X. *Notices of some Parts of the Surface of the Moon* By JOHN PHILLIPS, *M.A., D.C.L., F.R.S., F.G.S., Professor of Geology in the University of Oxford.*

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MY first serious attempts to portray the aspect of the moon were made with the noblest instrument of modern times, the great telescope of Lord ROSSE, in 1852. The mirror was not in adjustment, so that the axes of the incident and convergent pencils of light were inclined at a very sensible angle. This being met by a large reduction of the working area of the mirror, the performance was found to be excellent. I have never seen some parts of the moon so well as on that occasion. But when I came to represent what was seen, the difficulty of transferring from the blaze of the picture to the dimly lighted paper, on a high exposed station, with little power of arranging the drawing-apparatus, was found to be insuperable, and the effect was altogether disheartening. It was like setting down things *ex memoriâ*, to give the rude general meaning, not like an accurate and critical copy. I present as a specimen of this memorial a sketch of the great crater of Gassendi, marked No. 1. (See p. 344.)

I next mounted, in my garden at York, a small but fine telescope of COOKE, only 2·4 inches in the aperture; and, aware of the nature of the difficulty which beset me at Birr Castle, I gave it an equatorial mounting, without, however, a clock movement. The whole was adapted to a large solid stone pillar in the open air. It was not possible with $\frac{1}{60}$ of the (reduced) light of the ROSSE mirror to *see* so well; but it was easy to represent far better what one saw. A conveniently placed board to hold the drawing-paper, a well-arranged light, no necessity of changing position,—I made in this manner the drawing of Gassendi which is marked No. 2.

My next attempt was made in the same situation with a fine telescope by COOKE, of $6\frac{1}{4}$-inch aperture and 11 feet sidereal focus, mounted equatorially, in the old English mode, and carried by clockwork. With this excellent arrangement I was enabled to use photography very successfully, and to obtain selenographs 2 inches across in 5^s of time. The drawing of Gassendi (Plate XV. fig. 1) was made with this instrument (1853).

From these experiments the conclusion was obvious—that for obtaining good drawings of the moon convenient mounting was actually more important than great optical power; and that for such a purpose it was desirable to increase in every way the comfort of the observer, and furnish him with special arrangements for his own position and the placing of his drawing-board and light.

Having been called to reside in Oxford (1853–54), my plan for continual work on the moon was entirely cut through; it was impossible to mount a large instrument near my dwelling till (in 1860) the ground was arranged about the museum, so as to give me the requisite space and security close to the house which had been appointed for me by the University. I then arranged with Mr. COOKE for a new telescope of 6 inches aperture, to be protected in a well-planned observatory, the construction of which was aided by the Royal Society. I now propose to give a short notice of some of the results of my work with this instrument, in connexion with remarks on the most advisable course to be followed by other surveyors of the moon.

In making drawings of ring-mountains on different parts of the moon's disk, the artist will be much aided by a projection of the mountain-border on the scale intended, from a few measures, with its proper figure due to the latitude and longitude. Eye-drafts not thus controlled are apt to become absurd, by the heedless substitution of an ideal circle for a real ellipse. Thus I have seen Gassendi forgetfully represented in more than one skilful drawing. Even with the advantage of such a projection (of which I give an example for Gassendi, No. 5) very considerable difficulties occur. One is the variation of outline caused by the displacement of the boundary of light and shade, first when the incidence of light varies through different angles of elevation of the sun, and next when the moon's position causes her to receive the light at the point observed on a different lunar azimuth. Even on so great a ring as Copernicus the variation of the outline as given by different artists is remarkable—hardly any one agreeing with what is really the most accurate drawing of all, that by P. SECCHI; and that represents, not a simple ring, but a seven-angled outline. Dates must always be annexed to the figures; and as it is rarely possible to complete a good drawing of a large crater, except in two or three lunations or more, it becomes very essential that a bold free sketch be made of the moon's shadows to control the special work.

Strictly speaking, there should be at least three drawings of a ring-mountain—in morning light, at midday, and in evening. It would be better to have five drawings, one at sunrise and another at sunset being added to the three already named. It will be found most convenient to make the drawings within two hours of the moon's meridian passage.

Shadows thrown from objects on the moon have exactly the same character as those observable on the earth. They are all margined by the penumbra due to the sun's diametral aspect; this is always traceable except very near to the object; but in consequence of the smaller diameter and more rapid curvature of the moon's surface, the penumbral space is narrower. At the boundary of light and shade, on a broad grey level tract, the penumbral space is about nine miles broad, quite undefined, of course, but perfectly sensible in the general effect, and worthy of special attention while endeavouring to trace the minute ridges (of gravel?) or smooth banks (of sand?), which make some of these surfaces resemble the postglacial plains of North Germany, or central Ireland, or the southern parts of the United States, which within a thousand centuries may have been deserted by the sea.

To the same cause is due the curious and transitory extension of half-lights over some portions of the interior of craters, while other neighbouring portions have the full light. The effect is occasionally to produce half-tints on particular portions of terraces within the crater, as in the case of Theophilus, of which I present two drawings, one (Plate XVI.) showing this peculiarity in the morning light, the other (Plate XV.) not. The central mountains of that great crater are high enough to throw long shadows; and these, as they catch upon other peaks or spread, softening with distance, over the surrounding plains, present far greater variety of shadow-tones than might be expected on a globe deficient, as the moon really appears to be, of both air and water.

