Mare Orientale: the Eastern Sea in the West – Discovery and nomenclature

Richard Baum & Ewen A. Whitaker

The history of the discovery of the great impact feature on the Moon known as the Orientale basin is traced from its partial recognition in the eighteenth century to its identification and naming by the German astronomer Julius Heinrich Georg Franz sometime before 1906, through to Hugh Percival Wilkins who made the first detailed visual study in 1937, and the observations of Samuel Morris Green in the period 1938–1939. Some account is also given of later developments in the saga of its nomenclature and the eventual recognition of its true physical character.

Newcomers who take more than a casual interest in scanning the surface of the Moon by reference to post-1961 maps, may well be perplexed by this apparent anomaly of nomenclature, and justifiably ask for enlightenment. There is of course no error, no mistaken conception of orientation. East has long been identified with the direction of the rising Sun (Latin, 'oriens'), and west with the direction of its setting (Latin, 'occidens' – falling). So from our geocentric perspective, features such as Aristarchus, Gassendi and Grimaldi lie on the eastward half of the lunar disk; Mare Crisium, Atlas, Endymion etc., on the western half (Figure 1).

This logical convention first appears on William Gilbert's (1540–1603) 1600 manuscript drawing of the full Moon, on which Mare Imbrium is labelled 'Regio Magna Orientalis', and the combined Maria Serenitatis/Tranquillitatis/Fecunditatis area 'Regio Magna Occidentalis'.[1] This convention remained uncontested until the advent of the Space Age, when it became confusing to have the Sun rising in the west on the Moon – and indeed on other Solar System bodies with prograde rotation. Accordingly in 1961 the International Astronomical Union (IAU) approved a recommendation that: 'Astronautical maps, for direct exploration purposes, are printed in agreement with ordinary terrestrial mapping, North being up, East at the right and West at left.[2]

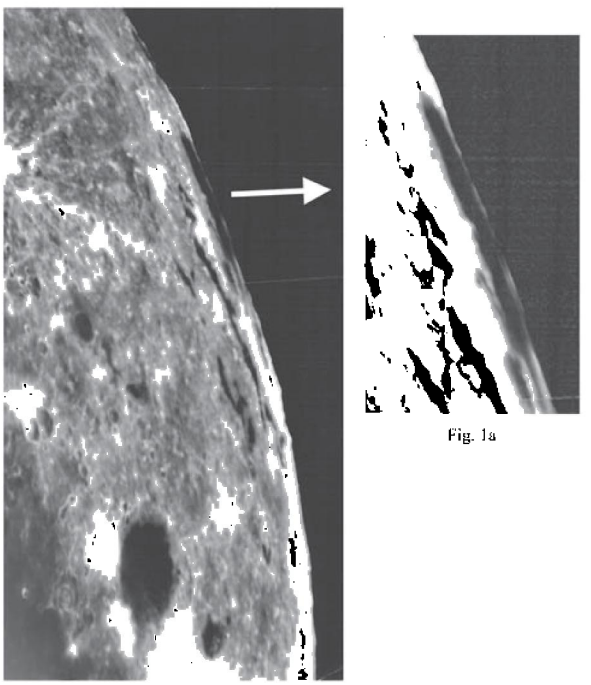

Fig. 1a

Figure 1. Mare Orientale. **1a**, Detail on farside of basin – Inner Rook Mountains. South uppermost. *(John Fountain/Denis Milon)*

(Author Whitaker attended that Congress, and can recall thinking that ten years of self-indoctrination that 'Grimaldi is east, Smythii is west' now had to be unlearned and reversed. Even after 45 years as a selenographer bound by the new convention, it is still necessary to think twice about E–W directions on our satellite.)

The fact that Mare Orientale is so named indicates that it received its name prior to 1961, since it straddles the traditional east limb beyond Grimaldi at about 20° South latitude (Figure 2).[3] But when did it receive this name, and from whom; indeed, who first actually observed the feature? Thanks largely to detailed imagery by the lunar orbiter, *Zond*, and the *Clementine* missions, we now know it is about the size of M. Humorum, centred in a remarkable and much larger system of concentric escarpments, the Orientale Basin. Because of the almost pristine condition of the whole basin and ejecta blanket, it is by far the best example available to us of the effect of the impact of an asteroid-sized body on a rocky planetary surface.

However, its location in the libratory zone means that it is presented for earth-based observation only at infrequent intervals, i.e. when both favourable libration and illumination happen to coincide. Even then, the strong foreshortening makes interpretation difficult, and the Sun has very little azimuthal motion with respect to features in the equatorial regions, thus differing from the polar areas where the Sun illuminates features from a wide range of azimuths.

