data and result are summarized in the following table:

SUMMARY

	Keokuk	*Carson*
Altitude of beginning	35° 57′	23°
Azimuth of beginning	78° 36′	300° 12′ (from south)
Altitude of ending	23° 0′	(not given)
Azimuth of ending	57° 42′	305° 12′ (disapr. not end)
Apparent slope	45° (moving to left)	45° (moving to right)

Time of fall	1931, June 12, 8:45 P.M. C.S.T.
Latitude of beginning	40° 9′ North
Longitude of beginning	93° 2′ West
Height of beginning	66 miles
Latitude of ending	39° 37′ North
Longitude of ending	93° 0′ West
Height of ending	45 miles
Latitude of ground point	38° 36′ North
Longitude of ground point	92° 56′ West
Length of path	44 miles
Projected length of path	37 miles
Altitude of Radiant (uncorrected)	31° 0′ (from ground point)
Azimuth of Radiant (uncorrected)	177° 10′ (from South)
R. A. of Radiant (corrected)	43° 8′
Decl. of Radiant (corrected)	+79° 59′

University of Iowa, September 2, 1936.

Contributions from the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD, President, *and* H. H. NININGER, Secretary

Bacteria in Meteorites*

By CHARLES B. LIPMAN†

For approximately a decade I have been engaged in studying the problem of the survival of bacteria, and to some extent of other microörganisms, in very old and very dry materials ranging in age from 25 years to periods of remote geologic time like the Pre-Cambrian. Purely as a side issue of this important problem I made a search also for bacteria in stony meteorites. I call this a side issue because no one knows where the meteorites hail from and therefore no one can know how long, if at all, the bacteria which they may contain have been there in a resting as distinguished from an active vegetative state. In other words, I wish to make it very clear and very emphatic that my studies on the meteorites have no bearing whatever in the present state of our knowledge on the problem of the survival of bacteria in materials whose age is known exactly or approximately. The two subjects are quite distinct and I do not wish them to be regarded as the same by persons whose forte is not so much clear thinking as clear shouting and denunciation. In other words, then, I examined stony meteorites for bacteria just to satisfy my curiosity on that point alone and not because that study had any bearing on the important subject which has for so long absorbed my spare time and

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energy, namely, the survival of bacteria for very long periods of time in a living though inactive state, nor because it had any necessary bearing on other subjects, as some people think and as I shall state in my concluding words.

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[1] 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, and since the only other person who can speak on the basis of his own experiments on this subject denies and refutes my findings, I wish to pay my respects to his work and his views today.

Mr. Roy introduces his paper by citing and commenting upon some of my papers dealing with the discovery of living bacteria in Pre-Cambrian rocks and in anthracite coal. I have already stated to you that that work and the work on the stony meteorites are distinct, and the results in the two cases have little or no bearing on each other. The only reason that I can find for his bringing them into the discussion is that it gives him an opportunity to state that Farrell and Turner said they had failed to corroborate my results on anthracite coal. He fails to state that they got similar results to mine but chose deliberately to interpret them differently. What is more important still is that Mr. Roy fails to mention that Lieske, one of the most distinguished of German bacteriologists, got results on anthracite coal which were exactly like mine. Lieske and I were unaware of each other's work until I had published my paper, Farrell and Turner had put in their demurrer, and Lieske published a paper supporting my findings precisely, except for his belief that the organisms in anthracite coal carry on a weakly vegetative existence, while it is my conclusion that they exist there in a resting state. In other words, while citing results which are not really relevant to my study on meteorites Roy does not cite both sides but only the one which suits his purposes; and mind you, that was after I had stated in print that Lieske had obtained results like mine and that our work was mutually confirmatory.

Now as regards Roy's experiments: He states that he wished to "adhere as closely as possible to repetition" of my technique. Please note how he did so. He used similar media to mine and in certain other ways followed my technique but in one of the most crucial phases of the experiment he deviates so strikingly from my procedure that all of his other precautions to follow me are rendered futile and Roy is on a totally different trail. I refer to his 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. 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. The smaller the specimen of meteorite, therefore, the less chance there is of discovering any bacteria in it. In the specimens used by me which Roy describes specifically in his paper it will be seen that except for one duplicate fragment the *smallest* specimen I used weighed 109 grams or approximately 13 times the weight of Roy's largest specimen. The reasons Roy gives for using small specimens instead of large ones such as I used are as follows in his own words: "Stony

