1937		α h m s	δ ° ′	Distance from Earth	Distance from Sun	Mag.
Nov.	10	21 16 12	+37 39.7			
	11	3 27	36 24.2			
	12	20 50 58	35 2.6	0.273	1.057	8.0
	13	38 47	33 35.4			
	14	26 58	32 3.2			
	15	15 31	30 26.8			
	16	20 4 29	28 47.0	0.271	0.992	7.7
	17	19 53 50	27 4.4			
	18	43 37	25 19.9			
	19	33 47	23 34.1			
	20	24 22	21 47.7	0.278	0.924	7.5
	21	15 19	20 1.3			
	22	19 6 39	18 15.4			
	23	18 58 20	16 30.6			
	24	50 22	14 47.1	0.295	0.855	7.5
	25	42 43	13 5.4			
	26	35 21	11 25.6			
	27	28 18	9 48.1			
	28	21 30	8 12.8	0.321	0.783	7.2
	29	14 57	6 39.9			
	30	8 39	5 9.6			
Dec.	1	18 2 35	3 41.8			
	2	17 56 44	+ 2 16.4	0.355	0.710	6.9

The brightness seems to be considerably fainter than the computed value. In the first part of October the comet appeared as a well-condensed round coma nearly three magnitudes fainter than the Pulkova prediction.

Comet Whipple (1937 *b*) which has been followed continuously since its discovery on February 7 is fading gradually in the southwestern sky. The most recent observation here made it 14^M on October 8. The southward motion will soon put an end to the observations in the northern hemisphere.

The two faint comets Hubble (1937 *g*) and Van Biesbroeck (1935 *d*) can be recorded only with the larger telescopes.

The *Handbook of the British Astronomical Association* gives a search ephemeris for the first return of Periodic Comet Gale (1927 VI) which is expected to reach perihelion next April. The period is about 11 years and after that interval the prediction is naturally uncertain. One can hardly expect the recovery at this early date. However, the chances improve next spring.

Williams Bay, Wisconsin, October 19, 1937.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Before these notes can appear, the first of the major fall showers will have come and gone, namely the Orionids. But it is hoped that our observers will have paid special attention to them as their importance has often been emphasized. However, November brings the Leonids, December the Geminids; as for the Bielids, there is no reasonable hope for their reappearance. The Leonids are now six years beyond the observed, and four years beyond the presumed maximum. Only a moderate number can be expected. However, meteoric astronomy is full of the unexpected and, in any case, we wish full records for every year on these meteors. Again we suggest parallax campaigns for the Leonids to our well-organized groups. The Geminids, coming after winter has set in, are rarely observed as they should be. Yet some years they rival or surpass the August Perseids in numbers; always they are good. Their lower angular velocity makes them particularly favorable for photography. Incidentally, more of our members are having some success in this field. We beg of every reader to send us a print, with description on back of each, of every meteor he succeeds in photographing. Only by comparison and study of large numbers can conclusions safely be drawn.

I was observing on 1937 September 29, using an eyepiece with 15-inch field, attached to the 18-inch refractor here, when a telescopic meteor passed. The meteor, lasting not over 0.1 sec, and orange in color, *certainly* crossed the latter half of the field as one of 10 magn., but I have the strongest impression that it was of about 12 magn. for the first part of its course. It passed out of the field so I do not know if it became brighter. This observation makes a note sent in by our member, J. D. Williams, of immediate interest to me. This note will be appended. Williams' observations were made near Tucson, Arizona. An important series of telescopic meteor observations has just come from one of our active Japanese members, Hideo Inouye. These latter were made with fieldglasses (?), aperture 26 mm, power 5, diam. of field 8°.6. He observed the first four days of August, watching the Delta Aquarid radiant. He sends me tracing of the B.D. maps upon which he has plotted the meteors. His success is most surprising.

1937		Began	Ended	Interval	Meteors
Aug.	1	11:55	13:00	65	19
	2	12:20	13:30	70	16
	3	12:00	13:20	80	21
	4	12:00	14:00	120	19
Totals				335	75

The faintest meteor recorded was 9 magn., only 7 were of 5 magn. or brighter. The radiant is not sharp: the meteors seem to radiate, each night, out from two or three centers from 1° to 3° apart. He further sends a table including interval 1935-10-21 to 1936-10-9 with the computed rates for 55 dates, including 4965 minutes of observation and 344 meteors. Inouye is an excellent observer and I hope he will not be drafted for the war in China.

As few of our members see the *Hydrographic Bulletin,* the following is reprinted from that of 1937 September 15, only a few changes in terms being made. I computed these heights last month.