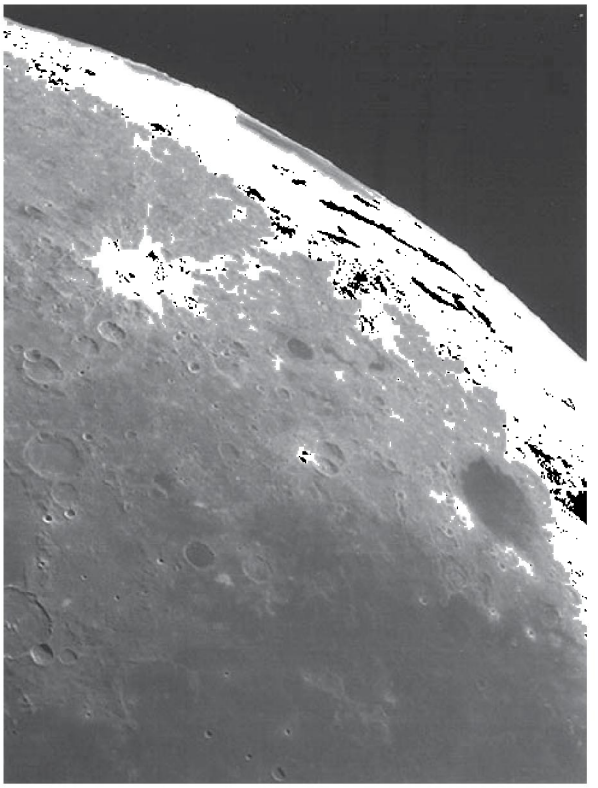

Figure 2. Mare Orientale. 2003 October 19 2305 UT, 10-inch f/7 Cave with Starlight Xpress HX 516 and 13% ND filter. Seeing Ant.III. This panoramic image of the Mare Orientale in relation to Gassendi and the southern portion of the Oceanus Procellarum was taken by Ed Crandall, Winston-Salem, North Carolina, USA. South uppermost.

First observations of the region

It is hardly surprising therefore, that not one of the early lunar maps, including the detailed 1679 map of Jean Dominique Cassini (1625–1712) and the carefully drawn 1750 Tobias Mayer (1723–1762) map, shows any indication of either the mare or the basin. One might expect that Johann Hieronymus Schröter (1745–1816) observed this area, and indeed he includes no less than 20 drawings of it in his *Fragmente*,[4] but only two of these include near-side detail, i.e., features close to the limb that are visible at mean libration. The remainder depict high mountain peaks rising from the limb beyond and south of Grimaldi, either as observed after Full Moon at a variety of librations in longitude, or silhouetted against the Sun's disk during an eclipse. He was sufficiently impressed by these many isolated peaks to name them Montes D'Alembert, and two large peaks further south, Montes Rook. In the introductory text he notes that he here found 'sehr hohen Mondcordilleren'[5] which suggests that he also observed actual chains of high mountains, presumably parts of the basin's escarpments. Following Schröter's example, all figures in this paper have south uppermost.

We reproduce a drawing of his made on 1788 September 24 at 4.15 a.m., 5.5 days before New Moon (Figure 3). At this phase, which is about two days after last quarter, there are no shadows in the limb regions, and the features n, o, p, q, r and s show as dark surface markings, which is exactly how Schröter describes and draws them.[6] Comparison with Earth-based photographs strongly suggests that what he observed and recorded here was the northern segment of what is now named Lacus Autumni, with s being a small section of Lacus Veris visible over the lower peaks in this segment of the current Montes Rook.

One final feature of this general region Schröter observed and drew is a prominent crater with a well defined central peak (Figure 3, insert), lying directly between Grimaldi and the limb. He measured its diameter as about 54 arcseconds – 100km or so (modern value 89km) – and noted that 'because of its location it is seldom visible'.[7] He named it 'Malvasia', but as we will see, it has since received two other names and two other designations.

John Russell RA, (1745–1806) an accomplished artist, was a contemporary of Schröter, but is much underrated as a selenographer. He produced a lunar map (without any names), a full Moon depiction, and a lunar globe in the 1797 to 1806 period.[8] An examination of the first two of these revealed that they both show notable detail in the region of interest (Figure 4). The two lines of dark markings lying above and to the right of Grimaldi immediately catch one's attention. Could one of these be the one observed and drawn by Schröter? Were Russell and Schröter delineating the dark markings at the same time? The latter began serious lunar observing in the winter of 1787–1788.

