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The Tenham (Queensland) meteoritic shower of 1879.

(With Plates XIV–XVII.)

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[Read June 25, 1936.]

VERY little information can now be gathered about a remarkable shower of meteoric stones that fell many years ago in a remote district in south-west Queensland. Only a few scraps of information have appeared in print, and these are largely contradictory. However, some very tangible evidence arrived unexpectedly at the British Museum in 1935 in the form of a remarkable collection of 102 complete meteoric stones with a total weight of 107¾ lb. This material had been in the possession of Mr. Benjamin Dunstan,[1] formerly Government Geologist of Queensland, who had been collecting information of the fall with a view to writing up an account for publication. This unfortunately he never did, and much of the information is now lost. The specimens were offered to the British Museum by his widow, but they came along quite casually as an appendix to a collection of fossils. With their appearance of ugly, black, and shapeless stones, they had run a chance of being overlooked and perhaps eventually lost, as has so often happened with private collections. Now they are carefully preserved and exhibited, and it is proposed to keep the set intact as an example of a unique shower.

[1] Benjamin Dunstan (1864–1933). Obituary notices in Queensland Government Mining Journal, 1933, vol. 34, p. 276, with portrait; Min. Mag., 1936, vol. 24, p. 284.

Mrs. A. M. Dunstan has since carefully searched through her late husband's papers and has kindly sent a map, photographs, certificate of chemical analysis, and various scrappy notes. Dr. H. C. Richards, Professor of Geology and Mineralogy in the University of Queensland, has also kindly made various inquiries and supplied some details. An inquiry by post to the place of fall brought no reply. The fall happened so long ago that a special visit to the remote locality seemed too unpromising to be undertaken. Fortunately, however, I was later able to get in touch with Mr. Michael Hammond, who at the age of nearly 15 witnessed the fall in 1879. He has very kindly dictated his memories in a letter dated September 19, 1936, and this account clears up some, though not all, of the doubtful points.

Below is collected together such information that has already appeared in print.

'Queensland Times', published at Ipswich, Queensland, August, 1911:

The Tenham Meteorites. Interesting specimens.—One night in February, 1869, Mr. M. Hammond, owner of Tenham Station, was camped with his brothers, whilst mustering cattle, near the junction of Cooper and Kyabra Creeks in south-west Queensland. The darkness was suddenly illuminated as if by a lightning flash, a noise like a rushing motor-car was heard, and upon looking up the brothers beheld a brilliant meteoric shower passing from west to east. Soon afterwards the locality in which the meteorites fell was found, and from time to time a number of specimens were collected, the largest weighing 130 lb.

Twelve months ago Mr. Hammond told Mr. R. A. Wearne, B.A., Principal of the Ipswich Technical College, about these meteorites, and upon being urged to give publicity to such an important discovery, he promised to bring them to Brisbane at the first opportunity. On the 8th of July ultimo Mr. Hammond fulfilled his promise and brought a number of the meteoric fragments with him to Brisbane. A photo of the meteorites was taken at the Wiley Studio, and the collection was then handed to Mr. Wearne for distribution. Mr. Wearne then interviewed Mr. MacDonald of the University Department of Mines and Mr. Dunstan, Government Geologist, and arranged to have analyses made of these most interesting extra-terrestrial rocks. The complete analyses are not yet to hand, but preliminary tests show that the Tenham meteorites are of the stony variety, but contain a somewhat large percentage of nickel and iron. Small stony like enclosures can be seen between the bright metallic patches upon a polished surface. The specific gravity of the specimens averages about 3·5.

Queensland Government Mining Journal, August 15, 1913, vol. 14, p. 404:

Queensland Meteorites.—The Mines Department has recently come into possession, through Mr. A. R. Wearne, of Ipswich, of a number of meteorites that fell in Western Queensland in 1879. They were presented by Mr. M. Hammond, of Tenham Station, Cooper's Creek, who lately brought from that place a bagful of the specimens. Mr. Hammond, thirty-four years ago [i.e. 1879], was an eye-witness of the storm during which these meteorites fell, when he, with his brother, was one night watching cattle at the junction of Kyabra and Cooper's Creeks, near Windorah. The storm covered an area of about half a mile, and some of the meteorites descended on a ridge of the adjacent range, and some on the plains. On the following day some of them were found on the surface and others embedded 2 ft. or more in the ground, the largest discovered being about 130 lb. in weight. They all have a metallic appearance. The Government Geologist (Mr. B. Dunstan) intends to thoroughly examine and have assays made of the specimens in his possession and publish a full description of them later. He states that they contain nickel-iron, the proportion of the former being large. Cobalt and manganese gave no reactions, so that if these metals are present they will be only in minute traces.

B. Dunstan, Queensland Mineral Index and Guide. Queensland Geological Survey, publication no. 241, 1913, p. 718:

Meteorites.—Tenham stones (15). Weights vary from 20 to 5241 grammes. *Loc.* Tenham Station, junction of Cooper and Kyabra Creeks, Western Queensland. *Lat.* 25° 30′ S., *Long.* 142° 40′ E. *Compo.* Mostly silicates, with a few per cent. of nickel-iron. *Sp. gr.*, 3·4. *Fall*, about Feb. 1879, between 2 and 3 o'clock in the morning, and apparently coming from west to east. *Observer*, P. Hammond, of Tenham Station. *Collections*: Geol. Survey Museum and Queensland University.

G. T. Prior, Appendix to the Catalogue of Meteorites, British Museum, London, 1927, p. 43:

Tenham, South Gregory, Queensland. Stone. Fifteen stones fell (?) in Lat. 25° 30′ S., Long. 142° 40′ E. (G. W. Card's MS. list of Australian meteorites, in Min. Dept., British Museum).

This information given in a letter from Mr. G. W. Card in 1925 was evidently derived from Dunstan's publication of 1913, which had escaped Dr. Prior's notice. There is no mention of the Tenham meteorite in Dr. C. Anderson's list of 1913.[1] Copying from Prior, it is listed by H. H. Nininger in 'Our stone-pelted planet' (Boston and New York, 1933, p. 231).

H. C. Richards in 1930 in his description of the Glenormiston siderite gives a list of known Queensland meteorites; Mem. Queensland Museum, 1930, vol. 10, p. 66 [Min. Abstr., vol. 4, p. 426]:

An undescribed collection of 102 fragments of various sizes and aerolitic in character which were seen to fall on Tenham Station near the junction of Cooper and Kyabra Creeks, in south-western Queensland, in the year 1869, by Mr. M. Hammond and his brothers.