Fireballs of 1937 June 14

As examples of what coöperation on the part of mariners can accomplish, the following two cases are outlined. The original observations all appeared in the *Hydrographic Bulletin,* within the past three months. Six American ships, *Commercial Quaker, Beaconlight, Dorothy, Java Arrow, W. H. Libby,* and *El Valle,* reported the first fireball which appeared at 0751 G.M.T. on June 14. The object was very brilliant, apparently slow in motion, and gave off fragments on its passage. The following data were derived:

Height at appearance	84 km over Long. 82° 53′ W Lat. 25° 28′ N
Height at disappearance	47 km over Long. 81° 24′ W Lat. 27° 20′ N
Length of path	254 km
Velocity	39 km/sec

Radiant	Azimuth 36°, Altitude 8° 21′
or	Right Ascension 249°, Decl. —41°

It will be seen that the body appeared at a lower altitude than usual: it must have had a considerable mass for a fireball.

The second body, not quite as brilliant, appeared at 084413 G.M.T., and was observed from the three American ships, *W. G. Warden, E. R. Kemp,* and *Argon.* In this case, as the fireball's angular path was very short as seen from two of the ships and headon as seen from the second, the beginning height could not be accurately calculated. All the other data are, however, very accurate. They follow:

Height at disappearance	50 km over Long. 95° 25′ W Lat. 27° 21′ N
Radiant	Azimuth 66°, Altitude 8° 19′
or	Right Ascension 227°, Decl. —17°

At intervals, special mention is made of the work of some member or group in the A.M.S. In the last two years or more, J. T. Kent of the Department of Mathematics, Texas A.&M., College Station, Texas, has sent in a number of excellent reports, not only of his own and of Mrs. Kent's, but of several friends whom he has been able to interest in meteor work. The Texas group used to be one of our most energetic, but for some years past has done less. It is heartening to see a revival of interest, due to the coming of another observer into the state. Some data follow:

1937	Began	Ended	Interval	F	Meteors	Observer
April 21	15:32	16:32	60	0.8	17	J. T. K.
					14	Mrs. Kent
May 4	14:55	15:55	60	0.6	11	J. T. K.
					7	A. Blumberg
5	15:05	16:16	71	0.6	17	J. T. K.
					12	D. Corley
6	15:15	15:35	30	0.4	7	J. T. K.
7	15:00	16:00	60	0.9	11	J. T. K.
					6	A. Blumberg
Aug. 11	13:20	15:28	128	0.6	83	J. T. K.
					54	C. Mitchell
					40	A. Blumberg
12	13:10	14:45	95	0.6	53	J. T. K.
					41	C. Mitchell

An examination of the maps shows that 10 out of 18 meteors plotted on April 21 were Lyrids. None was faint. The distribution of the paths is such that no good radiant may be derived. In May, the maximum number of Eta Aquarids was seen on May 5; out of 17 meteors plotted 8 were Aquarids, which was a larger percentage than for the other nights. Halley's Comet passed perihelion 27 years ago and is hence within 11 years of aphelion. Yet we find that these Aquarid meteors, moving in orbits approximately the same, are still appearing in fair numbers. This indicates more or less uniform distribution all around the orbit but also proves that we should let no year go by without observing them to get as complete a picture as possible. Observations from other members are at hand for both Lyrids and Aquarids: these will be discussed later. In closing all are again urged to get in as many nights' work as possible for both the Leonids and the Geminids.

Dual Observations of Five Meteors

Dr. Olivier once raised the question as to whether meteors may be detected earlier in flight with the assistance of optical power than with the unaided eye. Apparently five observations bearing on the point were made by R. Knabe, D. F.

Brinegar, and the writer in 1934 and 1935.

(1) Using a sport binocular, 20° field, 1.3×, limiting magnitude 7-7.5, a meteor with extremely great angular velocity was observed. From fainter than 5^M it attained 4^M in the first degree of its observed flight, passing out of the field after 5°. Knabe picked it up 10° later at 4^M, followed it through a long flight during which it reached 2^M and finally ended at 4^M.

The remaining observations were made with a binocular giving a field of 7°3, 7×, limiting magnitude 10.5-10.7.

(2) A $7^M.5$ meteor passed out of the field after a flight of 2°5. Knabe observed it at $1^M.5$. The length of the unobserved gap is not given. Four other meteors, 5^M to 8^M, were not seen by Knabe.

(3) A slow moving $4^M.5$ meteor 3°5 long was observed. Knabe's estimates were the same. He failed to see 12 others, 3^M to 8^M, which were visible in the binocular during the night.

(4) A 7^M meteor was observed for 3°5 as it left the field. Brinegar saw it at 5^M.