[1] "The Question of Living Bacteria in Stony Meteorites," by Sharat Kumar Roy, *Geological Series of the Field Museum of Natural History*, **6**, No. 14, December 12, 1935.

meteorites larger than 10 grams are seldom completely crusted. In studies of this nature the importance of complete encrustation cannot be overestimated, for the crust not only insures retention of the contents of the interior of the meteorites in their original form and condition, but also serves as a natural protection against the ingress of bacteria from dust and air." This statement is at least naïve, not to say amusing, 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. I can show a large specimen which I have that is just as completely crusted as Roy's largest specimen but Roy does not realize that the photograph which he publishes takes the props right out of his most important argument for using small specimens, and he has yet to answer the grave objection to small specimens which I have just stated. His only attempt at an answer is that from a report published in England he learns that soils may contain 100,000 to 1,500,000 bacteria per gram. Indeed they may contain many times those numbers as I know at first hand, but soils are not rocks. Conditions are excellent in soils for rapid reproduction of many soil microörganisms, but not so in rocks. It is probable that only resting stages like spores can survive in rocks and only a few of them. This is especially true when long periods for survival are in question.

But if a broken crust on a meteorite permits ingress of bacteria as Roy claims, why should his specimens have been exceptions to the rule? But Roy does not appear to realize that he "can't eat his cake and have it too." After going to great pains to prove, as he thinks, that meteorites with broken crusts can be easily contaminated, which claim I have just shown to be unproved, he tells us that bacteria could not have survived in meteorites because they do not find there food and other conditions for their growth. Such a statement certainly shows a lack of knowledge of and experience with bacteria. Many forms of bacteria, at least, go into the spore state when conditions are unfavorable in the respects just noted or in many other respects and remain quiescent until proper conditions for their growth supervene, when the spores germinate and the new organisms again carry on an active existence. If the necessary conditions for active life do not supervene the organisms may remain in the spore state indefinitely in the case of some forms of bacteria. In this way, therefore, bacteria may survive the unsatisfactory conditions of meteoritic matter contrary to what Roy thinks. This, moreover, is not surmise but well authenticated statement. I can furnish all the proof you want on that score if you will give me the time to do so. But when Roy says that bacteria cannot live in solutions consisting of rock powder or meteorite powder he shows again his limited experience with microörganisms. All assiduous students of general microbiology know this is not so because organisms have been found which have grown in a 10% solution of C.P. $BaCl_2$, in $N/10$ HCl (C.P.), in saturated $CuSO_4$ solutions (C.P.), *etc.* Is there any likelihood of more adequate food supply in these materials than in rock-powder extract? And mind you there were vegetative growths, not mere spore survival. But if this means survival, as it most assuredly must, either of the spore or of the vegetative state, please note what has become of Roy's arguments. I must pursue this matter still further. Roy makes some statements which he does not support or in which he contradicts himself. For example, he says "it has been known and later experimentally proved that *water with bacteria* can seep through stony meteorites (p. 196) when they are in contact with the earth." We turn to page 196 and find that all he has proved is that meteorites take up water. There is not a word of proof in his paper to the effect that they take up bacteria with the water. Water will penetrate many substances which may remain impenetrable to the things which water car-

ries in solution or in suspension. A little knowledge of the literature of physics, physical chemistry, and biology establishes the truth of this statement.

Roy argues further that because he found no bacteria in pebbles of peridotites and basalt "the possibility of bacteria surviving in stony meteorites is very small." My experience with densities of peridotites and basalts does not bear out Roy's claim for a close resemblance between their structure and that of stony meteorites. In fact, I find stony meteorites to be very porous as compared with the peridotites and basalts. Moreover, we know that basalts are igneous in origin, but no one knows of the immediate origin of stony meteorites, even if we should grant that the matter from which they were formed originally was igneous in origin. Following the statement I have just quoted from Roy he makes the further statement: "This was later confirmed by the negative results obtained when terrestrial bacteria, both bacilli and cocci, were inoculated in a culture medium consisting of meteorite powder and distilled water." I cannot find a word of evidence in his paper to support that, and he does not tell us whether he used spores or vegetative forms. Roy does not realize, moreover, that this statement of his is one of the many contradictions in his paper. If bacteria cannot live in suspensions of stony meteorite powder and water and if the surface of a meteorite before crushing is assuredly sterile how can meteorites become contaminated? Of course, he answers this by saying that the contaminants he finds are in the air of the operating chamber. But did he ever stop to think that there is something too perfect in his having found just one coccus and one bacillus as contaminants, and more marvelous still, that exactly those two organisms and no others were found in the so-called contaminated cultures and in the plates exposed to the air? The perfection of this coincidence is just too good to be true! While I am on the subject of contaminants I wish to point out that the relegation by Roy of the bacteria which I found in meteorites to the category of contaminants is a most arbitrary one if one recalls that my working conditions were no less aseptic than Roy's and still I found a considerable variety of bacteria in meteorites instead of just one bacillus and one coccus as did Roy, and I found the greatest variety and number in the specimen—the Johnstown, Colorado, meteorite—which had had the least period of contact with the earth. When Roy takes me to task for saying that this "meteorite had little or no contact with the earth," I answer that my authority for the statement was the man who made it possible for me to obtain the specimen, namely, Dr. O. C. Farrington.