I have had an opportunity of discussing with Professor Richards this discrepancy in the record of the date of fall. He was personally

[1] C. Anderson, A catalogue and bibliography of Australian meteorites. Rec. Australian Museum, 1913, vol. 10, pp. 53–76.

acquainted with the late R. A. Wearne, who wrote the newspaper article in 1911, and he thinks that 1869 must be the correct date. On the other hand, B. Dunstan in 1913 gave 1879, and this date also occurs in his MS. notes, which Mrs. Dunstan thinks must be correct. In the library of the London offices of the Agent-General for Queensland I have been able to trace the history of the Hammond family. Michael Hammond was born on May 1, 1864, the youngest son of James Hammond, who took up his first block of land in 1869, naming it Tenham after his birth-place (Teynham) in Kent, England. Michael afterwards became the owner of the Tenham Station of 350 square miles, which at one time was the farthest west white settlement in south-west Queensland. It his letters of September 14 and 19, 1936, Mr. Michael Hammond is quite definite about the year being 1879 (and not 1869), but he now gives the month as either March or April.

The Tenham head station or homestead is situated on the left bank of the Kyabra Creek, thirty miles SE. of the post-town of Windorah in Gregory South district. It is at lat. 25° 44′ S., long. 142° 57′ E. On a tracing, evidently from the pastoral map (2 miles to 1 inch) Mr. Dunstan marked approximately the area over which meteoric stones were found. This track (text-fig. 1) has a length of 41 miles and a width of about 3 miles. Its western end is at about 25° 30′ S., 142° 40′ E. (the latitude and longitude given by Dunstan in 1913, and repeated by Prior). On the Map of Queensland (16 miles to 1 inch) issued by the Surveyor-General in 1895, and used for the Geological Map in 1899, this locality is in Gordon County. At a later date there was a further subdivision of counties (see, e.g., plate 18 in Dunstan's Mineral Index, 1913; and 'The Times' Atlas, 1922); and Tenham homestead was then in Kyabra county, while the meteorite track was mainly in Thunda county, only just touching Kyabra and Grey counties. These county divisions have again now become obsolete. The locality is now in the Land Agent district of Charleville, and the post-town is Quilpie.

Mr. M. Hammond also tells me that the boundaries have been greatly changed. In 1901 with his brother-in-law he took up a holding 'Ingella' in the same district. As most of the meteorites fell on this area he now wishes to change the name of the fall from 'Tenham' to 'Ingella'. But as the latter name was not on the map in 1879 (nor on any map now available to me) such a change is clearly not advisable.

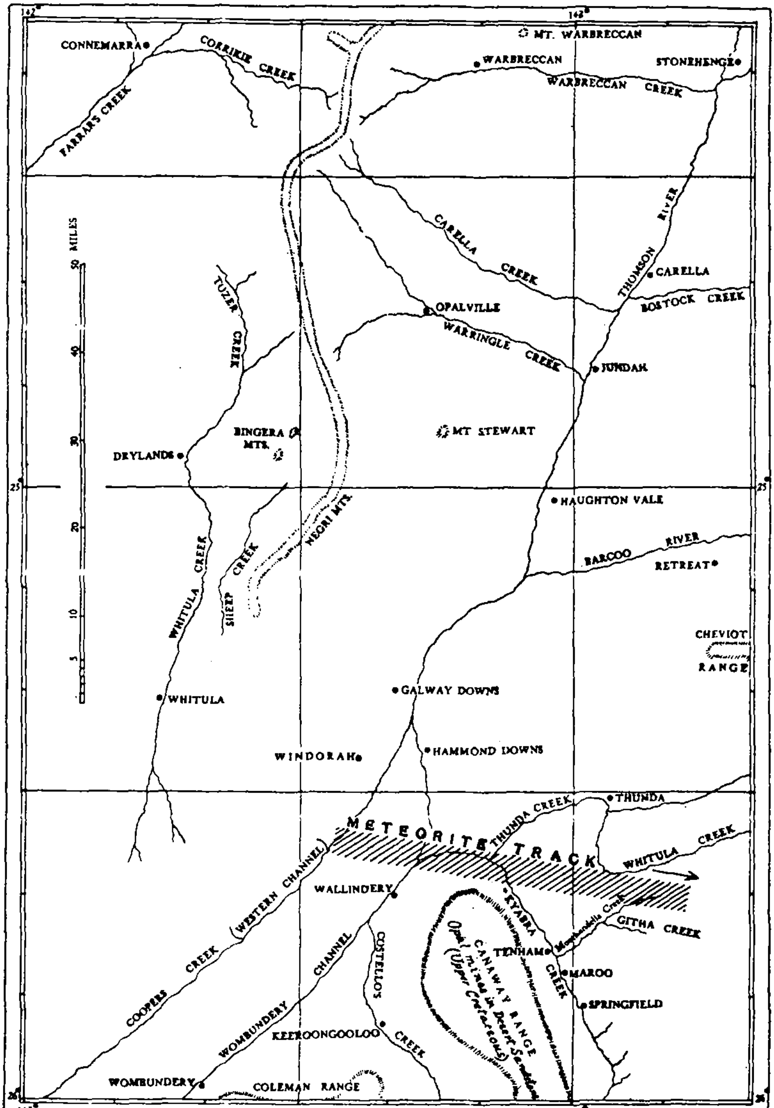


FIG. 1. Sketch-map of locality of the Tenham meteoritic shower, south-west Queensland. The 'meteorite track', about 41 miles in length, is copied from B. Dunstan's sketch (1913) and is open to some doubt. Mr. M. Hammond (1936) gives the length as approximately 12 miles.

There are also serious discrepancies in the statements of the number and weights of the stones. Wearne (1911) says a 'number of specimens', and gives the weight of the largest as 130 lb. Dunstan (1913) mentions fifteen stones ranging in weight from 20 to 5241 grams. Richards (1930) mentions 102 'fragments'. A MS. note dated June 27, 1913, gives a list of Dunstan's fifteen specimens with their weights and specific gravities, as follows:

No.	Grams.	Sp. gr.
1.	5241·9	3·46
2.	5146·8	3·40
3.	3637·0	3·40
4.	1964·1	3·48
5.	1840·0	3·39
6.	889·1	3·39
7.	714·7	3·39
8.	335·0	3·37
9.	221·2	3·41
10.	207·3	3·37
11.	82·4	3·41
12.	61·9	3·44
13.	60·6	3·42
14.	58·2	3·38
15.	20·7	3·41

Some of these pieces were sliced and polished, and used for making micro-sections; and the weights do not quite correspond with those given in the longer list below. Further, the values for the specific gravities were in several cases later corrected, and the work was evidently done by an inexperienced assistant.