If we suppose the moon's mass to have been derived from an outer ring of the earth-nebula, and, following the analogy of the planets in reference to the sun, admit its composition to have been the same as that of the earth, we should have as the originally outstanding lunar atmosphere, only $\frac{0 \cdot 0114}{1 \cdot 0000}$ part of that which surrounds, or rather which at first surrounded, the earth. The surface of the moon being $\frac{0 \cdot 0726}{1 \cdot 0000}$ part of that of the earth, the *barometric pressure* of the atmosphere on the moon would be less than that on the earth, in the proportion of $\frac{0 \cdot 157}{1 \cdot 000}$. The *height* of the lunar atmosphere, taken in terms of the pressure at the surface of the moon, would be the same as that on the earth (5 miles $\pm$). The refractions would be less than on the earth, in the proportion of the function of density, but still very sensible, even in rude observations of occultations of stars.

In like manner the water due to the moon's mass, would have its depth on the moon diminished to $\frac{0 \cdot 157}{1 \cdot 000}$ of that on the earth. If we assume the water on the earth spread over its whole surface to be 1 mile $\pm$, that on the moon would be 829 feet, a quantity not so great as to preclude the possibility of its being accumulated on the surface opposed to us, especially if we remember that the inequalities of internal earth-movement have in fact occasioned the greater part of our oceans to be collected on one half of the globe, while nearly all the land appears on the other half. In reference to this subject the opinion of Hansen, that the centre of gravity in the spherical moon is removed from the centre of figure $33\frac{1}{2}$ miles in the direction from the earth, may be kept in mind. If it could be admitted, the oceans of water and air might be wholly collected on the remote half of the satellite. Moreover, it must be remembered that in the rocks near the surface of our planet both oxygen in oxides, carbonates, &c., and water in hydrates, are stored up in considerable quantities. We may suppose the process of volcanic incineration and aqueous absorption to have gone to greater extreme in the moon than on the earth, and so to have reduced the original atmosphere and the original oceans to very much smaller amounts. To judge by the absolute freedom from all change but that of degradation, which is observed on the visible disk of the moon, and by the perfect and perpetual clearness of its sharply defined mountain-bordered limb, cutting clear against the unbending rays of the stars, it would seem the most probable opinion that *now* at least there remains no visible trace of atmosphere or ocean.

The different parts of the moon's surface reflect light very unequally; the dark parts have several degrees of darkness, the light parts several degrees of light. On the same level, as nearly as can be judged, under the same illumination, neighbouring parts are not only unequally reflective, but their light seems to be of different tints. Within the large area of Gassendi, under various angles of illumination, but more conspicuously when the angle of incidence deviates least from verticality, patches of the surface appear distinctly marked out by difference of tint, without shadow. It is well known that in this particular photography has disclosed curious and unexpected differences of the light, which were not apparent, or not so obvious, to the eye. Reflecting telescopes seem to be indicated as most suited for direct observation of differences of the kind of light on the moon.

The surface of the moon is hardly anywhere really smooth, hardly anywhere so smooth as may be supposed to be now the bed of a broad sea on our globe. By watching carefully the curved penumbral boundary of light and shade,—as it passes over ridge and hollow, rift and plain,—broad swells, minute puckerings, and small monticules appear and disappear in almost every part. In several of the maria, minute annular cup-craters about half a mile across are frequent; and on several of the exterior slopes of the crater-rings occur pits, ridges, fissures, and rude craters, something like the sloping surfaces of Etna. Copernicus is a good example of this common occurrence. It appears extremely desirable that the details of this magnificent mountain should be carefully reexamined on the basis of SECCHI's fine drawing, for the purpose, amongst others, of determining exactly how many of the bosses and ridges bear cup-hillocks; for many inequalities, which in feeble telescopes have but the indistinct character of being heaped up, appear distinctly crateriform with superior optical power*.

For the purpose of determining the true form of the summits, and the outline of the sides of many mountains, the method of observation of the shadows at different angles of the incident sunlight will be found very useful. Thus, exactly as, in the clear evening hours, one standing on the summit of the Malverns sees the long shadow sweep over the vale of the Severn, and distinguishes the forms of the several beacons and intervening passes, so in the clearer moonlight, the shadows which fall within the craters, and stretch along the plains, often reveal the presence of angular escarpments and deep fissures as well as of peaky summits crowning steep walls of rock.

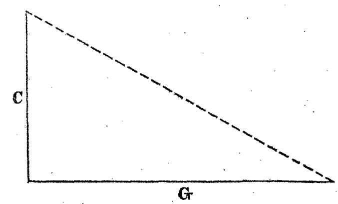
One of the circumstances which is thus often placed in evidence is the exceeding abruptness of many edges, and the uncommon steepness of many of the slopes. In particular, the interior edges of many ring-mountains appear with violently precipitous cliffs and chasms, more or less parallel to the general outline; while, more rarely, deep cross cuts in such situations appear to radiate within the ring, or to traverse its crest. An instance of the latter kind is found in Gassendi.