Writing to Thomas Hornsby (1733–1810), Savilian professor of astronomy at Oxford and founder of the Radcliffe Observatory there, on 1789 February 19, Russell tells how as a young artist: 'About twenty-five years since, I first saw the Moon through a telescope, which I now recollect must have been about two Days after the first Quarter; you will conclude,' he continued, 'how much struck a young Man conversant with Light, and Shade, must be with the Moon in this state; especially, as I was not taught to expect such clearness and expression, as is to be found near and upon the indented Edge.' A few days later he made a small drawing, 'but the

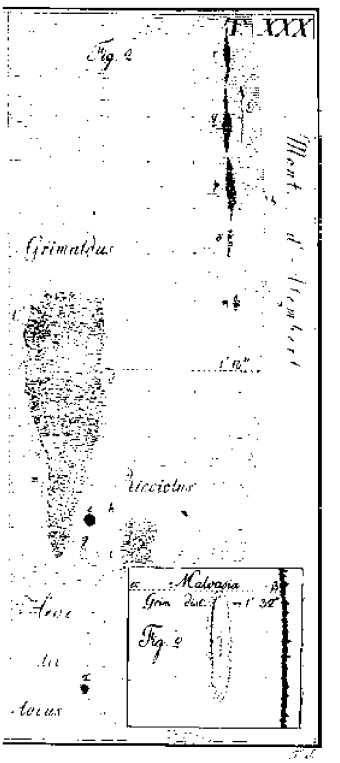

Figure 3. J. H. Schröter, *Selenotopographische Fragmente I* (1791), Plate XXX (part of) showing two lines of dark fleck limbwards from Grimaldi, 1788 September 24 at 4.15 a.m. Insert from Volume 2 of the same work, Plate LXIV, the crater 'Malvasia'. South uppermost.

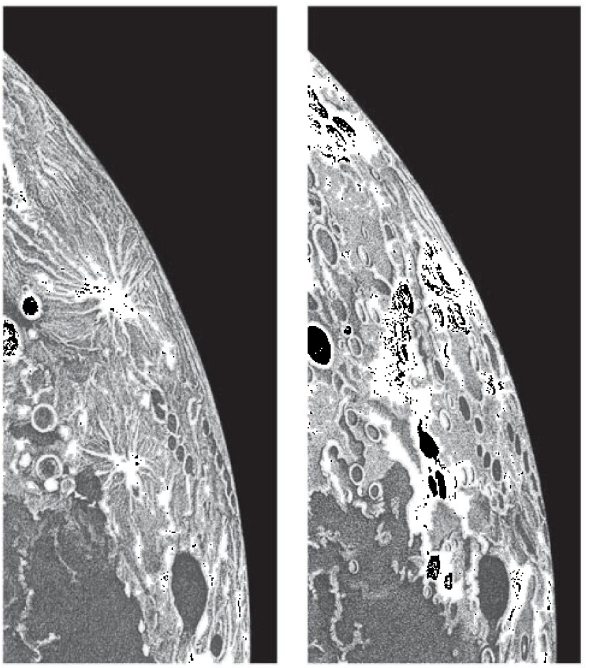

Figure 4. Portions of John Russell's full Moon and map engravings of the Mare Orientale area. South uppermost.

Moon being at the Full, I was not struck in the same manner, and I made no more attempts, till an accidental possession of a powerful Glass awakened my attention to this beautiful Object once more, and for several years I have lost few opportunities when the Atmosphere has exhibited the Object of my study and imitation.'[9] His main body of serious work seems to have begun in 1785.

He apparently used two telescopes, one a six-foot Herschellian reflector of six inches aperture probably acquired no earlier than 1782, since Herschel did not start to make telescopes to order before that date. The other instrument, which Russell preferred over the reflector, and which he used at low power, was a small Dollond achromatic given to him by his friend and fellow Academician John Bacon (1740–1799), the sculptor. It was provided with a micrometer, with which he took all his own measurements.[10]

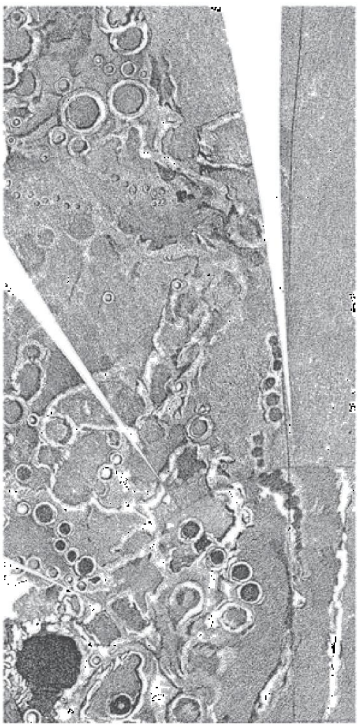

Figure 5a. Mosaic of parts of Russell's globe gores of the same area as Figure 4.

Identifying the map features with confidence is almost impossible, mostly due to foreshortening. This prompted Whitaker to see whether the globe might reveal more detail. Luckily he has Xerox copies of some unused original map gores that were intended for one of the globes, so he made second generation copies of the traditional east limb that lies south of the equator and assembled parts of them into a mosaic (Figure 5A). A flat surface is not a globe, of course, so gore edges diverge with increasing distance from the chosen 'polar' point. Russell placed the poles of his gores at the east and west points where the lunar equator and mean limb intersect, rather than the standard terrestrial practice of having them converge at the north and south poles.

