, and a larger space below and to the right, covered with depressions the long axes of which are orientated at right angles to the direction of flight. The lower part, below the crack, is rounded off into the lower section of the rear face and is comparatively smooth. The triangular area contains a deep groove, which has a length of 8 cms., a breadth of 2 cms., and a depth of 2 cms. below the general surrounding level. It possesses a curious short continuation at right angles to it on the left hand, evidently produced by confluence with a deep pit. As the photograph shows, its lower bounding ridge is steep and sharp, but the upper ridge is low and gives place to four shallow pits of polygonal outlines. The central two of these are separated by a ridge from a confluent depression above them. On the upper surface, just visible in the photograph, is a deep triangular pit, while on the extreme left, a circular one with an inner crateriform ring is situated. Above these again, there is a small, but deep, flat-bottomed depression, close to an elongated pit and surrounded by four smaller ones. Although the elongated depressions which occupy the rest of this portion are distinctive and arranged with their long axes pointing in the same direction, they have neither the depth nor the steepness of those on the front face. (Pl. 11.)

The rear face is seen best in Pl. 7. With the exception of a patch on the left, it is crusted. It is crossed by two fractures, which divide it approximately at right angles. Small shallow pittings are found over the greater part of its surface, often merging into one another. They are not uniform in shape or distribution. Large areas on the top and at the upper right hand corner possess a scooped out appearance, and are lined with small depressions of an average width of 1 cm. The crustal drift lines are longer and more thread-like than those of the other faces, but all they show is a radial arrangement, as if they were produced by heaping up from a centre of fusion. Here the crust attains its maximum thickness and its greatest irregularity of surface. The face itself

appears to have been originally a fracture plane, and its edges are more or less sharp.

The Crust.

Taken on the whole the crust of the stone is remarkably uniform in thickness and only the slight differences already mentioned have been noticed. It is of a dull black, lustreless colour, with a few small circular or elliptical patches of shining black. These when touched with a file prove to be fused metallic grains. Sometimes they project as small rounded knobs. The general appearance of the crust indicates a nearly felspar-free stone of the olivine pyroxene type, which it has indeed proved to be on petrological examination. Even to the naked eye, the surface of the crust is roughened, and when examined with a lens the roughness is seen to be caused by minute irregular threads, which form anastomosing systems, or a kind of lattice work pattern, over the outer crust of the entire stone. I term this structure "minutely scoriaceous," because under a lens it has a cindery appearance, which I regard as the result of fusion. Large areas of the crust are of a greyish-black tint, but this is only due to the accumulation of dust particles in the minute slaggy pores. Other parts show a few small scattered rust spots, and a certain amount of brown staining is present, which has been caused by the contact of the crust with the soil.

Internal Appearance and Structure.

The interior of the stone is of a uniformly light greyish-white appearance. Under a lens, white and light grey minerals can be seen, together with small, though well-distributed, metallic grains. In places small globules of a light bronzy troilite occur. The chondritic structure is hardly apparent to the naked eye, yet, very rarely, small spherical chondri do project. Darker grey patches, 3 or 4 mms. long, are also found here and there. The stone is traversed by very delicate black veins. In the large mass, eleven of these are present and at least seven of them are approximately parallel. They greatly resemble thin lines drawn by a hard lead pencil. The stone is a typical veined white chondrite, Cwa.

Perhaps the most interesting peculiarity of this stone is the large slickensided surface along which the piece A, and the missing

portion above it, have broken off. (See Pl. 11 and tracing.) Pl. 9 is a photograph of the stone with this part removed, and Pl. 10 a similar representation taken in a side light. This large slickensided surface is approximately square, and has an area of at least 240 sq. cms. It is not an exact plane, as the surface exhibits a little rolling. It must continue down and to the right, but there is no indication on the crust to show where the two meet. The slickensided surface is covered by a shining black, graphitic-looking substance, stained a dull red in places by rust. Its patchy appearance in the photographs is due to fragments sticking to the opposite sides after separation of the pieces. The parallel veins described in an earlier paragraph meet the slickenside plane at an angle of approximately 115°. Lines of weakness of this nature in a stone would naturally cause it to shatter along such a position on receiving a severe impact. It is curious to observe that the plane approximately coincides with what I believe to be the direction of flight.

An attempt was made to polish a surface of the piece numbered 259H, but owing to the friable character of the stone this was found to be practically impossible. On the smoothed surface, light grey chondri with rounded outlines can be seen. They have an average diameter of 1·75 mms., but occasionally reach 3 mms. The groundmass is white and is abundantly sprinkled with small sulphide and metallic grains. Light brown ferruginous stains, although usually found close to most of the metallic points, are more strongly in evidence along a black vein which traverses the specimen. This seems to prove that fine metallic particles are present in the vein.

Composition and Microstructure.

Under the microscope in thin sections, the chondri are not seen so well as they are on the smoothed surface of the stone. The microstructure as a whole is a confused, fine-granular one (see Pl. 15, fig. 1), with few chondri and fragments of chondri, not at all well differentiated from the rest of the groundmass.

Olivine and enstatite, in about equal quantities, are the principal silicates present. A monoclinic pyroxene which simulates the rhombic form, and is only to be distinguished by its inclined though low angle of extinction, occurs in small amounts. There are also a few clear grains which I take to be felspar.