The steepness of the moon-crater walls and slopes is much greater in general than in any, except very rare examples, known among the volcanic regions of the earth. Popular descriptions are, in this respect, very misleading; and the word-paintings which please so much the gratified ear, lose their reputation for exactness when confronted by

* See "Comparative Remarks on Gassendi and Copernicus," Roy. Soc. Proc. for 1856, p. 74.

the clinometer. When, on the surface of the earth, we observe incoherent materials resting at a slope approaching 45°, we frequently remark some peculiarity of the separable masses which allows of mutual support, or observe that the usual atmospheric agencies, the ordinary changes of temperature and moisture, have had only a very short influence on a newly exposed surface. After a very long exposure, even hard and continuous rocks, such as those of Malvern, sink down to a slope of 18°; and it is chiefly under freshly wasting escarpments of softer strata that we see, as in Mam Tor and the west front of Ingleborough, anything approaching to the steepness of the moon-crater walls. So in the old volcanic regions of Auvergne and Mont Dor, the Eifel and even the Phlegræan fields, which may be the fittest for comparison with the crater-covered tracts of the moon, very steep slopes are almost unknown, except for small spaces of consolidated rocks, such as in the Puy de Dôme, Monte Somma, and the Drachenfels.

Perhaps we may refer the obviously greater steepness of some of the surfaces on the moon to the lesser influence of gravity on the satellite than on the earth. If in a given mass of matter, exposed to various causes by which cohesion is influenced, we represent by C (vertical) the residue of cohesive force, and by G (horizontal) the force of gravity, the slope from C to G will be the final surface, and $\frac{C}{G}=$ tangent of its inclination to the horizon. On the earth, the force of gravity being more than six times as great as on the moon, the tangent of inclination will be relatively less.



Also, if the degrading influences of all kinds on the moon be taken as very much less than on the earth, this again will relatively increase the angle of slope; so that we appear to have no difficulty in understanding why lunar mountains may be so much steeper and less worn than the objects most like them on earth. Perhaps the same general consideration of the greater relative value of heat and other molecular forces, when compared with gravity, on the moon than on the earth, may account for the much greater amplitude, and the generally greater elevation of the moon mountains; for it is only exceptionally that Chimborazo, Teneriffe, and Elburz ascend on the earth to so great a height as the loftiest lunar summits*.

On the very crest of a ring-mountain it is rare to find a cup-crater; quite common to find them in the interior, especially towards the middle, and, in several cases, exactly in the centre. But it happens often that the central mountain-mass of a large crater, such as Gassendi and Theophilus, is of a different structure. In the former a complicated digitated mass of elevated land appeared to me for a long time to be entirely devoid of any small craters; by continued scrutiny at last I see on one of the masses a distinct depression. The area in Gassendi reminded me of the volcanic region of Auvergne, in which,

* On the general relation of the moon's surface to volcanic tracts on the earth, see a graphic passage in Herschel's 'Introduction to Astronomy,' p. 229, Edition 1, 1833.

with many crater-formed mountains, occur also the Puy de Dôme, Puy Sarcoui, Puy Chopin, and others which are heaps of a peculiar trachyte not excavated at the top, while the others are formed of ashes and lava-streams, and are all crateriform. The central masses of Theophilus (Plate XV.) are very lofty and grandly fissured from the middle outwards, with long excurrent buttresses on one side, and many rival peaks separating deep hollows, and catching the light on their small apparently not excavated tops. This is like the upheaved volcanic region of Mont Dor, with its radiating valleys, wide in the central part, and contracted to gorges toward the outside of the district.

The Vesuvian volcanic system, including the Phlegræan fields, exhibits, in all respects but magnitude, remarkable analogy with parts of the moon studded with craters of various sizes, as those adjoining Mount Maurolycus, engraved for comparison by Mr. Scrope in his admirable treatise on Volcanos (p. 232). It is probable that many of the differences which appear on comparing lunar ring-mountains may be understood as the effects of long elapsed time, degrading some craters before others were set up, and turning regular cones and cavities into confused luminous mounds. It would much augment our confidence in the possible history of the moon which these differences seem to indicate, if we could believe it to have ever been under the influence of atmospheric vicissitudes as well as changes of interior pressure.

That the latter cause has been in great activity at some early period of the moon's history is evident, not only by the many sharply cut fissures which range like great faults in our earthly strata for five, ten, twenty, and sixty miles, but is conspicuously proved by the great broken ridges of mountains which, under the names of Alps, Apennines, and Riphæan chains, make themselves known as axes of upward movement, while so many of the craters near them speak of local depression. I have not been able to discover in these great ridges any such marks of successive stratification, or even such concatenation of the crests, as might suggest symmetrical and anticlinal axes. The surface is, indeed, as rough and irregularly broken as that of the Alps and Pyrenees, and marked by as extraordinary transverse rents, of which one, in the Alpine range near Plato, is a well-known example. Must we suppose these mountains to have undergone the same vicissitudes as the mountain-chains of our globe—great vertical displacement, many violent fractures, thousands of ages of rain and rivers, snow and glacial grinding? If so, where are the channels of rivers, the long sweeps of the valleys, the deltas, the sandbanks, the strata caused by such enormous waste? If the broad grey tracts were once seas, as analogy may lead us to expect, and we are looking upon the dried beds, ought we not to expect some further mark of the former residence of water there than the long narrow undulations to which attention has already been called as resembling the escars of Ireland?

