The fossils of the Lower Lias Clay are not very plentiful; and the course of this clay is much hidden by drift; such shells as *Rhynchonellæ*, &c., are not, however, uncommon.

CORRESPONDENCE.

THE LUNAR SEAS.

To the Editor of the Geologist.

SIR,—When I commenced reading the first article in the last (the October) number of the GEOLOGIST—namely, that headed, "What has become of the Lunar Seas?" I expected to find that some attempt would be made in it to show that it was, at least, probable that seas did formerly exist on the surface of our satellite; and since astronomers concur to tell us that the moon is destitute of water, I cannot but think the expectation a reasonable one. But, reasonable or otherwise, it was doomed to disappointment, as the existence of such seas is quietly assumed, not only in the titular question but also throughout the paper. Thus we have (page 409), "When we look up to the moon, what do we see? Great ocean cavities and no water in them." (Page 410), "They do not tell us what *has become of the water* that once *was* in them," i.e., the so-called Lunar Seas. (Page 412), "*Then*" (when the moon was further from the earth) "it was it had its atmosphere and its ocean." (Page 414), "Doubtless the moon had once ocean and air," and "One thing, however, is certain, there are waterless ocean cavities on the moon." Now, I confess I should like to have some reason for the belief that any of the "waterless" cavities on the moon were ever "*ocean* cavities," or that at any time "the great *Oceanus Procellarum* was a rolling sea, and the *Mare Serenitatis* lay glittering under the golden streaks of our earth's bright beams," before even *speculating* on the question, "What has become of the Lunar Seas?"

But waiving this point, and assuming that there *were* formerly "Lunar Seas," on the simple grounds that, as Sir John Herschel tells us, "there are large regions perfectly level, and apparently of a decided alluvial character in the moon."* Why is it "of no use to say it is ALL gathered up on the other side"? A statement of the basis of this inutility would have been acceptable; some reply to the reasoning of Sir John Herschel on this point, for example.† Should we not be informed why "we cannot believe *that*?" Possibly, however, the basis of our alleged incredulity is supposed to be contained in the next passage. "The moon always presents one side to our earth, and therefore her ocean waters ought to be drawn up on this, and not the other side." Unfortunately, however, the fact stated will not carry the inference placed upon it. Even if the moon had been a perfect sphere, with its geometric centre coincident with its centre of gravity—which has been doubted—and having water distributed over its surface without any marked preference for either hemisphere; all other things being as now, *the earth's attraction* could not draw, or have a tendency to draw, her ocean waters all up on the side always presented to the earth; at most it could produce two oceanic protuberances diametrically opposed, one on the point of her surface nearest the earth, and the other at that most remote from it; in fine, two high water points, which, omitting the *librations* of the moon, would be stationary; since, in that case, the earth would appear immovably fixed in the heavens, as seen from any point on the moon's surface. Whilst, if the moon were so constructed that all her waters *were* gathered up on that side always turned away from us, the attraction of the earth would only

* "Outlines of Astonomy," 5th Edition, Par. 430.
† "Outlines," 5th Edition, Par. 436 *a*.

have the effect of slightly helping to keep them there, certainly not to transfer them to this side; and this not because of the intensity of the earth's attraction on the moon, but because of the *difference* in this intensity as exerted at her centre and at the surface remote from us; such *difference* enabling the earth to pull her satellite slightly away from the water on the remote surface.

But to proceed. Supposing it to be a fact that "we cannot say there is not a residual balance in favour of approach" (of the moon to the earth). Is it not making an unusually bold use of inability to infer from it that there *is* such a balance? But waiving this point also, and assuming, for the sake of applying a test to the *speculation*, that the moon "has once been farther off—very much farther off," it by no means necessarily follows that she has ever yet come "sufficiently within the influence of the earth's attraction" for "the waters of the moon to be transported to our globe." According to the hypothesis, the moon is at present nearer to the earth than at any former period, and, therefore, nearer than at the time of the deluge of the "*speculation*." Now there can be no great difficulty in determining whether the thing could happen at the present distance; that is, whether the earth's attraction on a body on the moon's surface, placed in the straight line joining the centres of the two globes (the most favourable position for the success of our world in the struggle), would be greater or less than the moon's attraction on the same body. In short, Is the earth's power, at present, to steal a "Lunar Sea" greater or less than the moon's power to keep it? If less now, then, *a fortiori*, according to the hypothesis, it must have been less in all former periods.

Let E be the earth and M the moon, A B the line joining their centres A and B, and C a body on the moon's surface in the line A B. Now the attraction of a body varies directly as its mass and inversely as the square of its distance from the body it attracts; such distance being measured from centre to centre.

Putting the earth's radius = 1, the distance of the centres is 60·2734, and the radius of the moon ·2729; hence the distance of the body C from the seat of the moon's attraction is, on this scale, = ·2729, and from the centre of the earth = 60·2734 — ·2729 = 60·0005.

Also, taking the mass of the earth as unity, that of the moon is ·011364.