Olivine and enstatite are also the chief minerals in the chondri. The former is found in the familiar monosomatic, polysomatic and ribbed forms. The latter, which is the more abundant of the two as far as the chondri are concerned, builds the usual fan-like radiating structures, which are often broken and imperfect, and also dense nearly crypto-crystalline masses. When these are examined under high powers they are s en to be composed of closely packed mosaics of small irregular particles of enstatite, with an occasional olivine granule. This structure is not like that of minerals crystalizing from a molten magma. Though not exactly analagous, similar structures have been observed by Merrill in the Hendersonville meteorite, though in this case the fragments are imbedded in a cement. Merrill is of opinion that the structure in the case of the American fall, is suggestive of a partial recrystallization of fine detrital material as seen in sundry metamorphic schists.[1]

Sometimes the radiated enstatite chondri are edged with small opaque grains of nickel-iron, troilite and specks of a black graphitic substance. One small olivine chondrus has a circular border of this mineral and a band of it down the centre, the two segments being filled in with minute olivine and enstatite grains. It also includes a few grains of metal and sulphide. Another unusual chondrule has rod-like olivine crystals set in an opaque black background, with a ragged irregular edge partly in contact with the granular olivine and enstatite of the groundmass and partly separated from it by a discontinuous zone of clear felspar grains. A similar form of polygonal outline is almost completely surrounded by a zone of water-clear felspar grains, the centre being opaque for the greater part, though speckled in places with minute transparent points. Intergrowths of olivine and enstatite also occur in the chondri. In one case two series of long rods of the former mineral meet at a wide angle with interpenetrating ends, and the spaces between them occupied by enstatite. The outlines of the chondri occasionally seem to indicate compression as they are flattened and not perfectly circular. The diameter of the best developed ones is approximately 1 mm., a few are larger, the great majority are smaller than this.

A microscope study of the groundmass in section revealed an exceedingly confused aggregate of olivine and enstatite grains and

[1] G. P. Merrill: Notes on the Composition and Structure of the Hendersonville, North Carolina, meteorite. *Proc., U. S. Nat. Mus.*, Vol. XXXII, pp. 79—82.

particles, interspersed with metallic nickel-iron, sulphide, and a few specks of a black, graphitic mineral. Occasionally there is a small, monoclinic pyroxene grain and a little felspar in small granules which exhibit bright grey polarization colours. The olivine grains are the largest, and although a few tend to show crystal outlines, the majority possess very irregular boundaries. Both the olivine and enstatite grains are much broken and fissured, though they are remarkably clear and free from clouding and inclusions. The larger grains are set in a finer matrix, which under high powers is resolved into the same minerals with the same confused arrangement. No true glass was observed. The enstatite of the groundmass sometimes builds flat tabular forms but is generally present as anhedral grains, rarely showing a few opaque inclusions.

The Opaque Minerals and Veins.

The opaque minerals are bright metallic nickel-iron, a light bronze sulphide and a black graphitic substance. They occur in rounded or irregular grains, separated or in juxtaposition, and also form larger irregular shapes. Sometimes the iron and sulphide grains have a kind of broken linear arrangement. The graphitic material has been seen to enclose portions of the fine granular groundmass, and it is evidently related to the substance which fills the fine veins. The latter pierce both groundmass and chondri indiscriminately. Sections cut especially for the study of the veins reveal complicated systems which branch in a most irregular way, enclosing the granular groundmass which does not appear to have suffered any alteration thereby. (See Pl. 15, figs. 3, 4.) The broader veins have a continuous inner lining of the opaque black graphitic mineral and are occasionally filled with sulphide and a little metal.

Petrographical Characters of the Crust.

The crust is usually ·8—·9 mms. thick and easily divisible into three zones. A well-defined outer layer approximately ·05 mms. thick. Inside this there is a clear layer composed of olivine and pyroxene grains, running into and not sharply differentiated from the third and thickest layer, which has a porous slaggy appearance, opaque for the greater part, but pierced with clear particles of the same crystals, olivine and enstatite, in places. In one section which was examined a large olivine crystal extends across the three

zones. It is bordered by a black opaque rim on the outside; in the second zone it is practically unaltered; in the third zone a black substance has developed and spread out from the cracks, leaving a network of clear unaltered material. The inner border of the third zone, where it joins the rest of the stone, is well differentiated and no alteration continues beyond it.

Description of 259 D.

This is a big irregular piece broken from a still larger mass. Its general appearance is shown in Pls. 12 and 13. Standing on its flat end it measures 19·5 cms. ($7\frac{3}{4}$ inches) long, 14 cms. ($5\frac{1}{2}$ inches) in maximum breadth, and 9·5 cms. ($3\frac{3}{4}$ inches) in maximum thickness. The flat end shows a few, broad, shallow depressions, some of which have been produced by the confluence of smaller pits. The opposite end is pointed, as the photograph shows, and is marked with shallow confluent pits separated by broad gently sloping ridges, and by a long funnel-shaped depression which is continued right across the stone. Where this meets the face shown in Pl. 13, it is 1 cm. across, but it widens out to over 4 cms. on the opposite side. It is bounded on the left by a sharp ridge, on the top of which there is a thickening of the crust. The opposite ridge is more strongly developed at the lower end only. The drift lines, when they possess any definite direction, cross the funnel. Below it the obtuse end sharply meets the face shown in Pl. 13. This is covered with large and small pits, the broadest and deepest of which on the lower part exhibit radial drift lines. The face meets the flat end in a right angle, the edge being quite sharp. A recent fracture of the stone, crossed by the typical thin black veins which distinguish this meteorite, is shown on the left of Pl. 13. The opposite side, not shown in the photographs, consists of larger and smaller faces running the entire length of the stone. Depressions do occur, but the majority of them are so broad and flattened out as to rather deserve the term undulations. The most interesting feature of this stone is the face shown in Fig. 12. It is a trans-atmospheric fracture over which a thin crust just developed before its impact with the earth. The irregularities of the fracture surface are barely crusted over and there was not sufficient time for a general smoothing down, or for the production of pits. The irregularities are accentuated in the photograph

by a light brown earth which adheres to the bottoms of some of them and which was undoubtedly picked up when the stone fell.