Among other curious phenomena probably referable to movement of the solid crust of the moon, are those long, straight, winding, or angularly bent fissures or cracks which the Germans call 'Rillen.' The distinctness of these cracks for such great lengths as some of them reach is consistent with extreme narrowness; very narrow spaces, strongly contrasted in brightness with the neighbouring surfaces, being easily traceable, if continuous, where much broader tracts of a square or circular figure cannot be discerned. This is familiar to persons who trace by the eye the far extended narrow telegraph wire. But more than this. The rills are, under favourable lights, seen to be really fissures with one dark and one enlightened side—deep dark fissures. Rills of this remarkable character do not appear to be branched; and in this respect the long rill of Hyginus, marked on MÄDLER'S map for ninety-two miles, may be compared with the great North of England dyke, which extends from Teesdale to near the Peak on the coast of Yorkshire, seventy miles, without a branch. Contraction, rather than violent movement of the moon's crust, seems to suit best the facts observed; and the same explanation may be fairly applied to most of the fissures filled with whinstone in the coalfields of Durham and Northumberland. Still the straight rill near Tebit (called the Railroad), nearly on the central meridian of the moon, bears the appearance of dislocation in the shadow thrown by one side.

The rill which descends from Herodotus is of a different but equally remarkable character. Parting from that dark crater—full perhaps of augitic compounds, in strange contrast with its neighbour Aristarchus, which shines as if formed of white trachyte—the rill takes a winding course with some irregularity of width and appearance, till it opens into what resembles an old delta, or dried gulf, margined by cliffs, and undulated by recesses and promontories. The delta-like space is uneven, like the bed of the German Ocean. Still, there are appearances in this seeming valley and outlet to an ancient sea, which can hardly be reconciled to the conjecture. The rill has no branches; in the middle of its course is an oblong crater which makes a part of the seeming channel; and thus this falls into the general rule which makes the rills dependent on the craters, so as to pass commonly, but not always, from one crater to another, and often to traverse them through the ring and athwart the interior space (Plate XVII.)*.

A very different class of phenomena may also be referred to some change of dimensions or some displacement of masses affecting large surfaces of the moon. These are the light-streaks which, from Tycho in particular, radiate, like false meridians, or rather like meridians true to an earlier pole of rotation. Other light-streaks pass off from Copernicus and Kepler, and several other mountains, but none are comparable to those from Tycho. There is this singularity about them; they are most distinctly visible in the full moon, and for some days before and after that phase. When the light falls at a low angle on the part of the moon's disk where one or more of these rays exist, they do not appear; as the sunlight strikes at higher and higher angles they come out bright and clear, again vanishing as the lunar evening comes on.

By the strictest examination these luminous bands are found to have no projection above and no depression below the surface, no shadow on either boundary. They can be traced across what look like seas, and equally traverse the crateriform mountains, continuously; sometimes branching, often varying in breadth. On a first view they seem

* See additional notices in the Supplement.

like a system of radiating fissures, and Mr. NASMYTH very ingeniously imitated their direction at least by a glass globe filled with water, which was made to crack in a nearly regular manner from a centre. But their great and unequal width, their entire want of relief, and the peculiarity of their reflexion of light, seem to point to some other cause. The reflexion seems to be of the kind called "metallic;" perhaps metals or metalloids may there be covered by a translucent crust, which may reflect light of low incidence, but transmit light of higher incidence, to be reflected from the surface below. This is the nearest conjecture which has occurred to me.

The parts of the moon's surface to which I have devoted most time are the ring-mountains of Gassendi and Theophilus. The sketches here given of Cyrillus and Catharina (Plate XVI.), are only first though not careless drawings, in which are omissions, which I hope at some future time to supply. Rather more progress has been made with Posidonius, Aristarchus, and Herodotus. I have also begun to sketch the large and noble group which lies to the south of Ptolemæus, and it is my earnest hope to be able to finish these drawings as well as to complete a good deal of work on the Rills.

In any further attempts of my own to contribute facts toward the survey of the moon, now again taken in hand by the British Association, I shall probably select for careful work some particular features, such as the mountains in the midst of a large crater, the bosses and cup-like hills on the outward slopes of such a crater, the rents in mountain-ridges, and the low winding banks which appear on the broad grey tracts. But for those who desire to perform a work of high value, and lay a sure foundation for accurate surveys of particular mountains, I would earnestly recommend a strict reexamination of every element in the great picture of Copernicus, for which we are indebted to the Roman Astronomer.

The descriptions which follow relate principally to Gassendi and Theophilus.

Gassendi (Plate XV.), whose centre is situate nearly in Lat. S. 16° 56′ and in Long. E. 39° 32′, has the long diameter of its apparently elliptical boundary inclined to the equator about 64° 30′. Measured in this direction, the ring has a diameter of forty-eight miles; the shorter diameter is about thirty-six. Sunrise happens when the moon is 10·5 days old, midday at about eighteen, and sunset at twenty-five days. In consequence of its position on the moon's disk, shadows usually fall from elevated objects a little toward the south.

At the instant of sunrise on the central peaks, the whole of the exterior ring is enlightened, except for a few miles on the south border, where the crests are low and divided (18th May, 1853, 10 P.M.). As the early morning advances, very broad shadows from the western border spread over the interior, and bring out in every part a mingled effect of unequal height and unequal reflective power of the surface. When the moon is eleven or twelve days old, the interior appears everywhere diversified by lights and shades, nowhere smooth, but marked by ridges and hollows in various directions. Within the great ring in all the S.W., S., and S.E. portions are broken ridges, not terrace edges, separated by considerable depths from the great encircling crest. Toward the northern part there seems a sort of confluence of small ridges from the interior, directed toward the spoon-shaped crater, marked A on MÄDLER's map. The mouldings of the surface of this very deep crater are best seen when the moon is a day older.