(5) A 7^M meteor increased to 5^M in less than 3°, then leaving the field. Brinegar picked it up 2° later at 3^M and followed it 5°. In the same night that (4) and (5) were observed, 15 additional ones, $4^M.5$ to $8^M.5$, were not detected by Brinegar.

J. D. Williams.

1937 October 5, Flower Observatory, Upper Darby, Pennsylvania.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
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President of the Society: H. H. Nininger, Colorado Museum of Natural History and American Meteorite Laboratory, Denver

Secretary of the Society: Robert W. Webb, Department of Geology, University of California at Los Angeles

Additional Notes on the Question of Living Bacteria in Stony Meteorites*

By Sharat K. Roy,
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In the October, 1936, issue of the *C.S.R.M.* in *P. A.*, I have read the criticisms made by Professor Charles B. Lipman (1936) of my publication, "The Question of Living Bacteria in Stony Meteorites" (Roy, 1935). Ordinarily, I should prefer to disregard Professor Lipman's comments, but the subject—the alleged presence of living bacteria of extra-terrestrial origin in stony meteorites—has considerable popular appeal, and I have received a number of inquiries concerning my rejoinder. It is for these reasons that I feel that I should answer Professor Lipman and thus make available to the reading public the facts in the case. I realize that it would be difficult for those interested in the present subject to follow the arguments without having in their minds the contents of the original papers, but,

*The Publications Board and the Editor of the Society wish it understood that they take no part in this controversy (see also the earlier paper by Dr. Lipman, *C.S.R.M., P.A.*, **44**, 442-6, 1936) other than to afford space for the free expression of views on both sides of the question by the investigators concerned.—Editor.

since it is not practicable to republish them here, I have, as an alternative, listed them at the end of this paper for contextual reading. Many of Professor Lipman's criticisms are petty quibbles over points that can be quibbled about *ad infinitum*. I have, therefore, chosen the major points and those that can be discussed profitably. It is hoped that the discussion will clarify the situation once and for all.

Professor Lipman objects to my referring to his papers dealing with his "discovery" of living bacteria in ancient rocks and in anthracite coal, on the ground that his work on these subjects and that on stony meteorites are distinct. Where and what is the line of demarcation? Are not his papers, whether relating to rocks, coal, or meteorites, based on his alleged findings of living bacteria in them? In citing his previous papers, however, my object was not to discuss whether the experiments reported therein were similar to or distinct from his work on meteorites but to point out what he has done in the way of searching for bacteria in ancient objects and what corroborations he has received from those who have verified his findings and his ambitous interpretations. His report on the finding of living bacteria in ancient rocks--two from the Pre-Cambrian and one from the Pliocene—appeared in 1928. This finding, which he calls a "startling fact," was not checked by anyone and needed no checking, for after declaring that some of the organisms in the samples were indigenous to the rock, he concludes: "The question of whether they have relatively recently gained access to the interior of the rock or have always been there remains to be determined by further investigations." No reports of these promised investigations, if any, however, have since been published. Three years after the preceding paper, Professor Lipman (1931) reported the finding of living bacteria in anthracite coal and contended that these bacteria had existed in the coal ever since it was formed, some 250 million years ago. Following this announcement, Farrell and Turner (1932) attempted to verify these findings, but failed to do so except in coal that was fractured and thus was exposed to the ingress of bacteria through surface seepage. Professor Lipman charges me with having failed to mention that Farrell and Turner got results similar to his own, but that they chose "deliberately to interpret them [the results] differently." I quote here Farrell and Turner's conclusions as published by Farrell (1933): "Farrell and Turner (*Jour. Bact.*, 1931 [1932?]) attempted to verify Lipman's findings on coal, but were unable to do so except in coal that was fractured and had become infiltrated with bacteria as a result of the seepage of surface and mine water. The microörganisms found in this cracked coal, and in the mine water and mine soil, were apparently identical with those described by Lipman, and were such as are commonly found in air, soil, and water. No bacteria were found in coal that was not fractured or cracked." A glance at the previously quoted passage will prove that I have not misinterpreted the results obtained by Farrell and Turner. True, they got similar results to Lipman's, but under what conditions? Only on coals that were cracked and had become contaminated by seepage of surface and mine water! *No bacteria were found in coal that was not fractured or cracked!*