The crust.

As a whole the crust is not so dull as that of the larger specimen and it contains more numerous and bigger, brighter patches. The crust on the obtuse end and on the side shown in Pl. 13 has a lustrous black colour and is marked with drift lines, minute scoriations and small projecting blebs of fused metal. The crust of the flat end has developed a series of minute intersecting shrinkage cracks.

The interior.

The general appearance of the interior of the larger stone and this one is so much alike that a separate description is unnecessary. The veins have not the same parallel arrangement, producing rather an irregular network, while one large spherical chondrus, 9 mms. in diameter, projects from the fractured surface.

I have attempted to fit this meteorite, which is so evidently part of a much larger stone, on to the big one but it does not coincide with any of its fractures.

Brief Descriptions of Smaller Specimens.

259 E, is a corner piece partly covered with crust showing pits and depressions with very well-marked, radial, drift lines. Both the crust and interior are very rusted. Veining and slickensiding are present. See Pl. 14, fig. 4.

259 F, which is illustrated in Pl. 14, fig. 1, is partly covered with a smooth, rather shining, black crust. Its interior is not so rusted as that of the previous specimen, while thick and thin black veins and a small patch of slickensiding are present.

259 G, H, I and K, illustrated in Pl. 14, figs. 7, 5, 3 and 6, are interior fragments which present no unusual features. They might be bits broken from the interior of one of the larger pieces so far as appearances go, though neither they nor any of the other smaller pieces can be fitted together.

259 J, shewn in Pl. 14, fig. 2, is a small crusted fragment showing well-marked veins and troilite inclusions.

THE SHUPIYAN METEORITE.

In the summer of 1913, Mr. C. S. Middlemiss and the late Mr. H. S. Bion of the Geological Survey of India, noticed a meteorite in the

Srinagar Museum, Kashmir. When the desirability of having a specimen of every Indian fall on exhibition in the Imperial collection in Calcutta, was represented to the Durbar, His Highness the Maharajah of Kashmir kindly presented the piece which is the subject of this note. According to Mr. H. S. Bion, who was working in Kashmir at the time and who collected all the available information about the stone, there are two other pieces in the Srinagar Museum, a large one weighing approximately 4,650 gms. and a smaller piece about the same size as the one presented to the Calcutta collection. The latter weighs 294·5 gms. The large piece is said to be complete with no broken surfaces of any size, covered with a black crust showing thumb marks and lines of flow.[1] Mr. Bion believed that the Calcutta specimen was broken off the smaller piece.

The fall is reported to have taken place in May or June 1913, and from another source in April 1912, at Shupiyan, Lat. 74° 50′ : Long. 33° 43′, the specimens being collected by the local police officers and forwarded to the capital of the State. As Shupiyan is a large village with a post office, it is quite possible that the fall may not have occurred in the place itself but somewhere in the surrounding district. No further details of any kind are available.

Description of the Stone.

The general appearance of the specimen can be seen from the photograph, Pl. 16, fig. 1, which is about natural size. It measures 9·4 cms. in greatest length, 6 cms. in greatest breadth and 3 cms. in maximum thickness. It has a specific gravity of 3·670. The surfaces seen in the photograph are crusted, with the exception of the upper right hand corner. The undersurface shows the fracture where it was broken away from the larger mass. This surface though dirty and discoloured is sufficient to prove that the stone is a brecciated grey chondrite, Cgb. The interior is of a light ash-grey colour and the texture firm, exhibiting a few small chondri and rust spots. Since the photograph was taken, the piece has been cut in two for further study, and the smoothed surface of one of the sections clearly shows a fine brecciated structure together with abundant, small, shining grains of nickel-iron collected into a short metallic vein in one place. The chondri are of a darker

[1] After these notes were written Mr. Bion obtained photographs of the big piece. See Pls. 18 and 19.

shade than the groundmass. The large face shown in the shadow on the photograph is covered with a thin, dull black crust which adheres firmly to the interior. Under a lens the crust appears minutely roughened and traversed by a few cracks. The only pittings visible are those on the narrow side face. They consist of two large depressions, approximately 3 cms. in maximum diameter, made up of groups of smaller pits.

Microstructure of the Stone.

Thin sections prove that the stone is coarse-grained, with the chondri, which are mostly circular or nearly so, well differentiated from the groundmass. The latter consists of a coarse granular aggregate of the usual silicates, olivine and enstatite, in the majority of cases considerably rust stained. Irregular grains of nickel-iron are well distributed through the mass, while a few troilite granules and small amounts of a black amorphous substance are also present. Enstatite in felted masses of radiated needles, or minutely crystalline grains, with an occasional inclusion of an olivine granule, and olivine in the grate or barred variety are the common minerals of the chondri. One of the latter contains a tabular, porphyritic, enstatite crystal and a prism of olivine together with smaller orthorhombic pyroxene individuals. A polysomatic chondrule of olivine has the borders of each individual marked off by a narrow opaque zone of greyish inclusions. Fragments of broken chondri have been seen in the groundmass.

THE KAMSAGAR METEORITE.