Directing our attention to the central mountain-mass, we perceive it to be divided into many digitated parts, each diversified by lights and shades, so as to resemble, more than anything which I remember, dolomitic or trachytic mountains. On their several peaks I have sought carefully for the concavities which might indicate former eruptions, but only on one of them, a little removed from the rest, do I feel sure of this occurrence.

Through these central mountains can be drawn a crescent concave to the S.E., and along it occur four small craters, three of them rising separately in the area, and the one already mentioned near to the eastern slope of the central mountain.

The ring of Gassendi, everywhere rugged and fissured, is broken through in one place completely, in another less distinctly, both in the south part of the contour, so as to open the area to Mare Humorum. In several other places it sinks between points greatly elevated. The highest point is on the east border (9000 feet according to MÄDLER), where a sort of lacuna, rather than crater, occurs in the middle of the crest; nearly opposite to this ridges detach themselves both outwardly and inwardly from the western border.

The north-eastern edge is cut across by three oblique narrow clefts, and the northern border is deflected by the concurrence of the ring of the smaller crater. The country round Gassendi is very ridgy and mountainous in the east, where it is pressed up, as it were, to the great peak and the lacunal crater. This is not the case on the west, which side is much lower. On the south, in Mare Humorum, are many small craters not yet mapped. On the north, in the high grounds leading to the old degraded crater of Letronne, are a few craters apparently of older date than Gassendi.

As the daylight advances, and especially at midday, much of what has been described disappears from sight; but Gassendi, in consequence of its ridges usually having some shadow toward the south, does not lose distinctness in the same proportion as Ptolemæus and the craters near the centre of the moon.

When the sun is on the meridian of Gassendi, the peculiarities of its surface in reflecting light appear conspicuous. Within the south border is a broad dusky space, apparently not much undulated, and resembling the dark parts of the Maria. This space sometimes appears interrupted by a cross band of comparative brightness. A darkly tinted space can also be seen in the N.E. No luminous rays stream from Gassendi. In the afternoon, the appearances described in the morning are discovered, as far as the main features are concerned, with shadows in the opposite direction; but the views have not appeared to me so interesting, nor is the terrestrial hour (early morning) for observation so convenient.

Theophilus, Cyrillus, and Catharina (Plate XVI.), situated south of the equator from

10° to 20°, and in west longitude 21° to 28°, form a remarkable triplet of ring-mountains nearly equal in magnitude, and in contact, yet offering singular differences of structure. They are not of the same date: Theophilus intrudes its continuous outline within the northern part of the older crater of Cyrillus; Cyrillus is linked to Catharina by a concave isthmus; Catharina includes the half-preserved ring of an older and smaller crater. In the centre of Theophilus is an aggregation of peaks; in the same part of Cyrillus is a huge double-horned mountain, and near it a considerable crater; neither of these features occurs in Catharina.

Theophilus, situated in lat. S. 10° to 13° and long. W. 25° to 28°, though nearly circular in figure, shows some diversity in this respect according to the incidence of light, being sometimes almost hexagonal. Copernicus also exhibits this diversity.

The longest diameter of Theophilus is above fifty-five miles in length. Sunrise happens when the moon is 5·2 days old, midday when about 12·7, and sunset at twenty days.

At sunrise the central mountain and all the surrounding ring are brightly illuminated, only narrow channels of darkness running into Cyrillus. But the interior of the crater is then wholly dark, except for a small breadth within and under the eastern crest (1863, April 24). When the sun's rays fall at a low angle on the surface of Theophilus, the shadow thrown from the lofty western crest (15,000 feet high) spreads widely over the interior of the deep crater, and is undulated on the edge so as to mark the effect of higher and lower parts of the crest. Between this shadow and the base of the central mountain the area appears clear like a floor; but beyond this, toward the north, east, and south, all is curiously uneven in heapy little ridges, and long partly fissured surfaces parallel to the ring. I can discern only one distinct crater in this surface, and that is under the north-eastern part of the ring, but there are several smaller pits. Perhaps larger instruments may show that some of the small heaps and ridges have cups on their surface.

To the central mountain (Plate XV.) I have given much and frequent attention, for the purpose of ascertaining the form of its much divided mass, and of discovering whether it contained any cup-formed summits. None were observed among the ten or more bosses which go to make up the rugged mass, elevated about 5000 feet above the central area.

When the sun's rays fall with less obliquity on Theophilus, the part which was wholly in shade under the western crest assumes a quite different aspect—many bold ridges and furrows showing themselves distinctly with light falling at 15° elevation. Some of these appear in the lower part of the figure in Plate XVI., but they really exist all round the inner and western part of the crater.

The phenomena which appear where Theophilus joins Cyrillus, are extremely curious and complicated, not in the least like as if one cone of volcanic eruption had intruded its convex sloping surface within another, but rather as if one great blister had pushed aside another and then burst, leaving a sort of double folding along the line of junction.