The gores produce some surprises

It immediately became clear that these gores include much detail that is not present in the map. The next obvious step was to compare Russell's portrayal of the area with modern Earth-based photographs, including some that had been rectified by optical projection of whole-disk lunar positive images on to a 36-inch diameter matte white precision hemisphere.[11] Also consulted were the *Clementine* and relevant *Orbiter 4* images, plus a map in Lambert equal area projection by Antonín Rükl[12] of the entire lunar hemisphere centred on the same point as Russell's gores.

The results of this comparison are shown in Figure 5B, which is a simplified interpretation of the limbward half of Figure 5A with a few well-known landmarks included for orientation. This may be compared with Figure 5C, which is based on a tracing from the Rükl map for positional purposes, but with simplified modifications made to include only those features portrayed in Figure 5B.

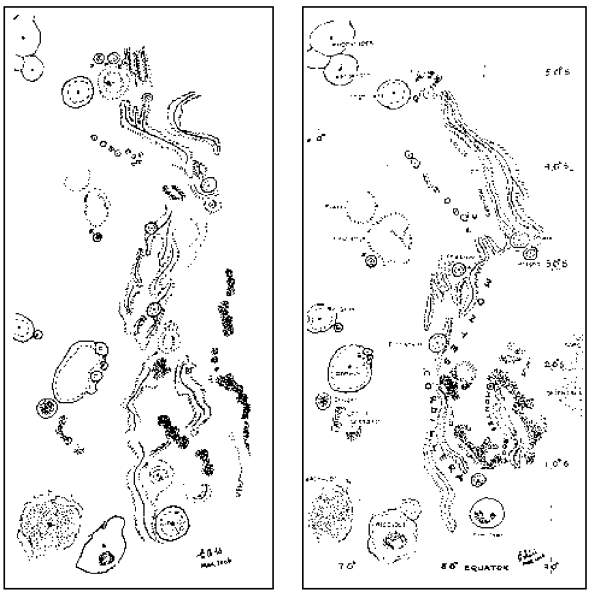

Figure 5b *(left)*. A simplified diagram derived from 5a. **5c** *(right)*. Diagram of features shown in B based on the Rükl map. South at top.

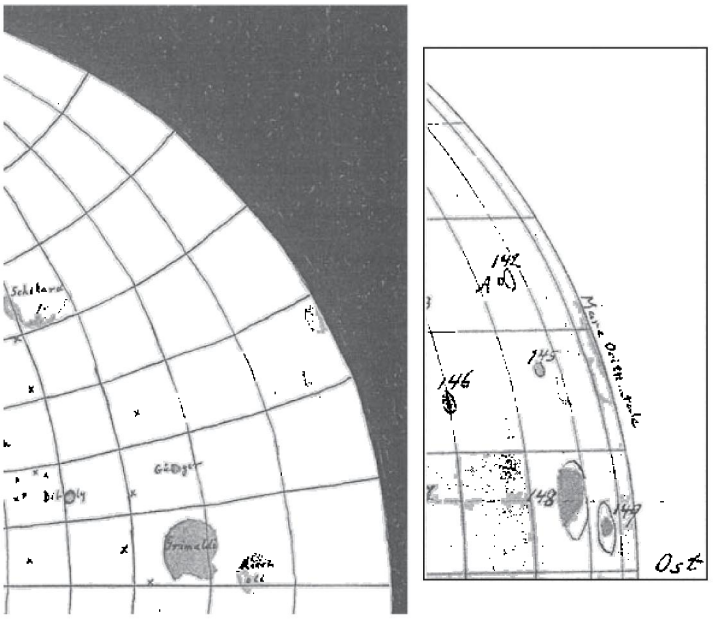

Figure 6a. *(left)*. Portion of Franz's 1903 stereographic chart. **6b** *(right)*. Portion of Franz's 1906 small orthographic map. South at top.

This comparision proved to be a total revelation; not only had Russell portrayed the dark surfaces with considerable accuracy, but he had also included the intervening mountain ranges, and even a chain of irregularly shaped small craters lying between Vallis Bouvard and Piazzi-Lagrange. Considering that Russell had to convert earth-based drawings into vertical views, without any measured anchor points in this area, it is remarkable how well his mapped features correlate with reality.

There is nothing to suggest the markings were seen by the Dresden surveyor/cartographer Wilhelm Gotthelf Lohrmann (1796–1840). Only four sections of the chart he planned appeared in his lifetime, the remaining 21 being published by Johann Friedrich Julius Schmidt (1825–1884) in 1878.