The Kamsagar meteorite is reported to have fallen in Kamsagar village of the Channagiri taluk, Shimoga District, Mysore, about 1 P.M. on the 12th November 1902. It is stated that a rumbling noise was heard and that the meteorite was quite hot when picked up. With these remarks Dr. W. F. Smeeth, State Geologist in Mysore, forwarded the meteorite to the Geological Survey of India, a gift from the Government of His Highness the Maharajah of Mysore to the Calcutta collection. We have to record our indebtedness to Dr. Smeeth and our obligation to His Highness the Maharajah for this interesting and valuable donation.

The stone is an almost complete individual, of tetrahedral shape, broken into two pieces. It weighs 1,293 gms., and has

a specific gravity of 3·526. Resting on the rear face which is the uppermost one in Pl. 16, fig. 2, it measures 9·5 cms. in height, 12 cms. in breadth and 9·3 cms. in thickness, approximately. The general appearance of the stone is perfectly indicated by the photographs and need not be described. The angle of the tetrahedron which formed the front, and which points downwards in the photographs is replaced by a flattened face, marked with a few circular or elongated shallow pits. The crust on two of the tetrahedral faces, seen on the right in Pl. 17, figs. 1, 2, is fairly smooth. On the lateral face seen to the left in Pl. 17, fig. 1, the actual crust substance is smoother than elsewhere and there are four well-marked grooves running from the front to the rear of the stone. The crust is thin and dull black with minute, glossy black blebs. On the rear face it is thickened and rougher and has a more scoriaceous appearance. The usual minute shrinkage cracks are well developed and occasionally the crust assumes a brownish-black tinge, more particularly at the bottom of the grooves on the lateral face previously mentioned. The interior of the stone is light ash-grey in colour, with light chondri, fairly abundant specks of nickel-iron and some troilite. The latter mineral tends to congregate in patches, a large one of which is visible at the fracture. It is a typical intermediate chondrite with the formula Ci. It is of a firm texture and takes a good polish.

Composition and Microstructure.

The stone is composed of the silicates olivine and enstatite, with small quantities of a monoclinic pyroxene, and perhaps a little felspar. The other constituents are nickel-iron, troilite and grains of a black, opaque substance which may be of carbonaceous origin. Sections show that the structure as a whole is much coarser grained than that of the Kuttippuram fall. The separation of the chondri from the groundmass is usually evident enough, but not by any means as sharp as in the case of the Shupiyan stone. The chondri are in most cases filled with enstatite (see Pl. 15, fig. 2), in coarse or fine radiated crystal forms; sometimes a filling of cryptocrystalline grains of the same mineral occurs, or even a combination of both these structures. Olivine chondri are rarer, of more irregular outline, and smaller dimensions than the enstatite ones. They are either granular or ribbed and in the latter case appear to be built up of alternating layers of olivine and glass. In

the groundmass large porphyritic olivine crystals are common with pieces of chondri, set in a paste of fine silicate grains. Large crystals of enstatite with sharply-defined outlines also occur in the groundmass. Troilite is easily recognised by its bronzy lustre, and, though usually separated, it is sometimes in contact with the irregular nickel-iron grains. Staining of the silicates by decomposition of the nickel-iron is quite common. The black, amorphous substance is found in minute grains and larger irregular pieces, which in one instance includes small olivine grains. When in contact the sulphide sometimes partly envelopes the nickel-iron and thus appears to be secondary to it. Linear inclusions of the black, amorphous body were noticed in one olivine crystal. Minute olivine crystals are also included in the nickel-iron.

Crust sections show three zones: an outer opaque black layer, very thin, and generally removed in the preparation of the slide; an indefinite inner layer, opaque to translucent, containing the remains of silicate grains; and an inner opaque layer with a few, small slag-like pores containing silicates. The inner edge of the innermost layer, although irregular and crenulated, is sharply separated from the rest of the stone. Flattened blebs of nickel-iron occasionally penetrate the crust.

EXPLANATION OF PLATES.

PLATES 7-13.—The Kuttippuram meteorite.

PLATE 14, FIGURES 1-7.—Small fragments of the Kuttippuram meteorite.

PLATE 15, FIGURE 1.—Microphotograph of the granular groundmass of the Kuttippuram meteorite.

FIGURE 2.—Microphotograph of chondri in the Kamsagar meteorite.

FIGURES 3, 4.—Microphotographs showing the intricate vein system of the Kuttippuram meteorite.

PLATE 16, FIGURE 1.—The Shupiyan meteorite.

FIGURE 2.—The Kamsagar meteorite.

PLATE 17, FIGURE 1.—The Kamsagar meteorite.

FIGURE 2.—The Kamsagar meteorite.

PLATE 18.—The Shupiyan meteorite.

PLATE 19.—The Shupiyan meteorite.

PLATE 20.—Map of part of Malabar district, where meteoric stones fell on April 6th, 1914.

Photo. K. F. Watkinson. G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(Half natural size.)

Photo. K. F. Watkinson. G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(Half natural size.)