Cyrillus varies greatly in appearance, according to the direction of the incident light. The interior is largely rugose, as if ridged and furrowed by lateral pressure. In particular the great double central mountain appears in the two drawings here given (Plate XV. and Plate XVI.) with a difference of outline very remarkable; as well as a difference of shadows, for which, however, the sun's position may perhaps account. The eastern border is remarkably rugged and broken, so as to become indefinite. The crater is unenclosed both to the south and north. Catharina seems to contain traces of more than one old crater enveloped and partly obliterated within it. It is incompletely bordered, or complicated in the boundary on all sides, and open or unenclosed on the south and north. If we regard Catharina and Cyrillus as twin craters of old date, broken into by Theophilus, we may admit the space full of old ridges and hollows to which Cyrillus opens, on the east of Theophilus, as a third and still older, once crateriform, mass which has lost almost every trace of the large ancient ring. In the same way the triplet of larger mountains entitled Arzachel, Alphonso, and Ptolemæus, seem to have been connected, Ptolemæus being the oldest, largest, and least distinct. These mountains, indeed, may be regarded as part of a vast crescent of 60° arc, extending from Barocius and Maurolycus, by Stöffler, Walter, and Regiomontanus, to Purbach, Arzachel, Alphonso, Ptolemæus, and Hipparchus. In each of these cases the oldest mountains, those most degraded and ruined, are near the equator. These are among the greatest of all the lunar mountains.

Another arc, more directly meridional (long. W. 60°), includes the very great rings of Furnerius, Petavius, Vendolinus, and Langrenus, whose diameters are about 5° of lunar latitude. The more degraded and probably the older of these are those nearest the equator.

In various parts of the moon occur twin mountains which do not communicate with one another; as Aristarchus and Herodotus, one light the other dark; Hercules and Atlas; Autolycus and Aristillus; Eudoxus and Aristoteles; Mercator and Campanus. Indications of this kind of symmetry or continuity of action in the old volcanic force, appear worthy of special study, in relation to the physical history of the moon.

Explanation of Plates.

PLATE XV.

Fig. 1. Gassendi, as seen in morning light.
Fig. 2. Theophilus and part of Cyrillus, morning light.
Fig. 3. The central mountain-mass of Theophilus enlarged.

PLATE XVI.

Group of Theophilus, Cyrillus, and Catharina.

PLATE XVII.

The twin craters of Aristarchus and Herodotus, with the rill proceeding from the latter. Several small craters on the side of the rill and about the seeming delta are omitted. The crater edge of Aristarchus appears to me a double crest, with a narrow deep chasm between the ridges. R. The rill from Herodotus. E.W. Borders of the seeming delta. *r*. Smaller rill.

The memoir was accompanied by several other drawings, which it is the intention of the author to present to the Royal Society for reference. The following is a List of these illustrations. Nos. 1, 2, 4, and 5 are referred to in the Memoir, pages 333 and 334.

No. 1. Sketch of Gassendi, taken in 1852, at Birr Castle, with the great telescope of Lord ROSSE (morning).

No. 2. Sketch of Gassendi, taken in 1852, at York, with an achromatic by COOKE, of 2·4 inches diameter (morning).

No. 4. Sketch of Gassendi, taken in 1862, at Oxford, with an achromatic by COOKE, of 6 inches diameter (evening).

No. 5. Working Plan of Gassendi, and Scale.

No. 6. Freehand sketches to illustrate the mode of working for general effect. Oxford, 1864.

No. 10. Posidonius, early morning, 1863. Unfinished.

No. 11. Posidonius, nearer to midday, 1863. Unfinished.

SUPPLEMENT.

Received May 23, 1868.

SINCE the preceding remarks were presented to the Royal Society, I have had the opportunity of reading the valuable memoir of J. F. J. SCHMIDT, the Director of the Observatory at Athens, entitled "Über Rillen auf dem Monde," 1866, and of comparing the maps of some parts of the moon which accompany his essay with my sketches. I rejoice to see how large an increase to the known number of rills has been made by this experienced observer, aided by the favourable "clearness of the Athenian climate."

In my sketch of Aristarchus (Plate XVII.), the principal purpose was to show the sharp-edged double western crest and the internal broad moulding. In the character of the double crater-wall SCHMIDT'S Map agrees with my drawing, and extends this feature to the eastern side.

There is less agreement in the shape of the interior surface, on which I have bestowed much attention, first with the 3-foot mirror of Lord ROSSE (power 200), next with my long achromatic at York, and finally at Oxford with my 6-inch COOKE. The country lying to the north of Aristarchus has been five times drawn by me, often with difficulty, for the appearances are very variable, with small differences of light. My results agree in general with that of the Athenian astronomer, and with an earlier map published by MÄDLER in 1837. I hope to complete a drawing of this tract.

In Plate XVII. Herodotus and the famous rill from it are merely sketched freely, to show the general course of the rill, and its opening into a seeming delta. The eastern border of the seeming delta (*E*) is treated as a rill by SCHMIDT and MÄDLER, and so it has always appeared to me in the part marked *r*, which turns up to the south so as to be rudely parallel to the first or main part of the rill from Herodotus, and seems to begin under a crest of mountain. The smaller notch in this outline (at *E*) has only been noted once. The western branch (*W*) is not marked as a rill by SCHMIDT, but may be traced on his map as a kind of coast by the line of the promontories, and so traced agrees with my outline. I propose to complete the drawing of this part of the moon in the next summer.

Plate 2 of SCHMIDT'S memoir contains map-sketches of rills lying east of Campanus, which I have also drawn. The appearances in this region differ somewhat from the map of MÄDLER, and the rills in particular are very interesting from their number, general parallelism, partial concurrence, and distinct relation to small and large craters.

In a third plate of the same memoir is a diagram map of Gassendi, and the region to the south, which may be compared with my drawing, Plate XV. fig. 1. The agreement is quite satisfactory in the general sweep and breaks of the border, the digitated central mass, the small craters in the area, the complexity of the eastern crest and slopes.