The *Mappa Selenographica* of Wilhelm Beer (1797–1850) and Johann Heinrich Mädler (1794–1874) was produced in four parts, each a quadrant of the lunar disk. Quadrant 1, which covers the area now in focus, was published in 1834, the remainder appearing in the following two years; it does not depict the dusky patches Lacus Autumni and Lacus Veris, although the small dark areas just north of Crüger are indicated. Eichstadt crater and Schröter's 'Malvasia' ('Riccioli b' on this map, but plotted 2° too far north) are shown, also a continuous range of mountains, named 'Cordilleras' after Schröter's lead, that stretch between these two craters. This range, plus more segments south of Eichstadt and extending to about 30° latitude, are drawn concave towards the limb, and would undoubtedly form a quasi-semicircular arc if rectified to a vertical view. The map also includes and names Montes Rook and Montes D'Alembert as projections on the limb. The text goes into some detail about the topography of the whole area, but does not mention the existence of any dark patches.[13] The 1876 map of Edmund Neison (1849–1940), generally follows that of Mädler, again without any hint of dusky patches, and shows topography that is less easy to interpret. The 1895 map of T. G. E. Elger (1836–1897) is equally bereft of detail indicative of a hidden sea; a fact of some significance as subsequent generations of British selenographers used it as their basic source of reference.

The dark areas rediscovered

J. F. J. Schmidt, in the *Erläuterungsband* to his large 1878 map notes that on '1854 Jan. 18. A distance east of the ray system of Byrgius lie grey flecks indicating a *mare*, which have already been noted by Schröter.'[14] His map, however, shows no indication of these flecks.

Apart from this brief reference, Russell's detection of the various dark patches of *mare* material apparently went unnoticed until the German astronomer Julius Heinrich Georg Franz (1847–1913) announced, 'Also on the Eastern limb between –15° and –30°, several new conjoined seas are intimated, which I found with the telescope.'[15]

At that time, about 1901, Franz was engaged in a programme of measuring selenographical positions on five lunar negatives taken at the Lick observatory and one from Potsdam. Two of these displayed the western *maria* (Smythii etc.) under very favourable librations, causing him to take measurements of many points on their boundaries. His results are accompanied by a small key map in stereographic projection on which Maria Marginis, Smythii, Spumans and Undarum are plotted using his measurements (Figure 6A); the first and last two names were coined by Franz. He notes that the eastern maria are 'only roughly indicated as I propose to place these more accurately when I am investigating the east limb.'[16]

In Franz's 1906 book *Der Mond* we find another small map, in orthographic projection this time, with the name Mare Orientale indicating the main dark mare (Figure 6B). The name is also mentioned in the text while describing his 'girdle of seas' (an allusion to his ideas about the topography of the far side of the moon): 'On the east side of the Moon I also discovered ... new *maria*, among them the large extended Mare Orientale, at –90° longitude, –14° to –22° latitude, and beyond that a southerly disconnected portion that overlaps the limb.[17]

Franz also received 26 more plates for measuring purposes, and his final tables and maps are to be found in his *Die Randlandschaften des Mondes* published in 1913.[18] In this he not only maps the dark areas, but also gives coordinates for various identifiable points on their boundaries and provides new names for these 'seas' (Figure 7), viz. Mare Veris, Mare Aestatis, Mare Autumni and Mare Hiemis, obviously after the four seasons, plus Mare Orientale. The first four were included in the IAU's official *Named Lunar Formations* (NLF) (1935),[19] but Mare Orientale was not included because its centre is situated outside the 90° mean limb meridian.

The decision was to have unforeseen circumstances. Mare Orientale featured on small general maps in popular works

such as Richard Schurigs' *Himmels-Atlas* (1909 edition)[20] and Ernest Debes' *Kleiner Mond Atlas* (1922),[21] both published in Germany, and in Federico Sacco's *Schématique de Sélénologie* (Turin, 1907), however the observing arm of the twentieth century British school of selenography with its reliance on the works of Beer & Mädler (1834–1837), Neison (1876), Elger(1895) and Goodacre (1930) was largely unaware that Franz had already charted and named the Mare. The exceptions were T. L. MacDonald, (third Director of the Association's Lunar Section, 1938–1946), and almost certainly Mary Blagg, S. A. Saunder, A. N. Neate, D. W. G. Arthur and others who shared Franz's interest in the accurate measurement of position and height. Walter Goodacre (1856–1938), second Director of the Lunar Section (1896–1938), may have had suspicions of something unrecognised in the area of interest, but his 1930 book *The Moon* is remarkably quiet on the matter.[22] Hence it is understandable, indeed perfectly reasonable, for a novice of that school on sighting Mare Orientale and finding it unmapped, to assume credit for its discovery. Even so, historical truth automatically disqualifies all claims except the one that has proven priority in terms of how the word 'discovery' is strictly defined. This in no way diminishes the importance or value of a later independent report which must perforce reflect great credit on its author and testify to their observational skill; rather it reduces the status of the observation to that of a self-discovery – of something one unwittingly brings to attention in all good faith without the influence of prior realisation or knowledge of earlier discovery.