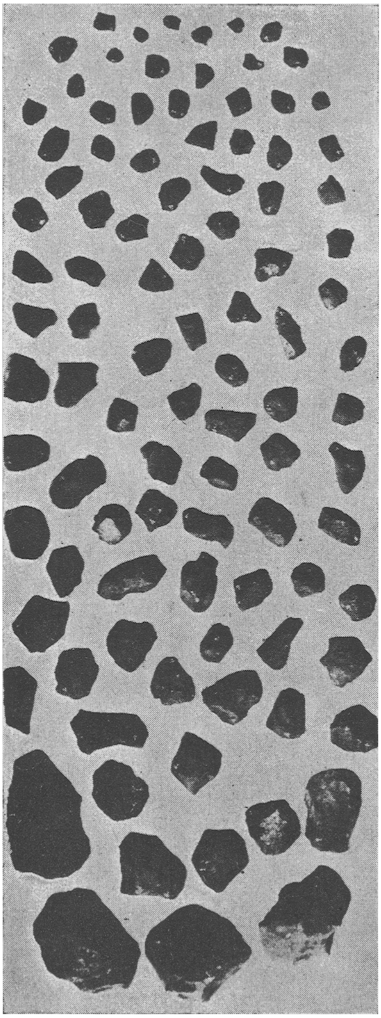


FIG. 2. 98 stones of the Tenham meteoritic shower. × $\frac{1}{10}$.

Early in 1935, 98 stones (text-fig. 2), nearly all of them complete individuals, were received at the British Museum from Mrs. Dunstan. Each of them is marked with a painted number T1 to T100. Nos. 5 and 13 are missing, although these appear in the photographs (unfortunately not dated) taken by the Department of Agriculture and Stock at Brisbane (pls. XIV–XVI). Later on in 1935 Mrs. Dunstan found and sent four more small specimens, which are entered below under nos. 101–104. These 102 specimens are listed below with their weights as determined by

Tenham meteorites in the British Museum collection.

No.	Grams.	No.	Grams.	No.	Grams.	No.	Grams.
T 1	5245	T 27	466	T 53	218	T 79	118·7
2	5160	28	457	54	213·5	80	110
3	4290	29	447	55	211	81	111·7
4	3645	30	440	56	206·2	82	98·7
—	—	31	426·2	57	204	83	95
6	1903	32	414·5	58	203	84	88·7
7	1497	33	404	59	192	85	88·2
8	1124	34	399·5	60	191·5	86	87·9
9	997	35	366·7	61	188	87	77·4
10	889	36	365	62	184·5	88	77·4
11	766	37	351	63	176·5	89	68·2
12	734	38	335	64	173	90	58·4
—	—	39	327·5	65	178·5	91	50
14	736·5	40	312	66	167·7	92	45·5
15	717·5	41	311	67	167	93	43·7
16	714	42	307	68	165·2	94	43
17	633	43	307·2	69	162·5	95	37
18	637	44	275·5	70	153	96	30·9
19	636	45	267·7	71	129·2	97	30
20	619	46	258	72	140	98	25·2
21	619·4	47	249·5	73	140·5	99	20·7
22	589·5	48	246·7	74	138	100	17·5
23	518·5	49	241·5	75	128·9	101	98·7
24	511·5	50	234	76	124·8	102	88·7
25	468·5	51	228	77	124·7	103	77·4
26	502·7	52	226	78	118·2	104	77·4

Mr. A. F. J. May of the Mineral Department of the British Museum. The total weight amounts to 48,982 grams = $107\frac{3}{4}$ lb. The largest is 5245 grams = $11\frac{1}{2}$ lb.

The missing no. 5 to judge from the photographs (pl. XIV) is much smaller than no. 4 and no bigger than no. 6, and it probably is no. 5 in Dunstan's list of specific gravities, with a weight of 1840 grams. The missing no. 13 must have weighed about 735 grams, to judge from the sequence in the list. The total weight of the 104 stones would then be 51,557 grams = $113\frac{1}{2}$ lb.

A chemical analysis of the material was made in the Government

Chemical Laboratory at Brisbane, and fortunately the certificate, dated September 30, 1913, has been preserved. The material was crushed and sieved through an 80-mesh sieve and separate analyses were made of the coarser and finer portions. These two portions, as shown by the original figures under I and II. correspond roughly to the metallic and silicate portions of the meteorite. They weighed

Analysis of the Tenham meteorite (I–III).

	I.	II.		III.	IV.	V.
Fe ...	83·8	20·2	Fe	7·43	7·70	6·03
Ni ...	11·8	0·9	Ni	1·05	1·19	1·06
Co ...	1·2	trace	Co ...	0·02	0·04	0·08
Mn ...	—	0·4	FeS ...	5·0	6·79	6·40
SiO_2 ...	1·5	38·4	SiO_2 ...	37·8	39·64	39·86
Al_2O_3 ...	—	1·9	Al_2O_3 ...	1·9	2·40	1·71
MgO ...	—	25·3	FeO ...	13·6	13·99	12·84
CaO ...	—	1·9	MnO ...	0·5	trace	0·39
S	—	1·8	MgO ...	24·9	24·71	24·75
P	—	0·3	CaO ...	1·9	1·79	2·01
&c. ...	1·7	8·9	P_2O_5 ...	0·7	0·25	0·26
			&c. ...	5·2	1·90	4·67
	100·0	100·0		100·0	100·40	100·06

I–III. Tenham, SW. Queensland. Analysis made in the Government Chemical Laboratory, Brisbane. I, coarse portion, 0·46 gram. II, fine portion, 30 grams. The difference ('&c.') stated as 'oxygen and undetermined'. Ti, Cr, As nil. III, calculated bulk composition.

IV. Baroti, India. '&c.' includes TiO_2 0·16, Fe_2O_3 0·44, Cr_2O_3 0·18, Na_2O 0·91, K_2O 0·04, H_2O 0·17. G. T. Prior, Min. Mag., 1914, vol. 17, p. 134, and 1913, vol. 17, p. 26.

V. Warbreccan, SW. Queensland. '&c.' includes TiO_2 0·21, Fe_2O_3 2·15, Cr_2O_3 0·41, NiO 0·12, Na_2O 0·92, K_2O 0·06, H_2O 0·80. G. T. Prior, Min. Mag., 1916, vol. 18, p. 8.