Time will not permit my critical examination of a number of other questionable features of Mr. Roy's paper, but before making my closing statement I wish to answer an assertion made by Roy that I am guilty of a "glaring contradiction" when I state that geologists informed me that meteorites, and especially stony meteorites, never become hot except on the surface when passing through the earth's atmosphere, and therefore the bacteria in the center might be secure, and elsewhere in my paper state that some bacteria in one of my meteorite specimens must have been killed by heating the meteorite in my large gas burner for 20 seconds. Roy asks "how could bacteria, if any, in a meteorite be destroyed by heating 20 seconds in a gas flame when they are not supposed to be destroyed by the intense heat which literally fuses the surface of the meteor during its passage to the earth?" Roy's question is easily answered and with the answer the contradiction of which he accuses me vanishes into thin air. Twenty seconds' exposure of a meteorite to a temperature of 1300° C. constitutes about ten times the exposure to heat which a meteorite suffers in its trip to the earth. It does not begin to burn until it develops friction on contact with the earth's atmosphere, but the earth's

atmosphere is so thin that it cannot take more than two or three seconds for a meteorite to pass through it. Furthermore, it will be noted that I did not say *all* the bacteria in the meteorite were killed by heating the latter for 20 seconds in a flame yielding approximately 1300° C. but only "some," just as "some" might conceivably have been killed in the meteorite during its journey to the earth. But all this could be only when the conduction of heat from the surface to the interior of the meteorite is good enough. Stony meteorites are very heterogeneous and very variable in mineral as well as chemical composition. The higher the metallic content the better the conducting powers of the meteorite for heat, but only in certain streaks or lines in the interior of the meteorite, not uniformly, as Roy thinks, when the time of exposure to heat is very short.

In closing this polemic I submit that the only person so far as I am aware who besides myself has actually searched for bacteria in meteorites, namely Mr. Roy, has presented a report of his research which does anything but prove that my facts and conclusions are in error. Starting out with the purpose of duplicating my technique in his experiments he soon modifies it so as to render his results worthless as a test of my findings and conclusions. Until better critical examinations than Roy's of my work can be brought forward my results and conclusions remain good. My final observation deals with the repeated statements or implications by Roy, and also by Hudson who wrote the introduction to Roy's paper, to the effect that I was directly hinting or attempting to prove by my results on bacteria in meteorites the extra-terrestrial origin of life. They are absolutely mistaken in this as in other things. I neither hinted at this nor stated it. In fact, if they will take the trouble to look up my paper in *The Scientific Monthly* (**19**, 357-67, October, 1924), written twelve years ago or more, they will find that I have published a very different theory of my own relative to the origin of life; and I still hold that theory. My paper on bacteria in meteorites was intended for nothing more than to give the facts of the situation. The origin of life has nothing to do with the case. What may be pertinent to the discussion is the application of my results to the question of whether life exists on other bodies in space besides the earth. It is this inability on the part of some people to keep from regarding distinct subjects as the same which makes so much trouble in scientific literature, as, for example, the present polemic makes for you!