Now with regard to living bacteria of extra-terrestrial origin in stony meteorites, Professor Lipman vehemently objects to my use of small specimens. He states (1936): "I refer to his [Roy's] choice of very small specimens of meteorites, the largest weighing only 8.65 grams. I have pointed out emphatically and on several occasions that the bacterial populations of rocks and similar materials are never more than very sparse." Bacteria, whether spore-formers or otherwise, are ubiquitous. Their average size is about 2 microns (1 micron or micromillimeter = 1/1,000 mm. = about 1/25,000 inch). The total weight of the meteorite specimens I have used is 23.61 grams, having a volume of approximately 15,640 cubic mm.—sufficient to house many hundreds of millions of bacteria. I do not know the bacterial population of rocks, and I cannot cite any authority, but since rocks vary widely in origin, texture, structure, and composition, which are obviously the chief factors that determine the scarcity, abundance, or absence of bacteria, it is safe to state that no general conclusion could be reached, even if extensive studies on the subject were made. Professor Lipman states that the bacterial population of rocks is "never more than very sparse" and attempts to substantiate his statement with the remark, "I have shown that in single specimens of rock like anthracite coal, ten to twenty times the size of the largest meteorite specimen which Roy studied, it often occurs that there are no bacteria." I believe that even Professor Lipman will be willing to admit that coal is not meteorite!

Apart from the untenability of Professor Lipman's analogy between coal and meteorite, he seems to contradict himself when he gives a list of the variety of bacteria he has found in a fragment of the Johnstown, Colorado, meteorite, weighing only 49 grams. The list is as follows (Lipman, 1932, p. 14): "In peptone soil extract, large variable rods were obtained in abundance (*B. megatherium*). Occasional coccus forms visible. In Na_2S peptone soil extract, very short rods or egg-shaped coccus forms, and also large variable rods in small numbers (*B. megatherium*). In addition, the Bristol's Algal Medium was examined and found in this case to contain large rods and large ovoid cells, and some fairly large coccus forms. Some cells there also appeared to be yeast-like or *Torula*-like." To say that the bacterial populations in meteorites "are never more than very sparse" and then to produce such an array of living celestial visitors in 49 grams must appear to everyone a strange form of logic! My reason for choosing small specimens, as I have mentioned in my previous paper, was that they could be handled more easily—an advantage which materially diminishes the chances of their being contaminated during the process of crushing. Furthermore, in spite of the diligent search of Chief Curator Henry W. Nichols and myself, we could not find any larger specimens that were completely crusted. Professor Lipman apparently, does not believe that the specimens I used were completely crusted. This is evidenced from his remark, "When one notes in the photograph which Roy gives of the specimens he used that at least two and perhaps three of the four were not completely crusted." He does not say what "one notes," but I believe he refers to the lighter spots in the photographs. Professor Lipman's suspicion is unwarranted and reveals only his unfamiliarity with meteorites. The lighter spots are thin films of burned material where the outer or heavier black crusts have been either pealed off or never formed. The crust of meteorites is not of equal thickness at every point. This condition is due to the fact that meteorites are the result of oft-repeated fracture, and hence their constantly changing surface is heated to different temperatures at different parts or points.

Not content with his criticism of incrustations of meteorites, Professor Lipman delves into still deeper phases of the subject—the origin, structure, and composition of meteorites. In his attempt to refute my statement that no bacteria were found in pebbles of peridotites and basalt, he states (1936), after omitting the word *composition* which I used, "My experience with densities of peridotites and basalts does not bear out Roy's claim for close resemblance between their structure and that of stony meteorites." It should have occurred to him that the terms *structure* and *composition* are not synonymous and that it is on composition, not structure, that the possibility of bacterial survival is dependent. What close resemblance there is between the composition of stony meteorites and terrestrial peridotites may be seen in the following passage which I cite from the work of the late Dr. George P. Merrill (1929, pp. 68-9): "These figures [average composition of stony meteorites, peridotites, and rocks of the earth's crust] are of interest when we consider that peridotites, which of all terrestrial rocks most nearly compare with meteorites, are of an igneous nature and of comparative insignificance as components of [the] earth's crust. They occur only as intrusives, that is, they have been forced up in a molten condition from unknown depths and intruded into and between the beds of overlying rocks. Their mineral nature is essentially the same as that of the meteorites, excepting that they frequently have undergone more or less alteration in which water and oxygen have taken a leading part, and contain no unoxidized metal. A striking and almost sensational similarity lies in the fact that they are sometimes diamond-bearing, as are also meteorites, though, so far as now known, only on an almost microscopic scale. The world's supply of diamonds both in South Africa and in the United States comes from terrestrial peridotites."

