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Report of the Meeting of the Society held on Tuesday, 24th February 1914.

THE Ordinary Monthly Meeting of the Society was held on Tuesday, the 24th February 1914, in the Imperial Secretariat (Treasury Buildings), at 5-30 P.M. In the absence of the President, Mr. H. G. Tomkins, C.I.E., F.R.A.S., was in the chair.

The minutes of the previous meeting held on Tuesday, the 27th January 1914, were read and confirmed.

The following presents received since the date of the last meeting were announced, and the thanks of the members were accorded to the donors, especially for the exceedingly valuable contribution from the British Astronomical Society in connection with the variable stars. As only a limited number of copies were struck they were sent only to those who were likely to appreciate them and the Chairman hoped that members would make use of the book :—

1. Monthly Notices of the Royal Astronomical Society for December 1913.

2. The Observer's Hand-book for 1914, published by the Royal Astronomical Society of Canada.
3. Journal of the British Astronomical Association for December 1913.
4. Sociedad Astronomica De Barcelona for January 1914.
5. Indian Weather Review—Annual Summary 1912—published by the Meteorological Department of the Government of India.
6. Monthly Weather Review for September 1913, published by the Meteorological Department of the Government of India.
7. Kodaikanal Observatory—Bulletin No. XXXIV.
8. Memoirs of the British Astronomical Association—Appendix to Vols. XV and XVIII.

The election by the Council at their meeting of the 17th February 1914 of Babu Gokul Chund Bural, Calcutta, as a member of the Society, was confirmed.

Chairman.—The first item on the programme is the discussion of Captain Urquhart's paper on the formations on the Moon. Captain Urquhart read his paper at a previous meeting and a long discussion took place which it was impossible to finish that evening as it was very late. I will therefore now ask Captain Urquhart to resume the discussion. (*Captain Urquhart's notes on the objections raised against his paper*).

The Chairman.—There are one or two remarks I would like to make with regard to what Captain Urquhart has said. In the first place may I ask one question as regards the large seas? Captain Urquhart holds that the large seas were formed owing to the impact of a bolide into the surface. He does not quite make it clear how the bolide caused the formation, though he made it quite clear that there was some formation of liquid matter which obliterated the objects on the surface of the plain. What I wish to know is whether Captain Urquhart holds that the bolide by its impact liquefied the surface, or whether it went through the surface thus making an outlet of the internal liquid matter in the Moon.

Captain Urquhart.—My point was that the seas were not caused by bolides at all.

Chairman.—That greatly simplifies the case. I am glad that Captain Urquhart does not hold that these seas are due

to bolides. It seems to me more likely there was some kind of volcanic action. Professor Pickring of America has described the volcanic craters of the Haiwai Islands, and one of them much resembles on a small scale these flat-bottomed formations. The work is in the Library. I think, however, that we may now put the seas out of the question. As regards the size of the other craters, Captain Urquhart mentioned that those who hold the volcanic theory suppose that the vent is 50 miles across to create these formations. I think that in any form of argument it would be wrong to suggest that the vent was anything like 50 miles. It is the formations themselves which are about this size. Naysmith gives a description of a possible method of formation in his book on the Moon. (Black-Board). I don't know that it is a very good one but it has good points about it.

Captain Urquhart.—This method makes out the rings to be ridges on the surface; but I think in the formations I am dealing with, the floor is always lower than the surrounding lunar surface.

Chairman.—I think it is rather doubtful to what extent this is the case. It is very difficult to measure these depths with great accuracy on account of the undefined edges of the shadows. We have nothing on the Moon to correspond to sea level on the Earth, and it is therefore difficult to compare these levels. As regards water on the Moon Captain Urquhart denies any. There may be water in combination with the lunar material, though I do not think that this would be sufficient to cause very large volcanic outbursts. I do not agree, however, that a volcano must depend solely on the presence of water. It is quite conceivable that immense forces in the lunar crust could exist without bringing in the action of water. I do not think that the mere fact that water is absent is sufficient to preclude the presence of large internal forces. Copernicus is a formation on which I have done a lot of work, and I think there is certainly evidence there of internal forces in the star-shaped formations round it. Similarly also with Tycho and several others. I may perhaps briefly mention my own work on the Moon as it has some bearing on this question. The object of my observation was the explanation of the white ray systems and Copernicus was the one on which I spent most time. If we consider the system simply as a formation apart from its albedo, it can be explained on the supposition that an internal force upheaved the crust at that point. After the upheaval there would be a subsidence, and this would cause the formation of

radiating ridges corresponding to the general idea of the rays round these craters. Now comes the question, are the rays elevated at all about the lunar surface? If they are, this supports the theory. After spending 5 or 6 years observing them on every possible occasion, I think no doubt exists that a great many of them at any rate are low elevations above the general surface. This then goes to show that there must have been internal forces far greater than would account merely for the crater cones. Moreover the ridges if formed as I suppose would be lines of weakness in the crust, and would therefore if internal forces existed be places where we might expect to find crater cones and curiously enough we do find them in considerable numbers down the crests of these ridges. I do not wish to put every thing on the Moon down to volcanic forces, but I think there is clear evidence of it having been there on a large scale. How the formations we are considering were built up, I do not think we yet know, but I prefer to look in the direction of forces which we know nature has employed on the Earth and evidences of which we see also in the Moon, rather than go outside our experience at any rate for the present.