0·46 and 30 grams respectively, which, if the separation had been complete, would correspond to a metallic content of 1·5 %. The nickel 0·9 % shown in column II, however, no doubt belongs to the metallic portion. With this assumption, and taking the ratio of Fe : Ni = 7·1 : 1 from a column I, the bulk composition has been calculated as given under III. The molecular ratio MgO : FeO = 3·3 : 1. This composition is strikingly similar to those of the Baroti (India, fell September 15, 1910) and Warbreccan (SW. Queensland) meteoric stones, which are quoted for comparison.

The general appearance of the stones is well illustrated in pls. XIV–XVI, and text-fig. 3. The shapes are irregular, and the surfaces smooth without any very prominent 'thumb-marks'. Except for four specimens that have been cut and polished, they are all complete stones with the crust broken in only a few small places. The surface sculpturing gives no definite indications of orientation of the stones during their flight. The colour varies from black to reddish-brown. A note by Mr. Dunstan states that this difference in colour is due to the stones

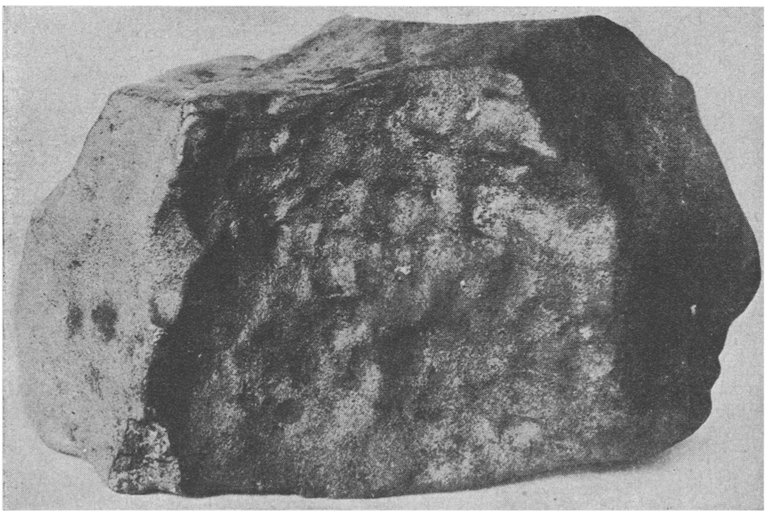


FIG. 3. Tenham meteorite. The second largest stone (T 2); weight 5160 grams. ½ nat. size.

lying in black or red soil. But more probably the brown colour is due to oxidation. The specific gravity of one stone weighing 43·1281 grams was determined by Mr. S. E. Ellis in the Mineral Department of the British Museum to be 3·46. Mr. Dunstan's values listed above range from 3·37 to 3·48.

Polished surfaces show a sprinkling of small white metallic particles of nickel-iron with irregular outlines (pl. XVII, fig. 2), which occupy less than 5 % of the total area, but varying in amount in different stones. Small bronze-coloured grains of troilite are less frequent. The stony portion (pl. XVII, fig. 1) shows much brecciation, with white and pale yellow fragments representing broken chondrules set in a darker grey ground. Well-defined chondrules up to 5 mm. diameter are sometimes seen. On some sections narrow black veins are seen. These cut through both the matrix and the broken chondrules.

Micro-sections show much fragmentary and iron-stained material, with larger fissured crystals of olivine, and a few broken chondrules of fibrous enstatite and of porphyritic olivine. The black crust is irregular, with a maximum thickness of ½ mm. This is the commonest type of meteoric stone, and may be described as a brecciated and veined enstatite-olivine-chondrite; and the chemical analysis shows it to be of the Baroti type.

This remarkable series of specimens from the Tenham shower is the best and most complete example of a meteoritic shower in the British Museum collection of meteorites. The Pultusk (Poland) shower of January 30, 1868, when it is estimated that a hundred thousand stones fell, is represented in the collection by 72 stones with a total weight of 18,188 grams, the largest stone weighing 9095 grams (20 lb.). The Holbrook (Arizona) shower of July 19, 1912, when fourteen thousand stones fell, is represented by 99 stones with a total weight of 7783 grams, the largest weighing 3120½ grams and the smallest 0·329 gram. The Tenham shower is represented by 102 stones with a total weight of 48,982 grams (107¾ lb.).

A large stone of 130 lb., mentioned in 1911 and 1913, is again referred to in Mr. M. Hammond's letter of 1936. He says: 'I intended presenting two large meteorites, but unfortunately the largest mass was misappropriated from my possession by an opal buyer, by name R. Pope. The weight of this stone should have exceeded 140 lb.' Now, it is a most remarkable coincidence that two large stones, said to be from this same region, were acquired for the British Museum collection in 1905 through the well-known opal dealer T. C. Wollaston of Adelaide, who had them from R. Pope. These are the 'Warbreccan' stones weighing 69 and 64 lb. (31,593 and 29,140 grams), and also a small stone of about 1 lb. (443 grams). The description of these stones was delayed until 1916, partly because the information supplied with them was not altogether convincing. They were stated to have been found in 1904 on 'Warbreccan run'. Dr. G. T. Prior gave the locality, first as 'about 40 miles west of Windorah',[1] and later as 'about 40 miles NW. of Windorah'.[2] The former statement was taken from a rough sketch-map supplied by R. Pope; and the latter appears to have been based on the position of

[1] G. T. Prior, Min. Mag., 1916, vol. 18, p. 7.

[2] G. T. Prior, Catalogue of Meteorites, British Museum, 1923, p. 189.

'Warbreccan run' as marked on Map 15 of the Queensland volume of 'The new Atlas of Australia' by John Sands, Sydney, 1886.

'Warbreccan run' I find on no later map. In the early days of settlement it no doubt extended for an indefinite distance from the Warbreccan head station (cf. this vol., p. 14). On the Surveyor-General's maps of 1885 and 1895 Warbreccan is in Musgrave county, Mitchell district, at about 80 miles north by east of Windorah (text-fig. 1). Later maps (B. Dunstan, 1913; 'The Times' Atlas, 1922) show it in Warbreccan county. A point 40 miles west of Windorah lies between Whitula and Canterbury, and one 40 miles NW. of Windorah is near Drylands; all of which are on the 1885 and 1895 maps. This rather suggests that in 1904 R. Pope was inventing a story. An interesting sidelight in his letters is that he failed to find a 'big fellow' said by the aboriginals to be covered by flood water. Mr. M. Hammond (1936) also mentions a gigantic stone, 'too large to move' seen by the aboriginals in a swampy area about two miles from the present Ingella homestead. This he was never able to find.