Then, if A and A′ represent, respectively, the attraction of the earth and moon on the body C, we have

$$\begin{aligned} A : A' &= 1 \times \cdot 2729^2 : \cdot 011364 \times 60 \cdot 0005^2 \\ &= \cdot 0744744 : 40 \cdot 89375 \\ &= 1 : 549 \cdot 12. \end{aligned}$$

That is, in round numbers, the earth attracts the body 550 times less than the moon does; or whatever inclination our attractive influence may give a "Lunar Sea" to precipitate itself on us, the moon gives it 550 times greater inclination to stay at home; and according to the hypothesis, this disparity of inclination was still greater in earlier times, and the more so in proportion to the antiquity of the time.

But suppose the organ of Stay-at-home-ness—I think the phrenologists call it "Inhabitiveness"—to be so feebly developed in a "Lunar Sea," that it *would* proceed on its travels, is it certain that it would go to the earth? Why not to the sun? We are told (page 414) that "it is not likely." So I think. But let us see whether the earth or sun would hold out the greatest attractions at present for a "Lunar Sea" on its travels. It is simply the question, which of the two bodies attracts the moon most powerfully?

Let S, E, and M be the sun, earth, and moon respectively; and the last in conjunction with the first, as seen from the second. It will be sufficiently accurate for our present purpose to take the distance of the centres of the earth and moon as = 60 radii of the former body, the distance of the centres of the sun and moon

as = 23,984 times the same unit, and the mass of the sun at 359,551 times that of the earth; then, putting S and E to represent the attractions of the sun and earth on the moon, respectively, we have

$$S : E = 359551 \times 60^2 : 1 \times 23,984^2$$
$$= 80899 : 35952$$
$$= 9 : 4 \text{ nearly.}$$

So that the sun's claim to a visit from a "Lunar Sea" is greater than the earth's in the ratio of 9 to 4; and if the moon, according to the hypothesis, were formerly farther from the earth, she would be, by so much, nearer to the sun, when in conjunction; and hence the attraction of the earth on the moon would be less, and that of the sun greater, at all earlier periods.

Apologizing for the length of this letter, I am, yours, &c.,

Torquay, Oct. 12th, 1861. WILLIAM PENGELLY.

To the Editor of the Geologist.

SIR,—Although the subject of the introductory paper of the October number of your justly popular journal more properly belongs to the science of Astronomy than Geology, yet, as some few of your many readers may be led from it to form unjust views of a by no means improbable reason which has been assigned for the absence of both air and water in appreciable quantities in that portion of the moon's surface which has ever been subjected to our observation, I think I may be excused for offering a few remarks on this subject, more especially as they may suggest an answer to the query propounded, "Seeing there are waterless *ocean* (?) cavities on the moon, where have these waters gone to?"

It has long been a well-ascertained fact that the moon rotates on her axis, and performs her revolution round the earth in the same period of time; it is also well known that if a stick loaded with a heavy weight at one end and a light one at the other be swung round by means of a string attached to the centre of this stick, that the heavy end will in the circulation assume a position further from the hand than the light one (see Herschel's *Outlines of Astronomy,* last edition, chap. vii.), hence it has been suggested by Professor Hansen, that the same cause which makes the heavier end of the stick describe the larger circle may in all probability be the reason why the moon always presents the same, or at least very nearly the same face to our earth, or, in other words, why the time of rotation on her axis and revolution round our earth coincide, namely, that in the moon, as in the stick, the centre of gravity does not coincide with the centre of symmetry. Let us now see what effect this would have on the distribution of water and air on the surface of a globe, as, although neither our moon nor the earth are truly circular, the difference of the effect produced in a globe of exactly the same figure as these bodies would be so small as in no way to affect the truth of our deductions or their applications; then, first, let us take the case of a globe (fig. 1), in which the true centre, or centre of symmetry, and the centre of gravity coincide. In this case supposing the sur-

face of the globe to be smooth, it would be surrounded by a stratum of water, B, of equal depth all over, and this again by an atmosphere also of equal depth. As soon, however, as the smooth surface gets broken up and converted into heights and hollows, the water would betake themselves to the lower parts—that is, the parts nearest the centre of gravity—leaving the higher or more distant parts dry, these again covered with an atmosphere now of unequal depth, this varying with the height, that is, the distance from the centre of gravity of the different parts of the surface. This may be said to be almost the condition of our earth, varied by tides in the sea, and winds, &c., in the atmosphere: the cause of these is no subject for discussion here. Let us now suppose a globe (fig. 2) in which the centre of gravity, B, does not coincide with the centre of symmetry, A. Draw a diameter through these points (A and B) and prolong it to C; the laws of gravitation will in this case make all the waters belonging to such a globe concentrate about the prolonged diameter on the side of the globe nearest to the centre of gravity, and, provided the surface be altogether smooth, they will form a perfectly circular sea, D, deepest in the centre, gradually shallowing towards its circumference; this again overlaid by all the atmosphere, E, assuming in its outline in like manner a perfectly circular form and also deepest in the centre; inequalities in the surface of the globe will of course modify these appearances, but a sufficient distance between the centres will occasion that side of the globe most distant from the centre of gravity to be as destitute of water or air is that portion of the moon's surface which has ever been exposed to the investigation of our telescopes. Unite two such globes as in fig. 3. In which A, representing the earth, has its seas distributed all over its surface, the whole having an enveloping atmosphere, and B, the moon, having its centre of gravity, *x*, more distant from the earth than its centre of symmetry, B, then its water and air would take the form represented in the figure; and the moon always keeping the same side towards the earth, it is quite evident that her sea and her atmosphere could never be seen by an inhabitant of the earth. It is thus clear that no mountain ridges are required to keep the Lunar Seas from flowing towards the side next our earth, nor in this case would any of the visible inequalities there ever be able to retain the smallest appreciable quantity of either air or water.