Revd. Mr. Ridsdale.—Captain Urquhart will forgive me if I say that the more I think over the matter, the more utterly impossible the theory of Dr. See's which he has so ably advocated appears to me to be. In the first place Captain Urquhart takes for granted that because the Moon is smaller than the Earth that therefore the volcanic force is less there than on the Earth. The volcanic forces, however, are by no means in any proportion to the relative sizes or masses of Earth and Moon. Volcanic force is generated merely within the thin crusts of either body, and therefore bears no proportion to their respective radii. So far from the volcanic force at the Moon's surface being less than that at the Earth's surface, as Captain Urquhart supposes, it was greater owing to the Moon's crust contracting much more rapidly than the Earth's crust, due to the Moon's mass being much smaller and therefore cooling much more quickly. Again, Captain Urquhart makes a difficulty in the matter of the great size of the lunar craters. But there is no difficulty really, because gravity is only $\frac{1}{6}$ × gravity at the Earth's surface. And this fact combined with the other I have just mentioned, *viz.*, that the Moon's volcanic force is actually greater than the Earth, will even more than account mathematically for the great size of the lunar craters. Captain Urquhart now says that as the gravity on the Moon's surface is less than on the Earth, the compression will therefore be less, and therefore

the force of projection will be less. But here again Captain Urquhart is mistaken, since the question of compression has nothing to do with the tract of a bolide when it has once got away from the surface. From that moment it will be only gravity that can affect its velocity and gravity being less at the Moon, both the velocity and distance of the bolide's path will be greater, and hence the craters formed will be greater.

Again the Moon never rotated more rapidly than it does now. For why should it have? It separated from the parent Earth most gently and gradually. It was not shot out from the Earth like a cannon ball, but owing to unstable equilibrium, the Earth-Moon mass was gradually elongated in the plane of its rotation. Two portions in the ratio of 81:1 parted company. This being so, the Moon always turned her face towards the Earth. How then was the Earth able to shoot bolides at the back of the Moon, on the side of the Moon that is turned away? For there are certainly craters equally on the further side of the Moon, as can be seen when the Moon is in libration.

Again and this I think is an unanswerable objection to this curious theory of Dr. See's—if the Earth produced craters on the Moon by volcanic bolides, why did not the Moon produce craters on the Earth by her volcanic bolides? Surely Captain Urquhart will not maintain that Vesuvius, for instance, is a lunar bolide.

Lastly, I would point out that all bolides from the Earth which were shot out in any direction not exactly normal to the Earth's surface would make an angle of incidence upon the Moon's surface equal to the angle of projection multiplied by the square root of the ratio of the distances from Earth and Moon to the point between them where attraction would be balanced. And this is equal to the square root of the ratio of their respective masses, or $\sqrt{81} = 9$. Thus according to Dr. See's theory the craters ought to form very sensible ellipses. But they do *not*.

Chairman.—Mr. Ridsdale and Captain Urquhart differ about the rate at which the Moon revolved. But I think Mr. Ridsdale's point could be put another way without touching the question of rate. What about the formations at the North and South Poles of the Moon? These at any rate did not ever appear in the middle of the lunar disc as viewed from the Earth.

Mr. Simmons.—Mr. Simmons said in his opinion Mr. Ridsdale had made a point when he enquired whether Captain Urquhart could cite any case in which bolides had produced the same effects on the Earth which it was claimed they had on the Moon. Those opposed to Captain Urquhart could point for a volcanic formation similar to that on the Moon to the district round Naples, and the Chairman had mentioned another case in the Hawacian Islands. The speaker thought the Chairman, Mr. Tomkins, had not attributed sufficient importance to the factor of shrinkage. Shrinkage had been in operation ever since the Solar system began to condense from the original Nebula out of which it was formed. It was still at work in the Sun, and caused its enormous heat. This led Mr. Simmons to turn to Captain Urquhart's having spoken of Jupiter as a young planet. Jupiter was millions of years older than the Earth, for it broke away from the shrinking Nebula long ago before the Earth did so. (Captain Urquhart interposed that he had referred to the state in which Jupiter is at present, and had not spoken of the planet's origin.) The speaker further considered Captain Urquhart was not justified in assuming that there never had been water, or air, on the Moon. He also could not accept Captain Urquhart's explanation that the absence of any district on the Earth which had been bombarded by the Meteors was satisfactorily explained by denudation, &c. Mr. Simmons in conclusion referred to the relative sizes of craters on the Earth and Moon, and to the circular as opposed to the elliptical form, which latter these lunar craters would have normally assumed if caused by bolides.