Professor Lipman then takes up the question of the origin of meteorites and states, in a positive vein: "Moreover, we know that basalts are igneous in origin, but no one knows the immediate origin of stony meteorites, even if we should grant that the matter from which they were formed originally was igneous in origin." Just whom Lipman includes in his *we* I do not know, but those who have studied meteorites and have become recognized authorities seem to know pretty definitely what the origin of meteorites is. As an example, I quote the late Dr. O. C. Farrington (1915, p. 205): "So far as the structure and composition of meteorites are concerned there can be no doubt that meteorites are of igneous origin. All terrestrial analogies indicate that in cosmic furnaces of some sort, fires glowed which gave meteorites the structures which they present to us. As between iron and stone meteorites, some differences of conditions existed which gave them somewhat different structures, since the iron meteorites show well-formed crystallization as if they had been maintained in a uniform condition of temperature, and that sufficient to keep them liquid or viscous for a long time, while the stone meteorites exhibit glass, chondritic structures, and other evidences of hasty crystallization which indicate rapid cooling." I may quote here also a passage from Dr. L. J. Spencer (1933, p. 297) which appeared as a review of Professor Lipman's previous paper (1932): "Organisms could not have originated inside an igneous mass; and if they had been introduced afterwards this could have happened when meteorites were lying in the earth's soil." Incidentally, Dr. Spencer is the leading student of meteoritics today.

Professor Lipman questions even the nature and the number of bacteria I found in my culture media and control plates. He calls my findings a coincidence that "is just too good to be true!" Insinuating remarks such as this, without an explanation as to why it is "just too good to be true," are merely meaningless battles of words, not argument or evidence. I may, however, mention here that my experiments were carried out at the Bacteriological Laboratory of the University of Chicago, supported by Dr. N. Paul Hudson, Dr. Floyd Markham, and, to a lesser extent, Dr. James A. Harrison. Dr. Markham, whose interest and curiosity as to the results were no less than mine, observed every phase of the experiment to its minutest detail and actually coöperated during the process of crushing the meteorite specimens and inoculating the powder into various culture media. When growth appeared (in three of the twelve tubes inoculated, and two control plates), stained smears were made by me, Dr. Markham, and Dr. Harrison, all of which showed identical results—a coccus and a rod. The organisms were then subjected to an appropriate series of tests and were found to be *Staphylococcus albus* and *Bacillus subtilis,* both of which are met most frequently as contaminants in laboratories. Furthermore, *Staphylococcus* does not form spores, and hence cannot live indefinitely without metabolizing. My interpretation, therefore, that these organisms were contaminants rather than survivors of extra-terrestrial origin, is a safe, conservative, and, above all, a logical one.

The fundamental issue is whether or not extra-terrestrial organisms exist in meteorites. Professor Lipman says that they do. He emphatically announces that "stony meteorites (aërolites) bring down with them from somewhere in space a few surviving bacteria, probably in spore form but not necessarily so, which can in many cases be made to grow on bacteriological media in the laboratory." Now the crucial question is how does he know that the bacteria he speaks of are extra-terrestrial? Why could not they be terrestrial? *Each and every meteorite specimen* that he has used had been in contact with the earth during an unknown interval of time and exposed to multiple agencies of bacterial ingress for periods ranging from eight to sixty-five years, at least. If extra-terrestrial bacteria could gain entrance into meteorites, why could not terrestrial ones? Both are bacteria and both had equal chances. It is obvious, therefore, that his conclusion that he has discovered living visitors from the skies is merely his own personal opinion and is not based on data that anyone searching for truth can or will ever accept.

Lastly, Professor Lipman declares himself to be the pioneer excursionist in the field of life beyond the earth. He asserts (1936): "When I undertook the study of the stony meteorites, there was no evidence, and there is not any now, so far as I am aware, that anybody had preceded me in a similar undertaking. In fact, even today, so far as I am aware, only one other person has worked on the problem and that is Mr. S. K. Roy, who decided to do so only after the paper telling of my findings appeared. In other words, I was and am the pioneer on this subject . . . " What this talk about pioneership has to do with the subject in question is not understandable. To be sure, I should make no attempt to deprive him of the honor of being a pioneer, if he were one. I am afraid, however, that he is not. The pioneer work of which he is a claimant and about which he speaks with such enthusiasm was done well over four decades ago by no less a savant than Louis Pasteur. Pasteur searched for microörganisms in fragments of a stony meteorite, Orgueil (a carbonaceous chondrite), which fell 1864 May 14, 8:00 P.M., at Orgueil, Tarn et Garonne, France, *with negative results!* Reference to Pasteur's investigations will be found in a paper, "Enseignements donnés à la Géologie par les volcans de la Lune," by the distinguished student of meteoritics, Stanislas Meunier (*Scientia,* March, 1925, p. 165). For the convenience of the reader I quote here from Meunier's paper the passage referring to Pasteur's work: "Ces masses, qu'elles soient de pierre, ou de fer, ou même composées de ces deux substances, ou bien charbonneuses, n'ont jamais présenté la moindre trace de corps organisés, et le grand Pasteur qui vint au Muséum me demander des échantillons de la météorite charbonneuse d'Orgueil, que j'eus l'honneur de lui remettre, n'y découvrit aucun germe organique."