The three Warbreccan[1] stones have the same general appearance as those of the large series of Tenham stones. In thin sections under the microscope they show the same characters, and the chemical analyses (p. 444) are essentially identical. There seems, therefore, little doubt that the 'Warbreccan' stones really belong to the Tenham shower. The only difficulty is that there are two stones weighing together 133 lb., instead of one of about 130 lb.; but this may be due to a lapse of memory on Mr. Hammond's part, with perhaps some confusion with the Thunda siderite of 137 lb. found in the same district (p. 451). Mr. Hammond informs me that he still (1936) has over 100 lb. of the Tenham stones in his possession. Including these and the Warbreccan stones (134 lb.), the total weight of stones recovered from the Tenham shower is about 350 lb. In this very thinly populated district it is probable that many more stones were never found. The total weight of stones preserved from the Pultusk (Poland) shower is given by Wülfing[2] as 200,932 grams (422 lb.).

Meteoritic showers.

Showers of meteoric stones have evidently been produced by the breaking up of a single large mass of friable material in the earth's atmosphere. While showers of usually only a few stones are not

[1] G. T. Prior, Min. Mag., 1916, vol. 18, plates I and II.
[2] E. A. Wülfing, Die Meteoriten in Sammlungen. Tübingen, 1897, p. 287.

infrequent, showers of siderites are very exceptional. Striking examples are those of Bethany (Gibeon) in South-West Africa, where 51 masses of meteoric iron with a total weight of 15 tons have been collected; and Henbury (Central Australia) where thirteen craters were formed.[1] A shower of three small siderites fell at Samelia in Rajputana in 1921. Siderites are generally larger than stones, and in several cases very much larger. The largest recorded single stone is Paragould (Arkansas, fell 1930) of 820 lb.; and the largest in the British Museum collection is Parnallee (Madras, fell 1857) of 133½ lb. The record size for a siderite is the Hoba (South-West Africa), estimated to weigh 60 metric tons, or, allowing for the enveloping iron-shale, originally nearly a hundred tons.[2] Being fragile and friable, stones are more liable to be broken than the tough and coherent siderites.

A meteorite entering the earth's atmosphere with a relative velocity of 20 to 40 or more miles per second meets with an enormous air resistance, and with the friction a high temperature is soon developed. The surface is melted, and this molten material will be swept off in the rush of air as quickly as it is formed; thus producing the trail of shooting stars and fireballs. As shown by the very narrow heating zone, even in the better conducting siderites,[3] this ablation of material must have proceeded as fast as the conduction of heat into the interior of the mass. Small masses are entirely dissipated in the atmosphere, to fall as cosmic dust. Only siderites can burn, since the stones (apart from the metal and troilite they contain) are already fully oxidized as silicates. The silicates would no doubt be vaporized, to condense again as dust. Only a really large mass could leave a remnant to reach the ground, and this would probably be but a small fraction of the original size.

Incandescence may commence at a height of about a hundred miles. As denser layers of the atmosphere are reached the increasing air pressure is sufficient to burst a friable stony mass, which may already have been cracked by the sudden change in temperature. The several fragments, scattered by the explosion, continue on their course. With the greater surface now exposed still more material is swept off, and a complete crust is formed on each piece. With detonating fireballs

[1] The numerous smaller masses of iron found scattered around the Henbury craters and around the single crater at Canyon Diablo, Arizona, resulted from the breaking up of the larger mass by the gaseous explosion that formed the crater.

[2] L. J. Spencer, Min. Mag., 1932, vol. 23, p. 7.

[3] Ibid., 1935, vol. 24, p. 16.

more than one detonation is often heard; there being second or third bursts as the fragments from the first burst reach denser layers of air. These several bursts may sometimes be traced in the character of the crust on the different surfaces of a fallen stone. The latest fractured surfaces may be only just singed, indicating that the velocity of the mass had been so checked by the air resistance that a correspondingly

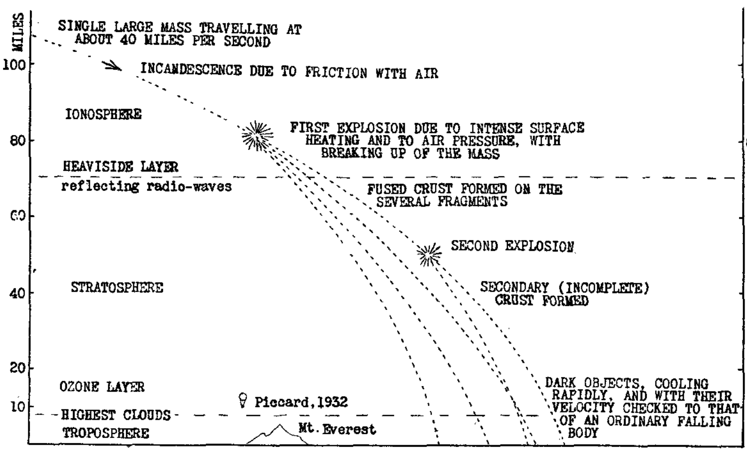


Fig. 4. Diagram of the fall of a shower of meteorites.

Owing to air resistance and the force of gravity, the smaller stones fall first and the larger ones carry farther.

lower temperature was developed. A stone of the Beardsley (Kansas, fell 1929) shower in the British Museum collection shows four stages of the crust, indicating that there were three explosions during the flight of the meteorite through the earth's atmosphere.[1]

Air resistance has operated to such an extent that with ordinary meteorites their initial velocity has been almost completely eliminated, the energy of motion being transformed into heat. Heat is then no longer generated, and for the last few miles the stones fall under the influence of gravity with a maximum velocity of an ordinary falling body—about 70 metres per second, but depending on the size and density of the body. The surface is quickly cooled, and the last-formed molten material consolidates as a thin layer of glass, forming the well-known crust. The air resistance is proportional to the square of the radius of the body, while the mass and its momentum are

[1] Min. Abstr., 1933, vol. 5, p. 300.

proportional to the cube of the radius. Smaller masses will therefore be relatively more checked than larger masses. In a shower the smaller masses will reach the ground first and in a more nearly vertical direction, while the larger masses will carry farther and in a direction more inclined to the vertical. This is illustrated diagrammatically in text-fig. 4.