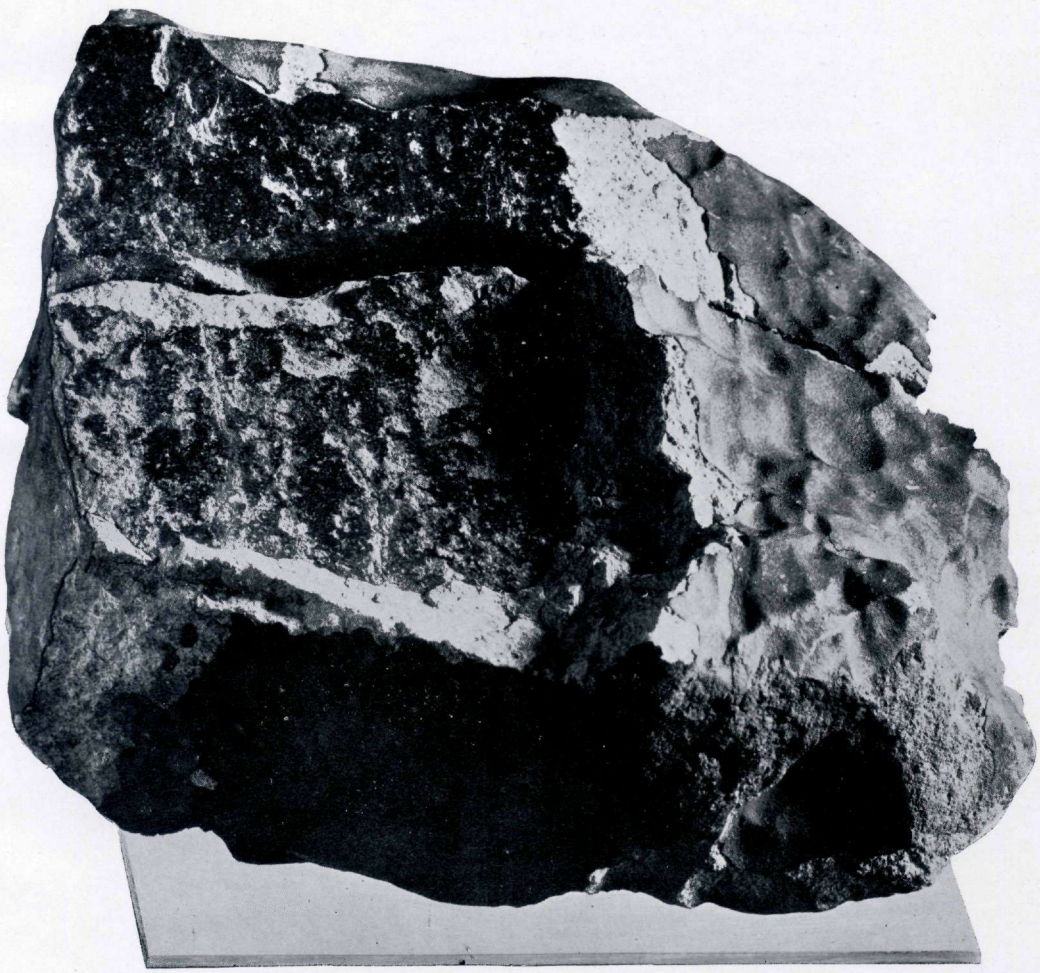


Photo K. F. WATKINSON.

G. S. I. CALCUTTA.

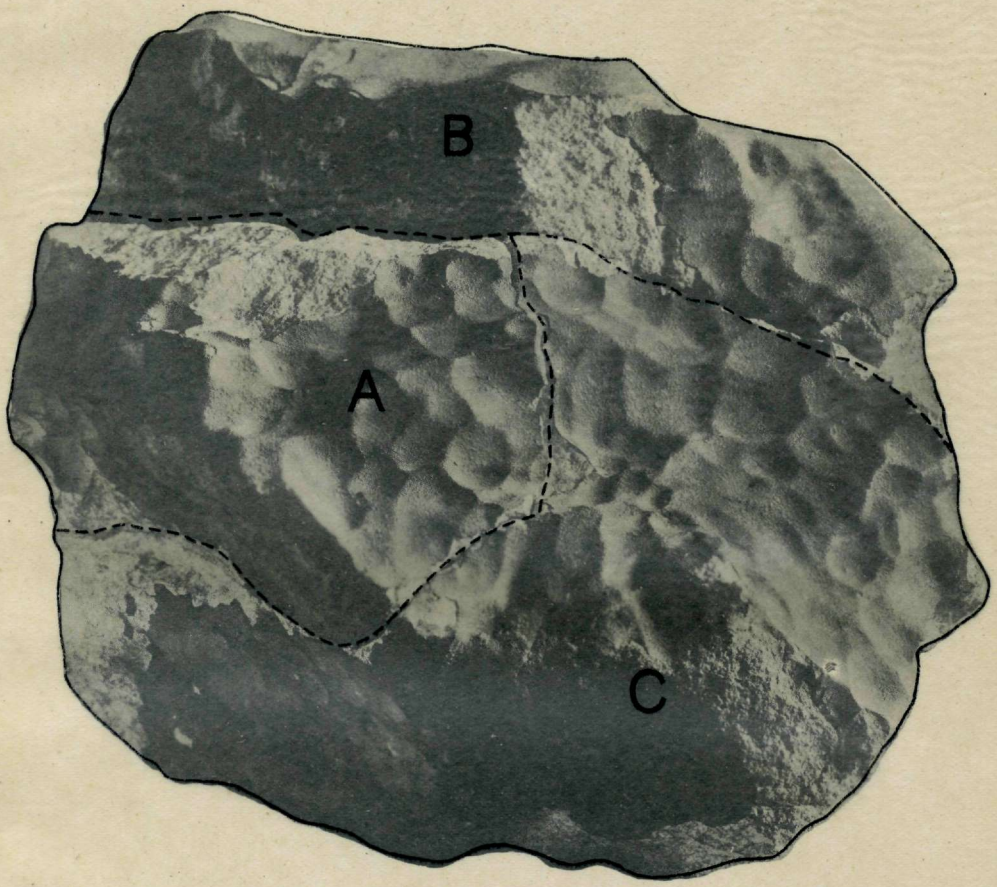
THE KUTTIPPURAM METEORITE.