Report of the Fourth Annual Meeting of the Society

The Fourth Annual Meeting, held at the University of California at Los Angeles on June 23 and 24, 1936, was the best attended and in practically every other respect the largest meeting in the history of the Society up to date. The following nineteen members were present at one or more of the various sessions on the two days (unless mentioned, the State is California): Lyle Abbott and Mars F. Baumgardt (Los Angeles), L. F. Brady (Flagstaff, Arizona), John Davis Buddhue (Pasadena), Ernest W. Chapman (Alhambra), Walter B. Clausen (Pacific Palisades), Howard R. Hill and Louis V. Kenkel (Los Angeles), Arthur S. King (Pasadena), Frederick C. Leonard (Los Angeles), Charles B. Lipman (Berkeley), Ransom Matthews (Los Angeles), Ralph I. Meeker, Jr., and H. H. Nininger (Denver, Colorado), Harry K. Sargent, Nathan Schwartz, Archie Wade, and Robert W. Webb (Los Angeles), and Walter T. Whitney (Claremont); in addition, a goodly number of guests attended. Fourteen technical papers, two from foreign members, and two popular lectures were delivered. Following are the program and the list of papers read:

PROGRAM OF THE FOURTH ANNUAL MEETING

The President of the Society presiding

Tuesday, June 23

10:00 A.M.: Session for Papers, including (1) Address of Welcome by Dr. Robert G. Sproul, President of the University of California, and (2) a Business Meeting, at which certain proposed Amendments to the Constitution and to the By-Laws (circulated with the call for the meeting) were unanimously adopted and the Articles of Incorporation of the Society were officially approved.
12:30 P.M.: Recess for Luncheon, Kerckhoff Hall.
2:00 P.M.: Popular Illustrated Lecture on "The Meteorite Crater of Arizona," by Dr. Mars F. Baumgardt of Los Angeles, followed by Session for Papers.
6:00 P.M.: Informal Dinner for Members of the Society and their Guests (about twenty present), Kerckhoff Hall.
7:00 P.M.: Excursion to the Griffith Observatory and Planetarium, Griffith Park.
8:00 P.M.: Planetarium-demonstration Lecture at the Observatory, on "A Trip to the North Pole" (including artificial displays of the aurora borealis and a shower of meteors), by Dr. Dinsmore Alter, Director, followed by Inspection of the Observatory and its Collection of Meteorites, and Observations through the 12-inch Telescope.

Wednesday, June 24

9:00 A.M.: Meeting of the Council (present, four members: the President, the Secretary-Treasurer, and Councilors Brady and Whitney).
10:00 A.M.: Session for Papers.
12:30 P.M.: Recess for Luncheon, Kerckhoff Hall.
2:00 P.M.: Session for Papers, concluding with Informal Reports by Chairmen and other Representatives of Committees in Attendance at the Meeting. Adjournment.

The scientific sessions, all of which were open to the public, convened in Room 310 of the Chemistry Building of the University; the meeting of the Council was held in an office of the Department of Astronomy (Room 343 of the same building). The Leonard collection of meteorites, on display in the Geological Museum (Room 300), was open for inspection during the entire time of the meeting. At its session on June 24, the Council voted that the Fifth Annual Meeting of the Society shall be held in June, 1937, in conjunction with the combined meetings of the A.A.A.S. and its Western Divisions, in Denver, Colorado.

LIST OF PAPERS PRESENTED AT THE FOURTH ANNUAL MEETING

(1) *"THE SPECTRA OF METEORITES" (an invited paper): Dr. Arthur S. King, Superintendent, Physical Laboratory, Mount Wilson Observatory of the Carnegie Institution of Washington, Pasadena, California.

(2) "A METEOR SPECTRUM": Mr. John S. Hopkins, Brackett Observatory, Pomona College, Claremont, California (introduced by Dr. Walter T. Whitney and paper read by him).

(3) *"BACTERIA IN METEORITES": Dr. Charles B. Lipman, Dean, Graduate Division, University of California, Berkeley, California.

(4) *"SOME REMARKS ON THE PHYSICAL PROBLEMS INVOLVED IN THE CRYSTALLIZATION OF IRON IN A GRAPHITIC MATRIX IN METEORITIC MATERIAL": Mr. L. F. Brady, Principal, Mesa Ranch School, Mesa, and Curator of Geology, Museum of Northern Arizona, Flagstaff, Arizona.

(5) *"ON THE MEASUREMENT OF METEOR VELOCITIES": Dr. Walter T. Whitney, Director, Brackett Observatory, Pomona College, Claremont, California.

(6) *"WHY IS A METEOR?": Professor H. H. Nininger, Director, Nininger Laboratory, and Curator of Meteorites, Colorado Museum of Natural History, Denver, Colorado.

*Papers marked by an asterisk were presented personally by their authors.