Unfortunately, in the case of the Tenham shower which, according to B. Dunstan, extended over 41 miles of ground in the direction of flight (text-fig. 1), there is no record of the distribution of the stones. This range of 41 miles is considerably greater than is usually the case, but it is not beyond doubt, for M. Hammond (1936) gives the length of the track as 12 miles. The tracks of showers that have been previously listed are only 3 to 16 miles long;[1] but these have not included the Futtehpur (India, fell 1822) shower, which ranged for some 70 miles.[2]

It has sometimes been suggested that craters supposed to be meteorite craters, but associated with which no meteoritic material has been found, might have been formed by the fall of a large mass of meteoric stone, which would itself be broken into fragments and pulverized, to be soon afterwards decomposed by weathering. Such a suggestion has been made in the case of the famous Siberian fall of June 30, 1908, where no meteoritic material has yet been detected. But it is evident that any such large meteoric stone would have already been broken up in the earth's atmosphere and its energy distributed and dissipated in a shower of smaller masses. With a large mass of iron the matter is different. This is not so easily broken up in the atmosphere, and with a really large mass the effect of the cube of the radius will predominate over the effect of the square of the radius, with the result that the mass may arrive at the surface of the ground with cosmic velocity. The kinetic energy is suddenly transformed into heat with the production of a very high temperature, sufficient to vaporize some of the meteorite and the terrestrial rocks,[3] giving rise to a violent gaseous explosion and so forming a crater and shattering and scattering the remnants of the meteorite.

[1] L. Fletcher, Min. Mag., 1889, vol. 8, p. 226; O. C. Farrington, Meteorites, 1915, p. 46.

[2] C. A. Silberrad, Min. Mag., 1932, vol. 23, p. 299.

[3] L. J. Spencer, Min. Mag., 1933, vol. 23, p. 399; Meteorite craters as topographical features on the earth's surface. Geogr. Journ., 1933, vol. 81, pp. 227–248; and Ann. Rep. Smithsonian Inst., 1935, for 1933, pp. 307–325.

Queensland Meteorites.

The following list of Queensland meteorites is based on the lists of C. Anderson (1913), B. Dunstan (1913), H. C. Richards (1930), and G. T. Prior's British Museum catalogue (1923 and 1927).

Gladstone, Port Curtis district. Siderite, 14½ cwt., found 1914, four miles south of Gladstone. 23° 54′ S., 151° 18′ E. Queensland Government Mining Journal, 1926, vol. 27, p. 312; H. C. Richards, Mem. Queensland Museum, 1930, vol. 10, p. 66, pl. 8 [Min. Abstr., **4**-426].

Glenormiston, Gregory North district. Siderite, 85½ lb., found 1925, 90 miles west of Boulia. 22° 54′ S., 138° 43′ E. H. C. Richards, loc. cit., p. 65 [M.A. **4**-426].

Mungindi, Maranoa district. Siderite, two masses, 62 and 51 lb., found 1897, over the border, three miles NNE. of Mungindi, New South Wales. 28° 58′ S., 149° 0′ E. G. W. Card, Rec. Geol. Surv. New South Wales, 1897, vol. 5, p. 121.

Rockhampton, Port Curtis district. Three stones, one of about 3 lb., fell in the town in the spring of 1895. 23° 23′ S., 150° 31′ E. H. Tryon, Queensland Naturalist, 1910, vol. 1, p. 170.

Tenham, Gregory South district. Shower of more than 104 stones, total weight more than 113½ lb. (perhaps about 350 lb.), fell about February, 1879, near Tenham station (25° 44′ S., 142° 57′ E.), 30 miles SE. of Windorah.

Thunda, Gregory South district. Siderite, 137 lb.. found before 1886 near Thunda (25° 30′ S., 143° 4′ E.), 30 miles E. by S. of Windorah. A. Liversidge, Journ. & Proc. Roy. Soc. New South Wales, 1887, vol. 20 (for 1886), p. 73; 1889, vol. 22 (for 1888), p. 341.

According to M. Hammond (1936) two masses of iron, the 'Old Man' and the 'Old Woman' were known to the aboriginals on Githa (or Gether) Creek (text-fig. 1; 25° 42′ S., 143° 3′ E.) on the Maroo holding. One of these (the 'Old Woman') was shown to him in 1881, and it was afterwards transported to the Thunda homestead, about 15 miles to the north.

Warbreccan, Mitchell district. Three stones, 69, 64, and 1 lb., said to have been found in 1904 about 40 miles west of Windorah, i.e. at about 25° 25′ S., 142° E. in Gregory North district. These stones, however, probably belong to the Tenham shower (p. 446).

The following require confirmation and description:

Cecil Plains, Darling Downs district. Listed by G. T. Prior (1927) from G. W. Card's MS. list (1925).

Ellerslie, Maranoa district. Stone 22½ lb. Listed by G. T. Prior (1927) from G. W. Card's MS. list (1925).

Le Gould, Leichhardt district. Like a cannon-ball, found near a felled tree two days' march beyond the Isaacs river. It was not collected, and there is no evidence that it was a meteorite. Le Gould, Geol. Mag. London, 1864, vol. 1, p. 142.

Queensland. H. A. Ward (1904), omitted by O. C. Farrington (1916), and discredited by G. T. Prior (1927). Perhaps a fragment of Thunda.

EXPLANATION OF PLATES XIV-XVII.

Meteoric stones from the Tenham (Queensland) shower of 1879.

(Photographs of pls. XIV–XVI by the Department of Agriculture and Stock, Brisbane; of pl. XVII by D. L. Williams, Mineral Department, British Museum of Natural History.)