There is some difference requiring reexamination in regard to the sculpture of the interior, and the linear inequalities, some of which are marked as distinct rills by SCHMIDT. I shall take an early opportunity of making a careful study of the points of difference.

SOUTH

GASSENDI.
after Sunrise.
1852. 1853. 1863.

Fig. 1.

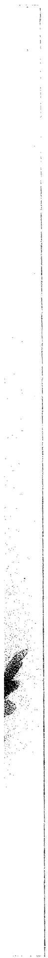
WEST

Scale of Geographical Miles.

THEOPHILUS & part of CYRILLUS.
25 March 1863. 8.p.m. Power 200 - 400.
Moon's Decl. N. 22. 7. Sun's Decl. N. 1. 44. Age 6. 23 days.

Fig. 2.

THEOPHILUS 24 April 1863.
Power 300 - 400.



EAST

ril 1863.

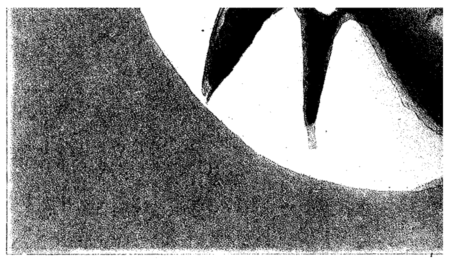
.00.

Fig. 3.

0 10 20 30 40 50 60

Scale of Geographical Miles

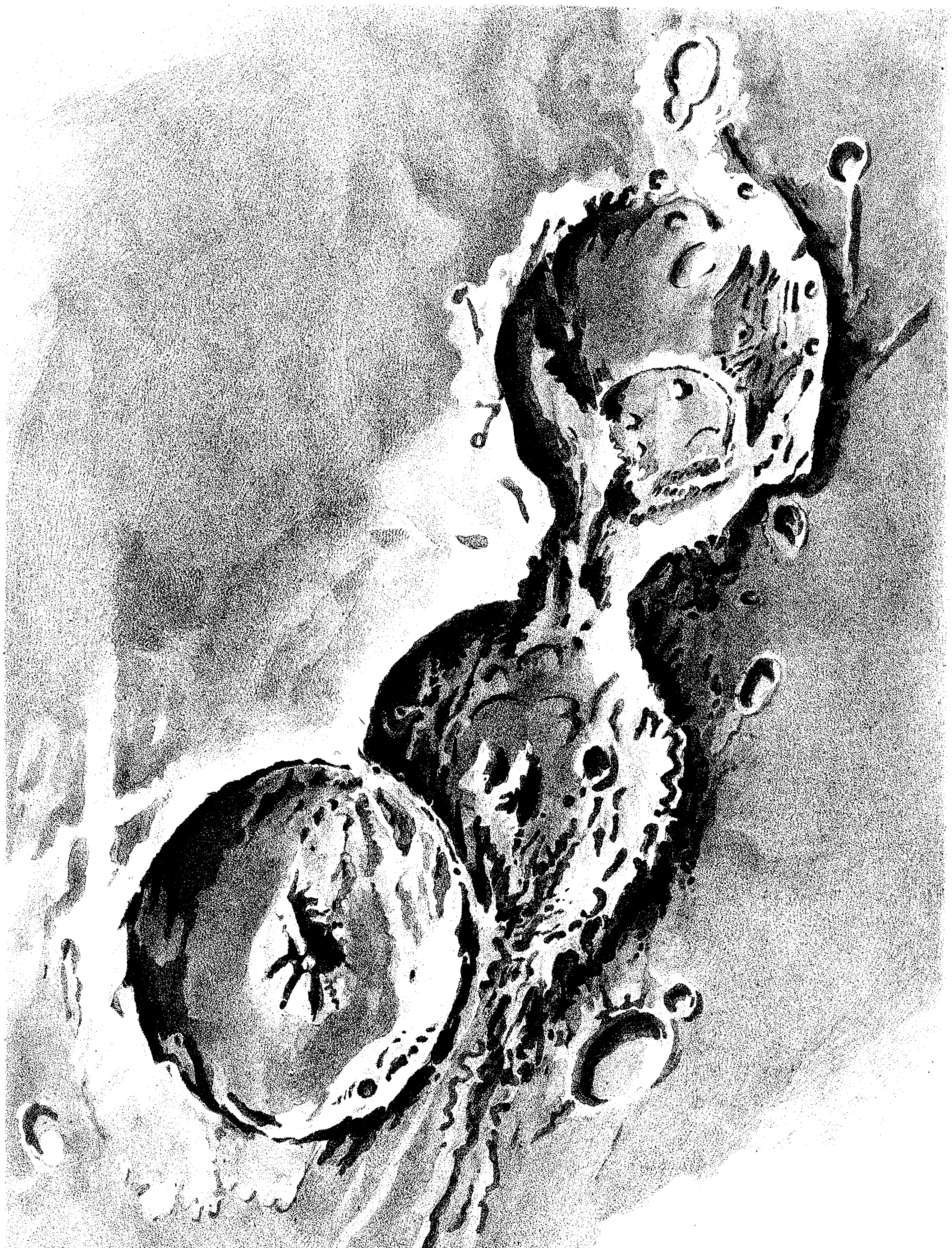
NORTH



Engraved by J. Basire.

SOUTH

WEST



EAST

NORTH

W.H.Wesley, lith.

J. Phillips, del.

SOUTH

WEST

EAST

NORTH

W.H. Wesley, Lith.