The situation changed in 1937 with the publication in this *Journal* of 'The Lunar Mare X' by Hugh Percival Wilkins (1896–1960), later to become Director of the Lunar Section.[23] 'Under conditions of extreme libration', he said in the opening paragraph, 'a large, very foreshortened, dark plain appears on the south-east limb of the Moon, extending from 10° to 30° south latitude, between the plain marked Mare Veris (International Map) and the limb. Its brightness is almost equal to that of the Sinus Roris or the lighter portion of the Mare Serenitatis, and is strongly contrasted with the general brilliancy of this part of the surface... This region is imperfectly shown on the existing maps. The greater part of the plain is beyond the limb in mean libration, and in order to confirm and detect further details, observations should be undertaken when extreme libration occurs just before full Moon, so that the mountainous east border shall be presented in profile on the limb.'[24]

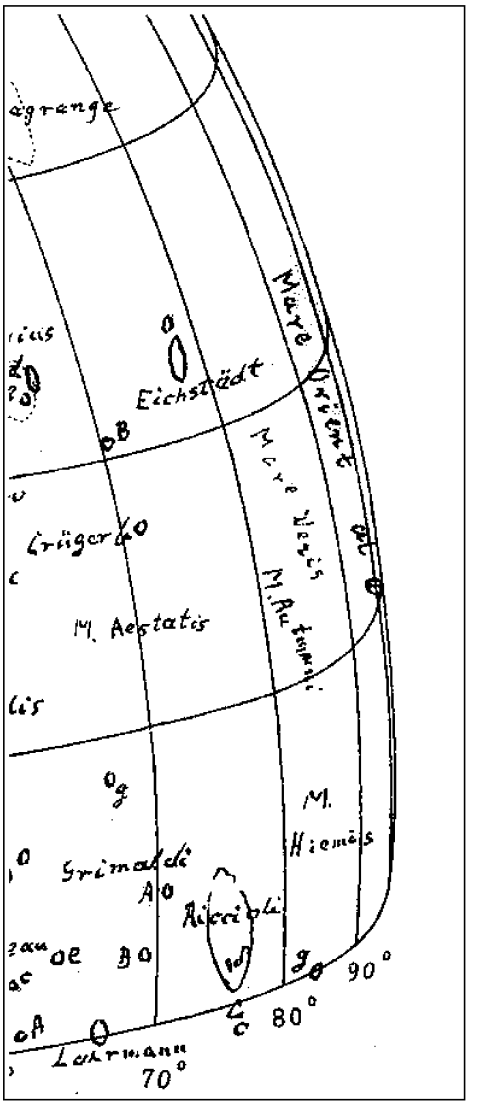

Figure 7. Portion of Franz's 1913 final map. South at top.

A drawing and a chart based on his findings accompany the paper, and mark Wilkins as quite probably the first to chart the feature in any detail, though not its discoverer.

In commenting on the paper Walter Goodacre noted, 'On Schmidt's map and my own (Section XX) there are indications of a large unnamed foreshortened area which corresponds closely with Mr Wilkins's drawing, and if this identification is correct, the sketches reveal the existence of a number of objects associated with this area which have not hitherto been recorded.'[25] Ill-health obliged Goodacre to step down as Director of the Lunar Section early in 1938. His successor T. L. MacDonald in discussing the work of the Section drew attention to the aforementioned paper: 'Mr H. Percy Wilkins had published a paper in the *Journal* early in the session describing an almost new Mare, which was mainly on the invisible hemisphere. This had only been described once before, by Franz, who named it the Mare Orientalis.'[26] Franz actually called it Mare Orientale, but H. P. Wilkins perpetuated MacDonald's error by subsequently referring to the feature as the Mare Orientalis.

Others now followed Wilkins' lead. Under date 1938 August 10, the young British amateur Samuel Morris Green (1921–1944) noted, 'This interesting Mare, drawn by H. Percy Wilkins ... was a prominent object on the S.E. limb, and the terminator was probably a little further east than in Wilkins' drawing.' He again observed on 1939 December 25 at 23h. 'Drawing was made independently of other records and much detail is hard to reconcile ... The Mare dilates into a widened bay on the east, on the floor of which lie two hills ... Further north the Mare narrows rapidly and ends near a big peak on the limb.'[27] Subsequently the region was examined by Keith W. Abineri and Patrick Moore, and later charted by Abineri.