REFERENCES

(*For contextual reading)

Farrell, M. A.:
*1933. *Am. Mus. Nov.,* No. 645.

Farrell, M. A., and Turner, H. G.:
1932. *Jour. Bact.,* **23**, No. 2, pp. 155-62.

Farrington, O. C.:
1915. *Meteorites* (The Lakeside Press, Chicago, Illinois).
Lipman, C. B.:
1928. *Science,* **68**, No. 1760, pp. 270-3.
1931. *Jour. Bact.,* **22**, No. 3, pp. 183-98.
*1932. *Am. Mus. Nov.,* No. 588.
*1936. *C.S.R.M., P.A.,* **44**, No. 8, pp. 442-6; also *C.S.R.M.,* Fasc. **2**, 40-4, 1936.
Merrill, G. P.:
1929. *Smith. Sci. Ser.,* 3.
Meunier, Stanislas:
1925. *Scientia,* p. 165.
Roy, S. K.:
*1935. *Field Mus. Nat. Hist., Geol. Ser.* 6, No. 14.
Spencer, L. J.:
1933. *Min. Mag.,* **22**, No. 142, p. 297.

Australites: Are They Glass Meteorites?*

By Charles Fenner,
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The range of meteorites has been accepted to include: (*a*) irons, which are metallic, (*b*) stones, which consist mainly of silicates, and (*c*) stony irons, which are intermediate. There is no general agreement that this range should be extended to include, as "glass meteorites," those objects that are called *tektites.* There appears, however, to be a growing volume of opinion tending in that direction. There are at present about eight series of tektites known. The name "tektites," given by Suess, does no more than imply that these objects are "melted." All the known tektite series consist of highly siliceous glasses, Libyan glass being up to 97½% SiO_2. Otherwise, the composition is comparable with, but quite distinct from, that of volcanic obsidian. Tektites are glassy fragments, found in considerable numbers over certain extensive areas in central Europe, Malaya and the neighboring islands, Australia, Tasmania, French Indo-China, the Philippine Islands, the Libyan Desert, and the Ivory Coast of Africa; possibly also in South America. The tektites of each area have their own distinct characteristics. The Tasmanian area is included also in the Australian area; that is to say, in northwestern Tasmania both forms (Darwin glass and australites) may be found. The objects are always wholly glassy, mostly irregular and fragmentary in shape, frequently corroded or abraded, but sometimes quite fresh and of remarkable regularity of form. In weight they vary from one gram up to a few grams, but lumps of Libyan glass occur up to 16 pounds in weight. Usually the region within which any series can be found has been reasonably well defined. Australites occur over an area of 2,000,000 square miles; Libyan glass appears to be limited to an area of 3,000 square miles. The compositions in each case are well known, and are characteristic for each series. Roughly, australites consist of: SiO_2, 70%+; Al_2O_3, 13%+; FeO and Fe_2O_3, 6%+; MgO, 2%+; CaO, 3%+; K_2O and Na_2O, 4%+; with traces of Mn, Ti, Ni, Co; specific gravity, 2.3 to 2.5. Each series has its characteristic color, and may thus be distinguished, except that the three series of southeastern Asia and the adjoining islands are all pitch black. Each series has also a characteristic variety of forms, and with a little experience it

*Read at the Fifth Annual Meeting, Colorado Museum of Natural History, Denver, June 22 and 23, 1937.

[The reader is referred also to two other papers on australites by Dr. Fenner, published in the *Trans. Roy. Soc. South Australia,* **58**, 62-79, 4 figs., 6 pls., 1934, and **59**, 125-40, 3 figs., 1935.—Editor.]

appears to be a simple matter to distinguish the locality of any tektite from its form and surface markings alone. In highly abraded specimens, chemical and physical differences might need to be determined in order for one to be quite sure of their identity. It has been agreed by Dr. L. J. Spencer that the australites are the most puzzling of all the tektite series. It is because the writer has interested himself particularly in australites, of which he has now examined many thousands of specimens, that Dr. F. C. Leonard has done him the honor of requesting the preparation of this paper, which is therefore devoted mainly to a description of australites. The writer has also visited the heavily forested and largely unpeopled area of northwestern Tasmania, where Darwin glass (or Queenstownite, Suess) occurs, but this particular tektite series is quite distinct in form, color, distribution (and possibly, also, in time) from the australites.