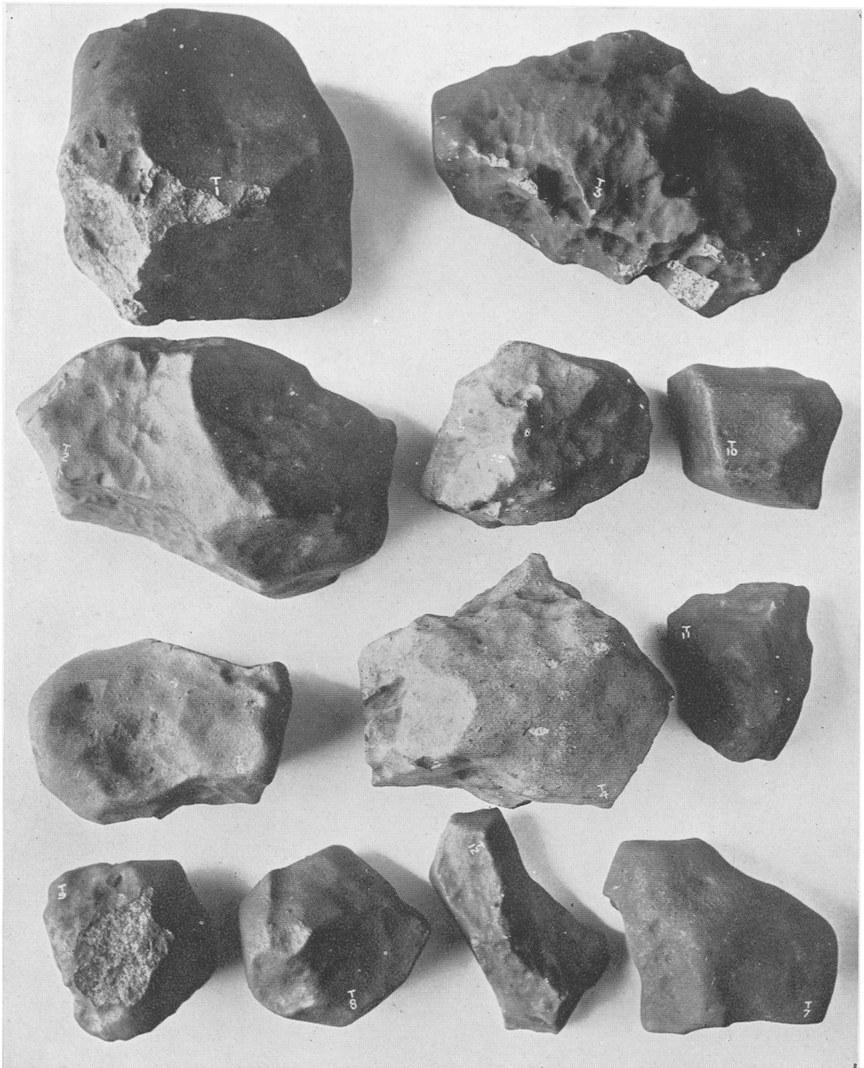
PLATE XIV. Twelve stones, nos. T 1–T 12. × ¼.

— XV. Twenty-six stones, nos. T 13–T 38. × ¼.

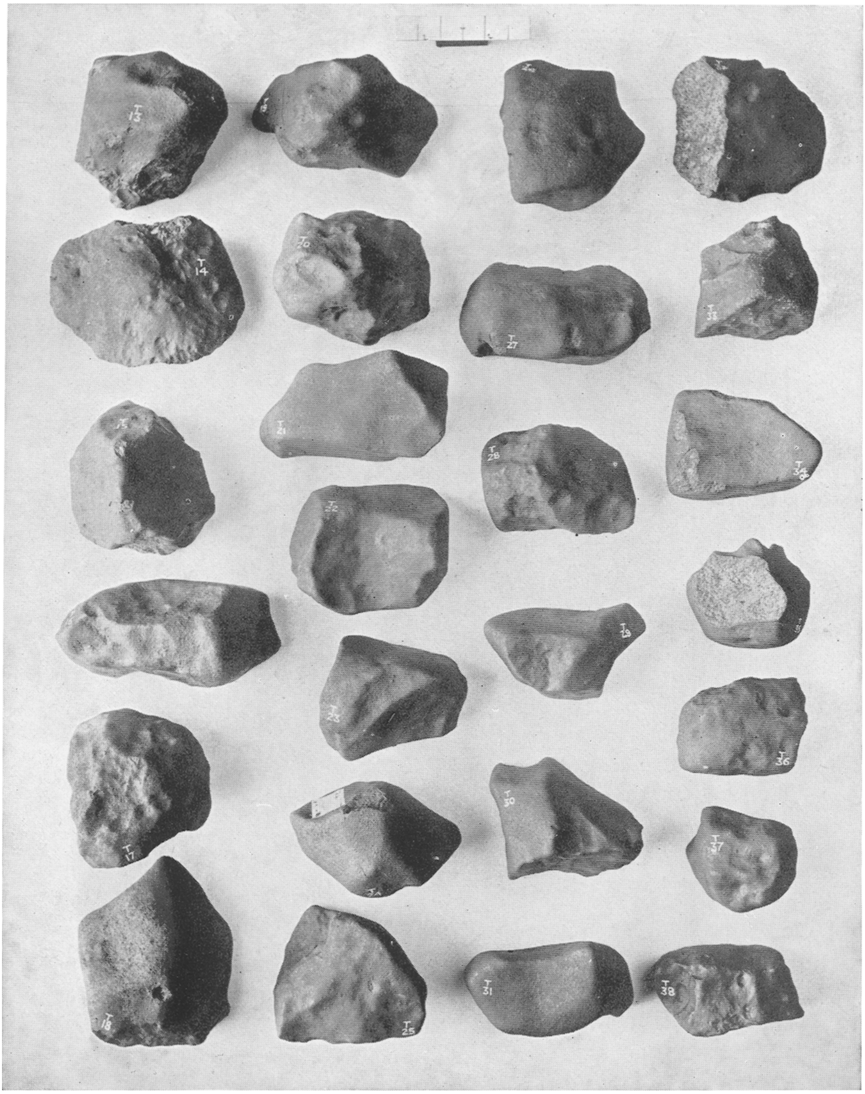
— XVI. Sixty-two stones, nos. T 39–T 100. × ¼. The scale at the top of pls. XV and XVI is three inches long.

— XVII. FIG. 1. Polished section of T 65, showing the stony portion with chondrules. × 1¾.