Fig. 1.

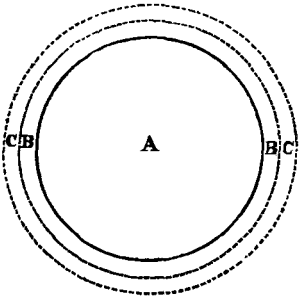
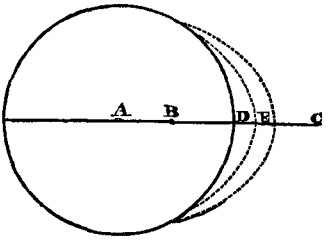


Fig. 2.

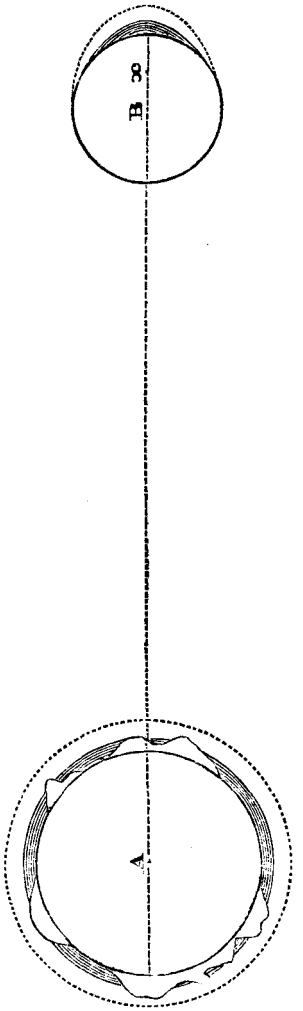


The effect of gravitation, as exerted by the earth on the waters of the moon, supposing it thus constituted, is by no means so readily understood; but strange as it may seem, it would only occasion such a tide in the Lunar Seas as would tend to increase their central depth; in other words, to heap up their waters in that part of the moon which lies most distant from the earth.

Even to the unassisted eye the surface of the moon showing different shades of colour, may suggest the idea of heights and hollows existing in that planet; the telescope proves the existence of mountain ranges generally of a circular form, and of large comparatively level plains, which at one time were supposed to be seas, and hence their names, "Mare Nubium," &c., &c. Modern observation proves that no waters roll in these seemingly arid wastes—in my opinion, the inquiry which here naturally suggests itself to the observer is not, what has become of the waters of these so-called seas? but, did waters ever exist in them? When examined

by telescopes of great power, such as Lord Rosse's magnificent reflector, the mountain ranges seem almost without exception to be of volcanic origin; generally circular, with a central valley, having again in its centre a small conical hill, they resemble most wonderfully our terrestrial volcanos; even the lava currents and volcanic stratification are in some clearly traceable, while neither on their rugged sides, nor on the enormous blocks which in one or two instances are visibly strewed over the flat bottoms of the central valleys, does the abrading power of water appear ever to have exerted its strength, even although these central valleys are mostly sunk below the level of the general surface. At the same time it is but just to state that large regions are also to be found perfectly level, and seemingly possessing an alluvial character, and in one or two cases mountain ranges which afford no proof of volcanic structure have also been observed.

Fig. 3.



Another question naturally suggests itself. Allowing that at one time seas rolled and rivers ran on the face of the moon presented to our earth, and that by some as yet unknown influence these waters had been abstracted from their original abode and drawn down through the opened windows of heaven in such enormous quantities that "all the high hills that were under the whole heaven were covered." What has now become of these waters? Why do they not yet prevail? They do not seem to have been returned to the moon.

Before concluding this short and imperfect notice, it may be right to state that even our earth, having, as may be readily seen by inspecting one of the common terrestrial globes, one of its hemispheres mostly covered with water, while on the other, land is in large excess, would indicate a slight difference between the true place of its centre of gravity and centre of symmetry. I may also state that in the case of a globe of the size and constitution of our moon (being rather more than 2100 miles in diameter), a distance of about forty miles between these two points would occasion the phenomena above referred to. It might also be a subject of no small interest to inquire into the appearances which a world constituted as the moon is thus supposed to be, would present to its inhabitants; but this, with many other interesting, and therewith connected discussions, belonging more properly to Astronomy, cannot be here entered into.

I am, your obedient servant,

Reswallie, 15th Oct., 1861. JAMES POWRIE.