The three authorities who have most interested themselves in the tektite problem are Dr. L. J. Spencer, of London, England, Dr. A. Lacroix, of Paris, France, and Dr. F. E. Suess, of Vienna, Austria. Their recent most informative papers are, respectively, "The Tektite Problem," *C.S.R.M., P. A.*, **44**, 381-3, and Fasc. **2**, 32-4, 1936, also *Min. Mag.* (London), **24**, Mar., 1937; "Les Tectites de l'Indochine," *Archives du Muséum National d'Histoire Naturelle* (Paris), **8**, 1932; and "Zur Beleuchtung des Meteoritenproblems," *Mitteilungen der Geologischen Gesellschaft in Wien,* **25**, 1932. Suess and Lacroix incline to the theory of the meteoritic origin of tektites; Spencer suggests the possibility of their formation by the impact of large meteorites upon siliceous rocks, but agrees that this theory is difficult to apply to australites.

It has generally been accepted that there is no known volcanic rock of the same composition as a tektite, but Dr. F. Fitz Osborne, of McGill University, has directed my attention to a paper by Dr. N. L. Bowen (*Am. Jour. Sci.*, **3**, 1-34, 1922), wherein is described a rock of comparable composition to that group of tektites known as australites. The fact is interesting, but does not appear to have any important bearing upon the problem of the origin of australites. For quite other reasons, the theory of the volcanic origin of tektites has become untenable. Tektites (moldavites) have been known for 150 years. Australites have been known for over 100 years. It is just over a century since Charles Darwin was given a well-formed australite, in Sydney, Australia. which he later described, suggesting a volcanic origin. During succeeding years, these glassy foreign fragments have interested a large number of scientific workers, and there has been a considerable output of literature, with a remarkable variety of theories of terrestrial origin. But, even if it is agreed that tektites, or any one series of tektites, are of meteoritic origin, there still remains a variety of theories as to the mechanics of their formation and distribution. It may be of interest at this point to recall that in 1665 so alert an investigator as Robert Hooke was at one with his scientific contemporaries in discrediting the possibility of heavy foreign bodies (meteorites) falling from the sky. The following list of theories, though not complete, will give some idea of the perplexity of the problem presented by these objects. It refers mainly, but not wholly, to australites, and indicates the reluctance of most workers to accept what is called the "simple and easy" theory of meteoritic origin, and their preference for imagining almost any other conceivable method of production.

Darwin (1844) put forward the theory of the volcanic bomb. From the points of view of form, composition, and distribution, this theory has been abandoned. Clarke (Sydney, 1855) said that they looked as though they had been "cast in a mould." Walcott (Melbourne, 1898) records suggestions that they were "pressed by a saucer-shaped mould." The name "emu stones" preserves a belief that they were dark-colored pebbles that had been smoothed in the gizzards of emus. There was a European suggestion concerning moldavites that they were relics of a prehistoric glass factory. Twelvetrees (Hobart, 1897) and Verbeek suggested that they were volcanic blebs from the mountains of the moon. Suess (Vienna, 1898) advocated the theory of cosmic (meteoritic) origin. Hildebrand (1905) was more conservative. He asserted that tektites, particularly australites, were artificial products, formed by man, savage or civilized, either by accident or by design. Dunn (Melbourne, 1912) came forward with his volcanic-bubble hypothesis, claiming that the australites originated from bubbles blown from terrestrial lavas. Various other writers have suggested that they were formed by fusion of dust in the earth's atmosphere by lightning. Spencer (*Nature*, 1933) refers to a theory that tektites were colloidal bodies formed by the action of humic acids on the underlying rock, in certain climates. Jensen (Northern Territory, 1915) suggested the origin of australites as limestone concretions. Lacroix and Michel put forward theories that tektites were formed in the earth's atmosphere by the friction and oxidation of meteorites composed mainly of the lighter metals. Spencer (London, 1933) suggested that tektites were formed by the fusion of siliceous rocks at the earth's surface, as a result of the impact of meteorites. The variety of these theories indicates the complexity of the problem of the origin of these small glassy objects.