J. Phillips, del.

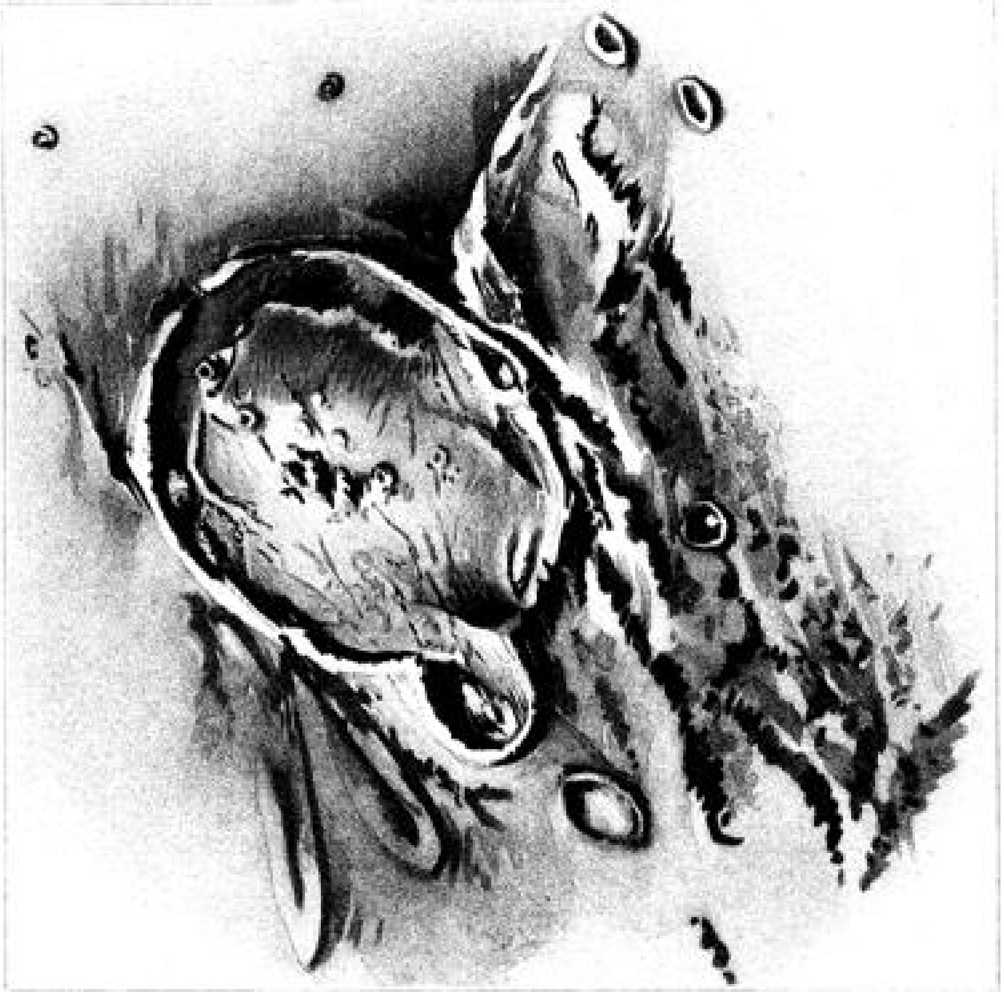
J. Phillips.

SOUTH

GASSENDI.
after Sunrise
1852. 1853. 1863.

Phil. Trans. MDCCCLXVIII. Plate XV.

Fig. 1.



WEST

Scale of Geographical Miles

EAST

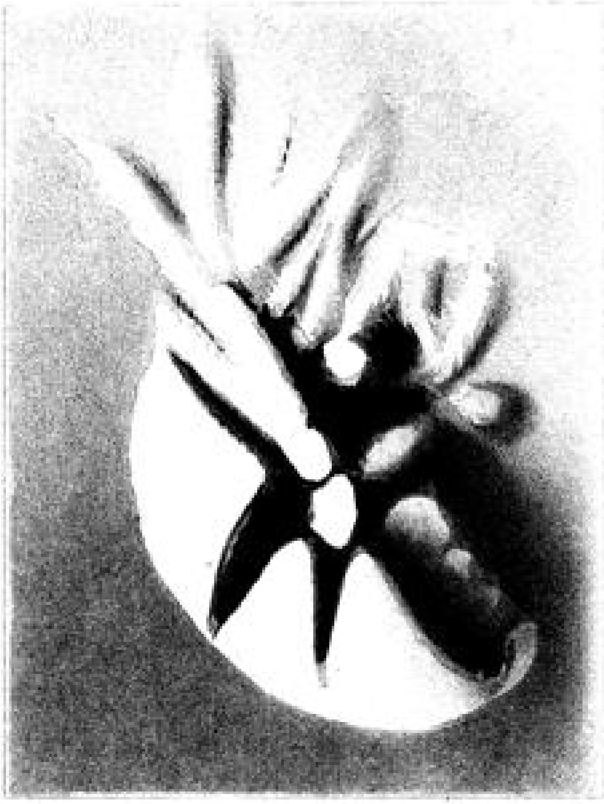
THEOPHILUS & part of CYRILLUS.
25 March 1863. 8 p.m. Power 200-400.
Moon's Decl. N. 22. 7. Sun's Decl. N. 1. 44. Age 6.23 days.

Fig. 2.

Scale of Geographical Miles

THEOPHILUS 24 April 1863.
Power 300-400.

Fig. 3.



NORTH

Engraved by J. Basire.