(Half natural size.)

Photo. K. F. Watkinson. G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(Half natural size.)



Phcto. K. F. Watkinson.

G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(Half natural size.)

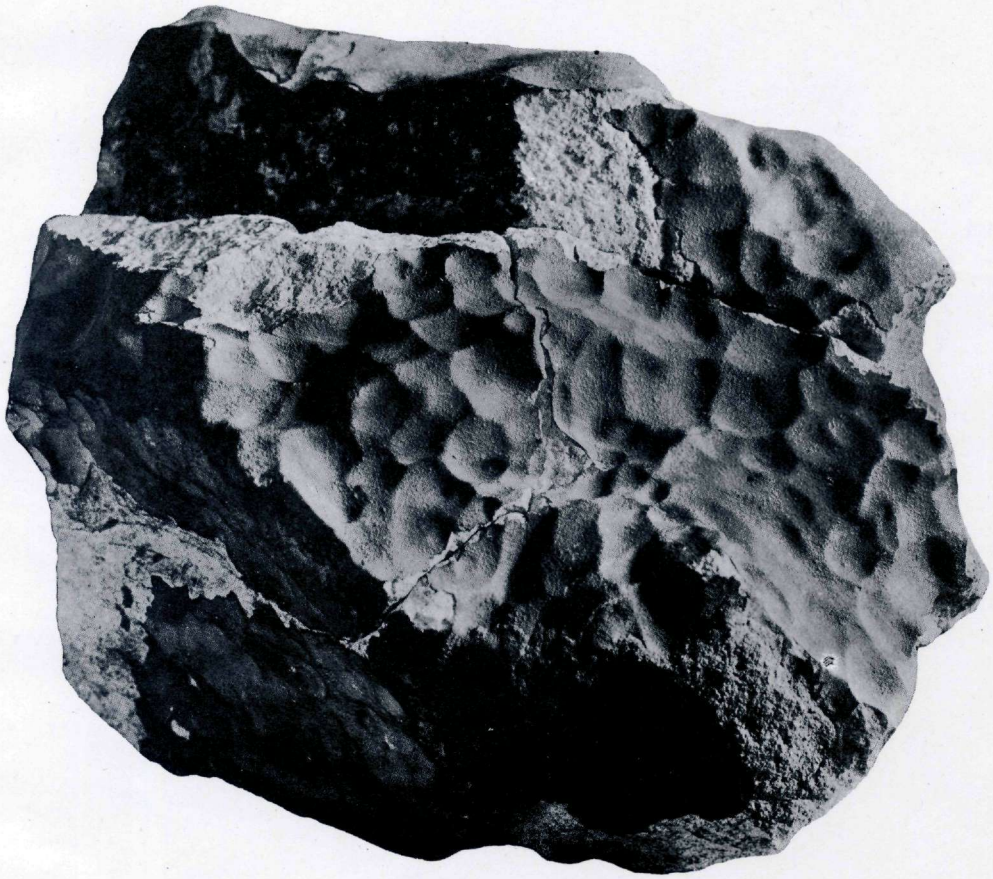


Photo. K. F. Watkinson.

G. S. I. Calcutta.

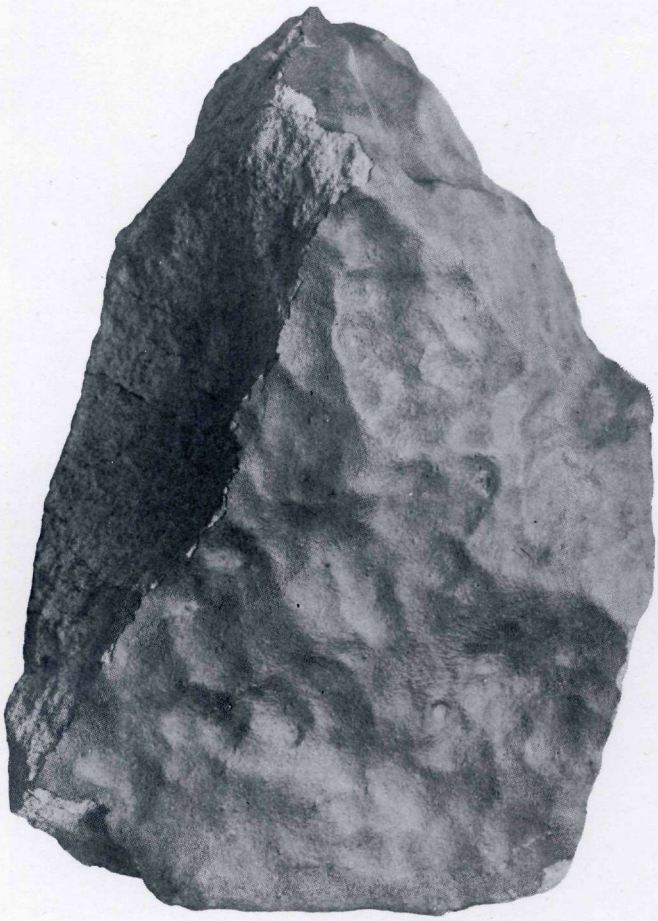
THE KUTTIPPURAM METEORITE.

(Half natural size.)