As has been stated, one of the outstanding characteristics of australites is the regularity and simplicity of the forms taken by them. Of these, the most striking is the "button," a round object symmetrical in form, averaging 1 to 2 grams in weight and looking something like a "pudding in a saucer." The "saucer" portion of the "button" is formed by a flange which projects upward and outward around the equator of the specimen. Because of its nature, this flange tends to break off very readily, and perfect flanged specimens are accordingly relatively rare. The next important form is the "lens," round, and shaped like a biconvex lens. The separating line between the two surfaces in this case is called a "rim." The other regular forms have either flange or rim and are distinguished by their shape in plan, the names indicating their outline: (*a*) "buttons" and "lenses"; (*b*) "ovals"; (*c*) "boats"; (*d*) "canoes"; (*e*) "dumb-bells"; (*f*) "teardrops." Of these forms, "lenses" are by far the most abundant, constituting more than 50% of the specimens, with "buttons," "boats," "ovals," "teardrops," "canoes," and "dumb-bells" in the order named.

The average weight of australites is one gram, the smallest known being ⅛ of a gram and the largest being 218 grams. They are distributed somewhat irregularly over the whole of Australia and Tasmania and the neighboring islands, south of a line which passes through the northeastern corner of the State of New South Wales and the town of Derby in northwest Western Australia. It is estimated that between one million and ten million australites occur within these limits. It has long been accepted that some part of the form of australites must have been imposed upon them while they were in a liquid or viscid state, spinning forward through the atmosphere.

If one recovers and sorts the material deposited on a tarpaulin immediately behind a railway engine, vast numbers of very minute blebs of glassy material may be obtained, having shapes suggestive of those of australites, *viz.*, "spheres," "ovals," "dumb-bells," "teardrops," *etc.*, but though these things *resemble* australites in form, there is a marked and consistent difference between the actual shapes of australites and those of the tiny blebs formed from the slaggy particles. Microscopic examination of thin sections of australites provides definite evidence of two distinct and separate periods of melting. This evidence is supported by the macroscopic examination of the surfaces of fresh specimens. The back or upper surface has consistently different features from the front or lower surface. The writer put forward a theory (*Trans. Roy. Soc. South Australia*, **59**, 132, 1935) that the typical "button" (for example) was originally a molten sphere, similar in shape to the little spheres formed in the smoke of a railway engine, and that latterly this glassy sphere, spinning through the atmosphere while still hot, became fused on its forward surface, some of the material flowing back to form the flange and the remainder evaporating or being carried away in the air, thus reducing the mass of the original sphere by nearly fifty percent. It has been objected by Mr. Fletcher Watson, Jr., (*Nature*, 1935) and supported by Dr. L. J. Spencer, that tektites could not have been completely fused during their brief flight through the earth's atmosphere. Accepting this objection as valid, and considering it in conjunction with the definite evidence of two distinct phases of melting, one is forced to the conclusion that there are at least two important chapters in the history of the movement of australites through the atmosphere; *first,* they were formed in some way as spheres and as ellipsoids and in hourglass shapes, possibly in an instant; *second,* while still molten or viscid, they went spinning through the air, re-fusing on their forward surfaces and thus acquiring the characteristic australite shapes. Professor Suess has suggested that the molten glass acquired the original forms at the moment of the blasting of the silica content of a burning light-metal meteorite, the subsequent friction of flight re-melting the front part of each form, as already described. This suggestion constitutes the argument for the meteoritic origin of australites. The whole of the evidence regarding form, composition, and distribution shows that all the australites had their origin at one time. The magnitude of their numbers and the vastness of their distribution, extending alike over rock surfaces of all ages and compositions, invalidate both the volcanic theory of their origin and the theory of meteoritic impact. On the other hand, all the known factors accord with the idea of a single widespread shower of glassy blebs falling upon the earth's surface from some cosmic source.

A Course in Meteoritics at the U. C. L. A.

The Editor wishes to report that he has a class of fifteen "upper-division" (*i.e.* "senior-college") students in a course in meteoritics which is being given for the first time during the fall semester of the academic year 1937-38 in the Department of Astronomy of the University of California at Los Angeles. The new course, known as "Astronomy 118" and named "Meteoritics," is described in the *General Catalogue* of the University for 1937-38 as a course in "The science of meteorites and meteors. Open to upper-division students whose major subject is some physical science, particularly astronomy, geology, or chemistry." The class will meet three times a week throughout the first semester and the course will yield three "units" of credit toward the bachelor's degree in the University. Farrington's *Meteorites* (1915) is being used as the textbook, while Nininger's *Our Stone-Pelted Planet* (1933), the *C.S.R.M.*, and other original papers are serving as collateral reading and source material for the course. It may be of interest to note that of the fifteen students enrolled in the class, five are "majors" in astronomy, nine are "majors" in geology, and one is a "major" in botany! As far as our knowledge extends, this is the second time only that a course in meteoritics has been taught (*cf. C.S.R.M., P.A.,* **43**, 603, and *C.S.R.M.,* Fasc. **1**, 42, 1935).