Captain Urquhart.—I must reply very briefly to some of the points raised. Mr. Tomkins admits that volcanic forces as we know them do not altogether explain the formations on the Moon, but he attributes such formations as Copernicus to internal forces of some kind. My argument is that the bombardment theory is the only one that satisfactorily accounts for the surface formations as we find them. Even if we admit the great cohesion in the material of the Moon's crust necessary to allow a formation of the size of Copernicus to swell out like a mighty bubble and then collapse, the existence of such tremendous forces in the already dying Moon requires, I think, a stretch of the imagination much greater than any allowed for in the bolide theory.

As regards the Revd. Mr. Ridsdale's objections, I did not mean to suggest that the volcanic forces on the Earth and the Moon would be directly proportionate to their sizes.

What I meant was, that volcanic action on the Moon would probably be less and not greater than that on the Earth; first owing to the absence of water in any very large quantities on the former, and secondly owing to a much less surface or crust resistance to the exploding force.

Mr. Ridsdale takes for granted that the Moon gently slid away from its parent Earth and has never exposed its "back" to bombardment; I, on the other hand, maintain that it most probably did revolve faster on its axis than it does now and that we have no valid reason to suppose that it ever formed a part of our Earth.

As to what he considers the unanswerable objection of mutual bombardment, the Moon no doubt did have an occasional shot at the Earth in its younger days, but such shots would never produce a vesuvius, but craters or depressions much deeper than any we find on the Moon, owing to the much greater velocity caused by the Earth's attraction, that is if the bolides escaped destruction in the Earth's atmosphere. But there can be no evidence of such depressions as they are covered by many thicknesses of stratified rocks.

I have already shown that any bolides shot out from the Earth well away from the line of centre would most probably fall back on the Earth, but here again any traces of such must be deep down in the crust, completely obliterated during early geological ages.

Mr. Tomkins allows that the Moon may have revolved faster on its axis in past ages, but he thinks it impossible that the Moon's poles could ever have been exposed to bombardment from the Earth for they never shift. In a recent issue of the Society's Journal appeared an article by Mr. Hart on the "Shifting Ecliptic," in which he showed how the Earth's poles in past ages pointed towards the Sun and will do so again in the distant future. Is it then impossible that the Moon may have similarly moved in relation to the Earth?

My previous remarks cover Mr. Simmon's objections. I quite admit that volcanic action took place on the Moon (and we have evidence of that in the crater cones), also that there must have been water present though not in any very large quantities, and no doubt a gaseous envelope, however tenuous, must have surrounded the Moon in the earlier stages of its cooling. Both Mr. Simmons and Mr. Ridsdale do not seem to realise that it is not the relative sizes of craters on the Earth and the Moon that constitute the main difficulty, but their actual structure. The "crater" on the Moon are depressions

in the surface (the floor in many cases being several thousand feet below the surrounding surface), whereas volcanic action forms a cone with a crater on top.

The meeting was then adjourned.

Reply to criticism on Captain Urquhart's paper on the Moon.

MR. TOMKINS' objections :—

(a) That the seas are almost similar in every respect to large flat-bottomed craters; and that, if bombardment is responsible for the latter, it must also have produced the seas.

The reply to this is—

(1) That we should expect large depressions on a globe to take a more or less circular formation.

(2) That the borders of the seas do not show a continuous rampart of a similar form to that surrounding the ring formations.

(3) That the surface of the seas show numerous relics of the earlier surface formations (*vide* Elger's "The Moon," p. 3), which shows that the older surface must have been depressed, probably owing to natural shrinkage of the globe, and its formations more or less obliterated by the overflow of the liquid interior. There are no signs of an earlier surface formation left in any of the large walled plains.

(b) That the great size of the bolides required to produce such formations makes it very doubtful if the Earth could ever have thrown them out, and that the supporters of the meteoric theory usually go outside the Earth to the Solar system for their meteorites.

I have already shown that there are at least two serious objections to the bolides having come from outside the Earth-Moon system :—(1) Such bolides would very seldom strike the Moon normally to its surface. (2) Their striking velocity would be much too great to produce formations of the kind we find on the Moon's surface.

The only objection that seems to me to have any weight is the doubt whether the Earth was capable of throwing out such huge masses. I have already shown that the size of the craters would be many times the size of the missiles which