At the 1948 and 1952 IAU General Assemblies, the name 'Mare Orientalis', along with many others proposed by Wilkins, was not given any official recognition, the reason being that: '...the formations to which he [*i.e.* Wilkins] wishes to attribute these names are, in general, small or observable close to the limb, under mediocre conditions. Most of them are already designated by letters, which were adopted by the IAU as being definitive.'[28]

Wilkins resubmitted his proposals to Commission 16 of the 1955 IAU Assembly in Dublin, but after some general discussion, William Herbert Steavenson (1894–1975), a prominent BAA member, proposed the following resolution which was passed unanimously: 'The Commission recommends to the Union that at the present time – and particularly pending the completion of the proposed photographic map of the Moon – no official recognition shall be given to additional lunar nomenclature.'[29]

The preparation of the above mentioned *Photographic Lunar Atlas* (1958–1960)[30] at Yerkes Observatory was a project initiated by Gerard Peter Kuiper (1905–1973), who invited D. W. G. Arthur (one time Secretary of the BAA Lunar Section) and Whitaker to participate in its production. This included making some necessary small corrections to nomenclature data as given in *Named Lunar Formations* in response to the much greater and improved coverage afforded by photography then available. At that time, we decided that the name Mare Hiemis should be deleted from the 1935 IAU list, as this was merely a small arcuate patch of dark material on the floor of a prominent 90km diameter crater – it was in Schröter's 'Malvasia' (NLF names the crater Riccioli A). At the same time, the name Mare Orientale was reinstated since it was a major feature and overlapped the mean lunar limb.

During the preparation of the *Rectified Lunar Atlas* (1961–'63),[31] at the Lunar and Planetary Laboratory, University of Arizona, Arthur and Whitaker added 66 new names and made several more amendments. Arthur renamed Malvasia crater 'Schlüter'; this and all the other amendments and additions were accepted by the IAU in 1964.

Mare Orientale reveals its true identity

A very important 'discovery' stemming from this programme of rectifying lunar photographic images by projecting them onto a white hemisphere was the fact that Mare Orientale is ringed by two very prominent concentric mountain ranges or scarps, the outermost one corresponding with Mädler's 'Cordilleras'. The discovery was made by William K. Hartmann who with Kuiper introduced the term 'multi-ring basins' to define such features, and went on to study this and the other nearside basins, publishing the results in 1962.[32] Maria Autumni and Veris were shown to be lying just inside the outer and inner rings respectively of the Orientale basin.

It is not without interest to point out that the multi-talented Harvard College professor Nathaniel Southgate Shaler (1841–1906), had in part anticipated Hartmann, for in a letter dated 1872 September 25 printed in the *Harvard Annals* he notes, 'The study of the border regions of the moon has shown that there are mountain ranges on the extreme edge, the Rook mountains, and other masses, which are undoubtedly the bordering walls of large craters. The above-named mass is probably part of the wall of a crater having a diameter of several hundred miles; we may infer with safety that it extends, or once extended, far beyond the visible region.'[33]

Shaler, a distinguished American geologist, also drew attention to 'certain very faint rays which appeared to point to centers of radiation on the unseen side of the moon.'[34]

The multiple imagery of the Orientale basin and its surroundings provided by *Lunar Orbiter 4*, both in the angles of illumination and viewing, illustrated in remarkable detail the structure of 'the bullseye', and resulted in a plethora of studies. Kuiper was so impressed by its appearance that he proposed the whole formation be renamed Mare Annulatum, i.e. ringed sea. However, at this time the question of how to name the entire formation arose, since 'mare' traditionally referred to smooth, dark-floored, quasi-circular dark areas. Much correspondence ensued, with designations such as 'thalassoid', 'arena', and 'basin' being proposed. Here is a direct quote from a memorandum dated 1969 May 8, in which Donald Menzel (1901–1976), chairman of the IAU Lunar Nomenclature Working Group writes: 'We recommend that Montes Cordillera be redefined to completely encircle Mare Annulatum on the outer perimeter, bounding Annulus Concordiae, and that Montes Rook be also defined as a circle lying between Lacus Pacificus on the interior and Annulus Concordiae on the outer.'

So this would re-name Mare Orientale as Mare Pacificus, the whole basin out to Montes Cordillera would be named Mare Annulatum (even though only the central area is true mare), and Mare Autumni would be lost in Annulus Concordiae. This brought immediate protests from both Arthur and Whitaker, and the next memo from Menzel, dated 1969 July 15 includes the following: 'We have agreed that the central part of the great formation should retain the name Mare Orientale. We have agreed to change the names of Mare Veris and Mare Autumni to Lacus Veris and Lacus Autumni. Mare Aestatis becomes Lacus Aestatis. We define Montes Rook as applying to the circular mountains bordering Mare Orientale. We recognize that this border is not entirely complete, but it is clearly part of the same basic system and therefore deserves the same name. The same applies to Montes Cordillera, of the outer boundary of the same formation. These apply to the whole ring.'