G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

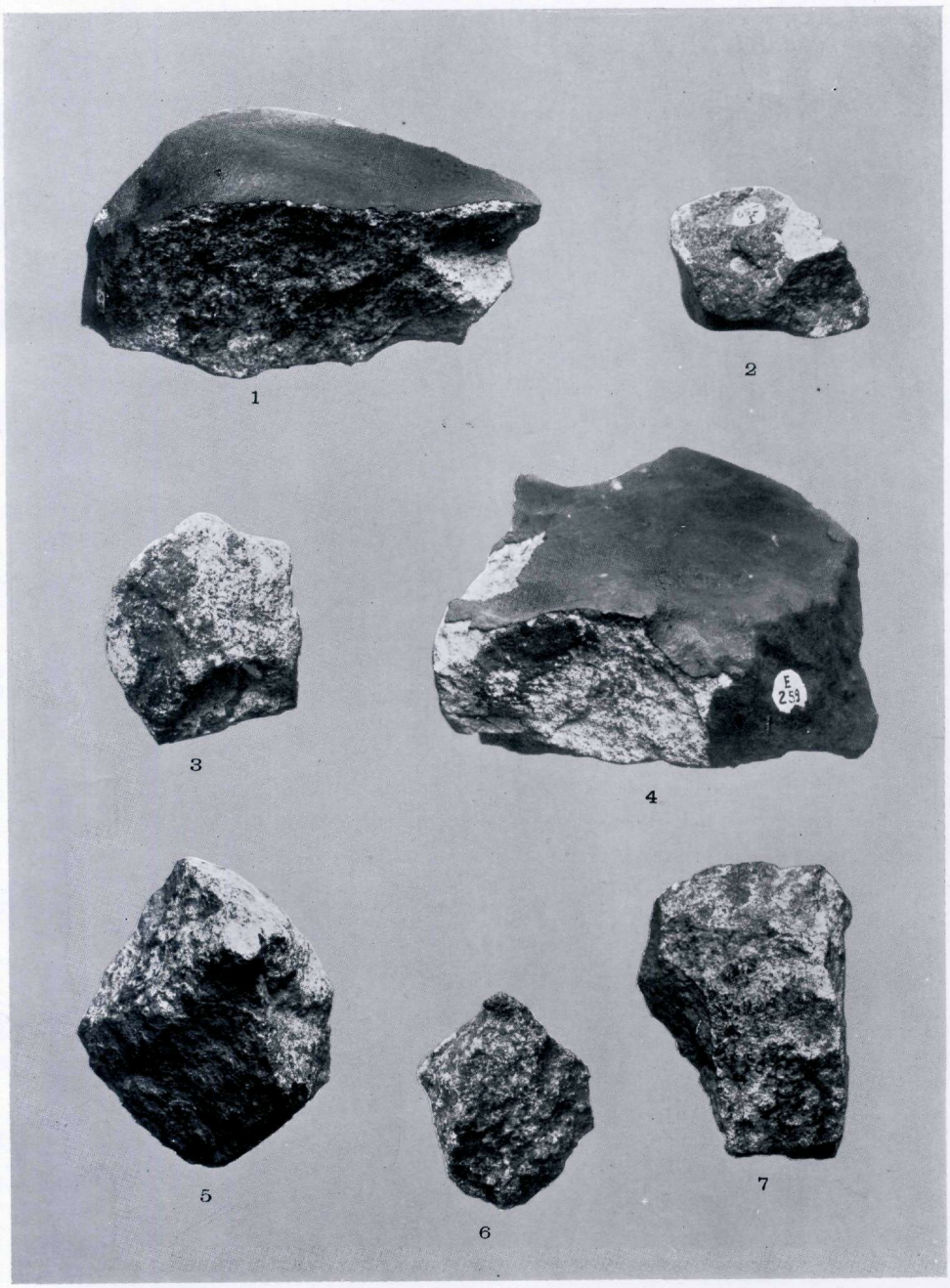
(Three-fourths natural size.)



G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(about two-thirds natural size.)



G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE,
small fragments.
($\frac{2}{3}$ natural size approx.)

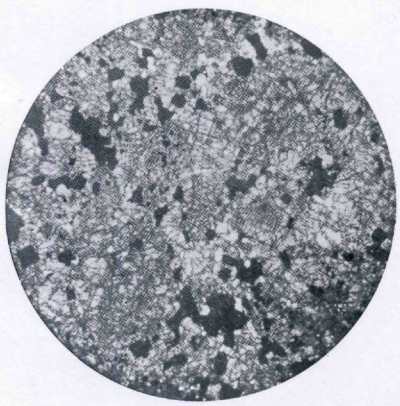


FIG. 1. THE GRANULAR GROUNDMASS OF THE KUTTIPPURAM METEORITE.

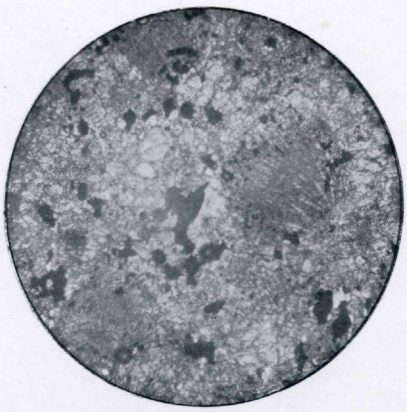


FIG. 2. CHONDRI IN THE KAMSAGAR METEORITE.

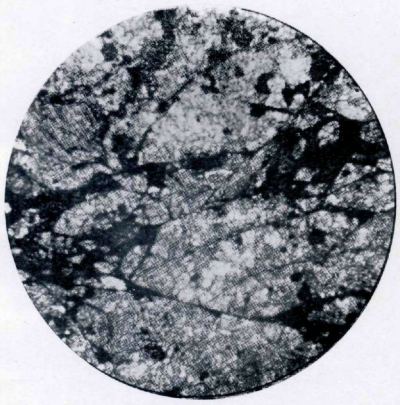


Photo. K. F. Watkinson.