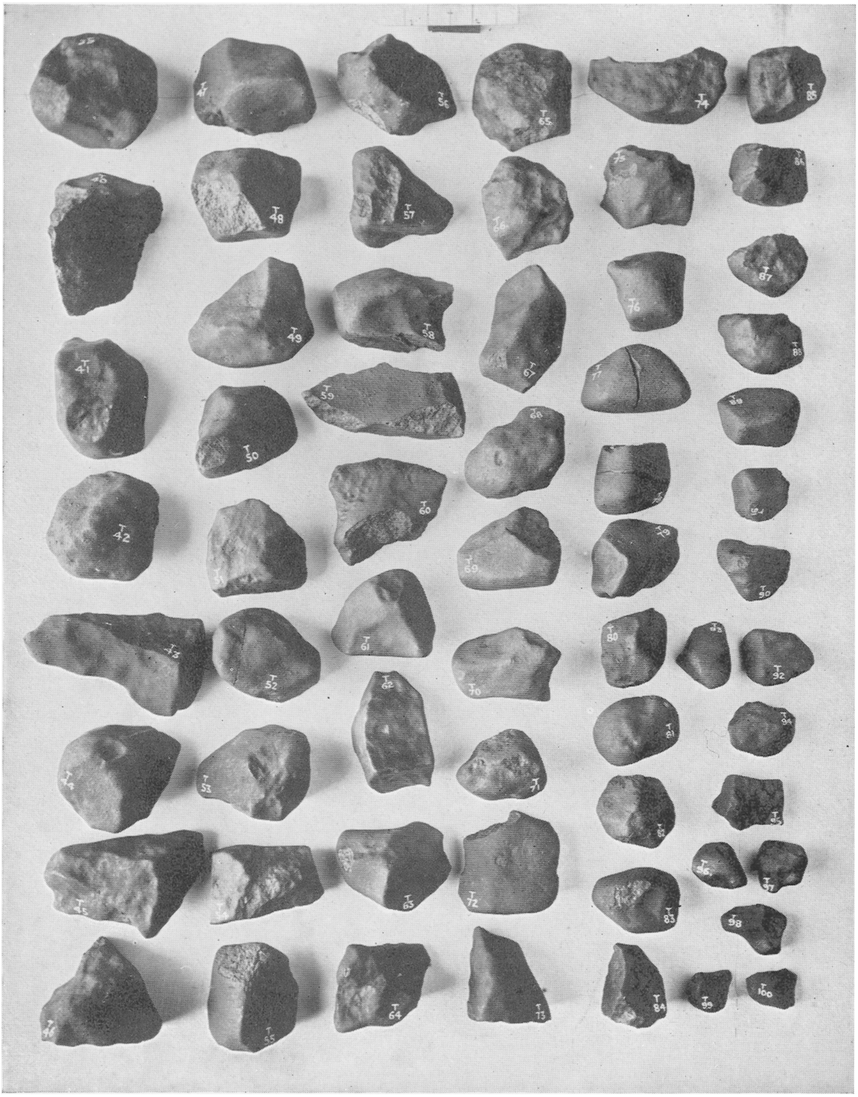
— — FIG. 2. Same section with light reflected from the metallic portion. × 1¾.



L. J. SPENCER: TENHAM METEORITIC SHOWER
(Twelve stones, nos. T 1–T 12. $\times\frac{1}{4}$)



L. J. SPENCER : TENHAM METEORITIC SHOWER
(Twenty-six stones, nos. T 13–T 38. $\times\frac{1}{4}$)



L. J. SPENCER: TENHAM METEORITIC SHOWER
(Sixty-two stones, nos. T 39–T 100. × ¼)

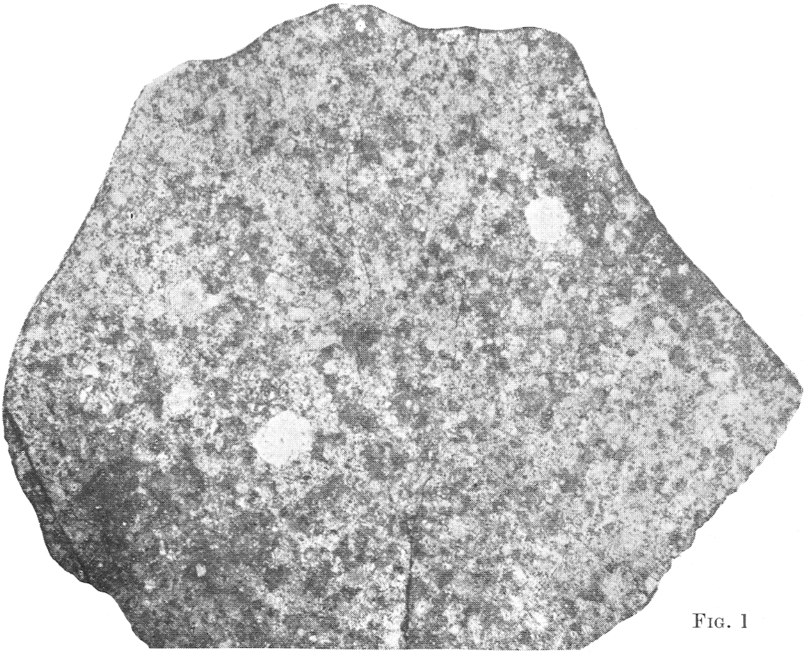


FIG. 1

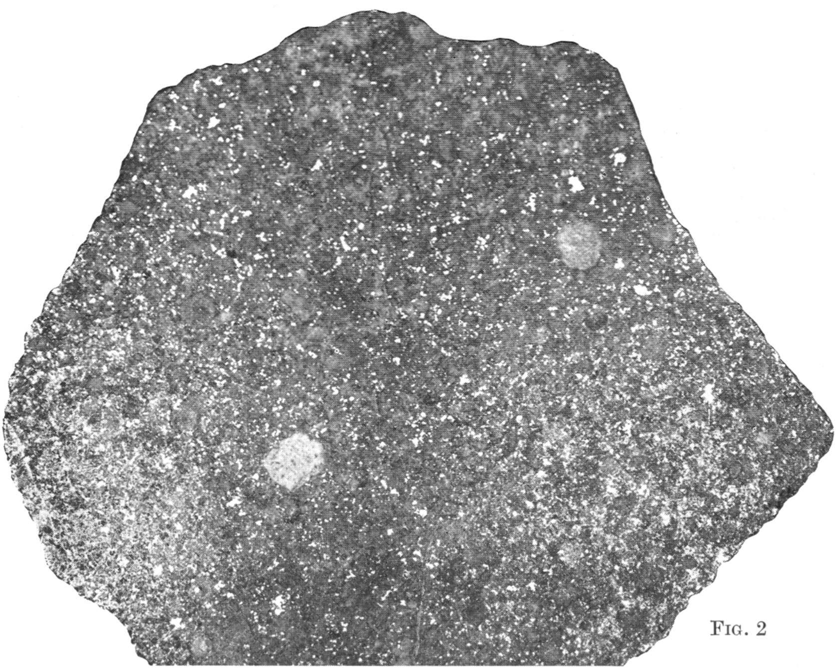


FIG. 2

L. J. SPENCER : TENHAM METEORITE