FIG. 3.

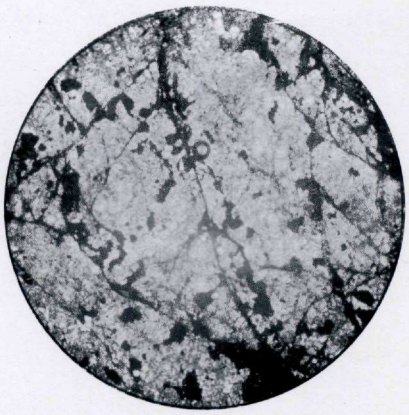


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FIG 4.

THE INTRICATE VEIN SYSTEM OF THE KUTTIPPURAM METEORITE.

(all figs. × 20, approx.)

Fig. 1. THE SHUPIYAN METEORITE.
(natural size.)

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Fig. 2. THE KAMSAGAR METEORITE.
(about four-fifths natural size.)

THE KAMSAGAR METEORITE,
(about four-fifths natural size.)

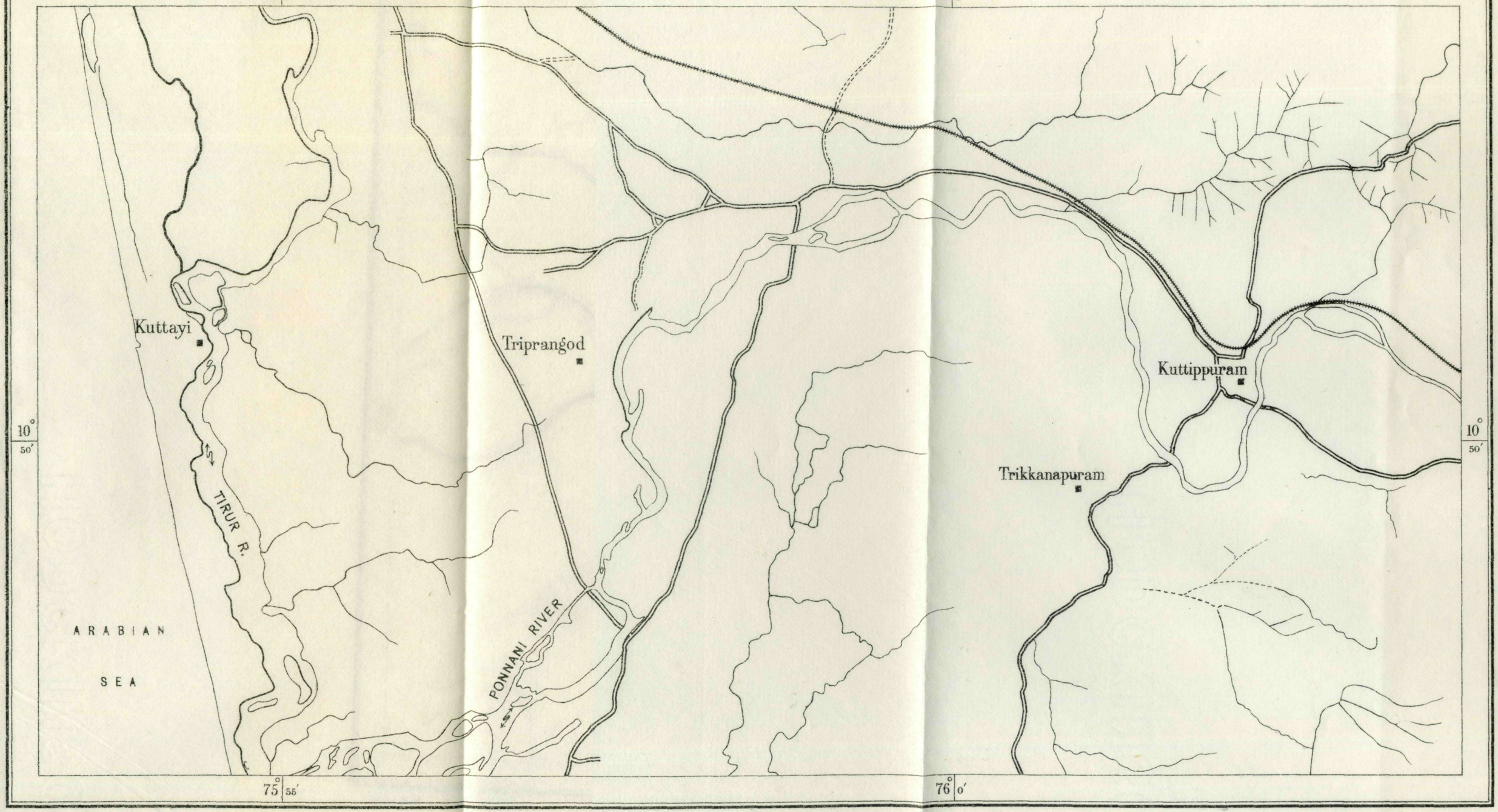
G. S. I. Calcutta.

G. S. I. Calcutta.

THE SHUPIYAN METEORITE.
in the Srinagar Museum, Kashmir.
(about three-fifths natural size.)

G. S. I. Calcutta.

THE SHUPIYAN METEORITE.
In the Srinagar Museum, Kashmir.
(about three-fifths natural size.)



Scale, 1 inch = 1 mile.

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Map of part of the MALABAR district showing the villages KUTTIPPURAM, TRIKKANAPURAM, TRIPRANGOD and KUTTAYI, where Meteoric stones fell on April 6th, 1914.

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