At the 1970 IAU convention in Brighton, these proposals were passed without further dissent. So, after quite a chequered history since its first detection over two centuries ago, the Eastern Sea remains in the west.

Acknowledgments

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Notes and references

1 For detail see Ewen A. Whitaker, *Mapping and Naming the Moon: A History of Lunar Cartography and Nomenclature*, Cambridge University Press, 1999, 10–13. A fuller account is to be found in Ewen A. Whitaker, 'Selenography in the seventeenth century', in *The General History of Astronomy 2A*, *Planetary astronomy from the Renaissance to the rise of astrophysics, Part A: Tycho Brahe to Newton*, Cambridge University Press, 1989, 119–143. William Gilbert was physician to Queen Elizabeth I.

2 *Trans. IAU. XI B,* 235 (1962)

3 Mare Orientale, located at 20°S latitude and 93°W longitude, looks like a target ring bull's-eye, and is one of the more spectacular large scale features on the Moon, but is difficult to observe from Earth because it is located on the extreme western edge, and straddles both the near and far side. The mare is defined by three concentric ring structures; the outer, the Montes Cordilleras, has a diameter of 930km; the inner rings are the Outer and the Inner Montes Rook, which have diameters of 620 and 490km respectively. The Mare Orientale is about 3 billion years old and was probably formed by the impact of an asteroid-sized object. The collision caused ripples in the lunar crust which resulted in the three concentric ring features, while magma flooded the impact site creating the dark smooth region we call a mare.

4 Johann Hieronymus Schröter, *Selenotopographische Fragmente zur genauern Kenntniss der Mondfläche*, two volumes, the first published in 1791, the second in 1802.

5 *ibid*. 1, 414

6 *ibid*. 1, 426

7 *ibid*. 2, 368

8 E. J. Stone, 'Note on a Crayon Drawing of the Moon by John Russell, R.A., at the Radcliffe Observatory, Oxford', MNRAS **56**(3) 88–95, 1896. See also 'A Portrait-Painter Who Studied the Moon', *The Illustrated London News*, 1930 October 18, 673–674 (extracts from the Stone paper but with additional illustrations). A major study is W. F. Ryan, 'John Russell R.A., and Early Lunar Mapping', *Smithsonian Journal of History*, **1** (1966), 27–48 (hereafter Ryan). See also *Daily Telegraph,* 1995 August 16, in relation to an exhibition of his work at Guildford House Gallery, Guildford, late summer 1995.

9 Cited by Ryan, 28. Original in Museum of the History of Science, Oxford.

10 H. C. King, *The History of the Telescope,* London, 1955, 126–127

11 See ref. 32.

12 A. Rükl, *Maps of Lunar Hemispheres,* 1972, map 4.

13 W. Beer & J. H. Mädler, *Der Mond*, 1837, 339

14 J. F. J. Schmidt, *Charte der Gebirge des Mondes: Erläuterungsband*, 1878, 271

15 J. H. G. Franz, 'Der West-Rand des Mondes', in *Mitt. der Kön. Univ. Sternwarte zu Breslau*, **2** (1903), 32. Franz is one of the unsung heroes of selenography. The son of a physician, he studied mathematics and natural sciences in Halle and Berlin. By 1876 he was observer at the Royal Observatory in Königsberg, and in 1892 was appointed extraordinary Professor. Five years later he succeeded Galle, the optical discoverer of Neptune, as director of the observatory at Breslau. Though he published numerous papers on measurements of comets, asteroids and double stars, his main work was on the figure and libration of the Moon. With the heliometer at Königsberg he accurately measured 150 points across the surface of the visible hemisphere. Computations based on these results enabled him to accurately define the figure of the Moon, and in 1899 he published his *Die Figur des Mondes* which contains a small scale map showing elevated and depressed regions of the surface. His most important work is 'Die Randlandschaften des Mondes' (1913). In this he describes the positions of limb formations measured from plates taken at the Lick and Paris observatories. These results were employed in the IAU *Atlas of Named Lunar Formations*. In 1882 Franz led the official German expedition to observe the transit of Venus from Aiken, South Carolina.

16 *ibid*., 49

17 J. H. G. Franz, *Der Mond*, 1906, 90. The 'portion that overlaps the limb' shows at the top of Figure 1. It was named 'Mare Pacificus' by the Soviets, but the *Orbiter 4* images show that it is not a mare but a doughnut-shaped dark surface deposit that mantles mountains and other terrain types.

18 J. H. G. Franz, 'Die Randlandschaftendes des Mondes', in *Nova Acta. Abh. der Kaiser Leop-Carol. Deutschen Akademie der Naturforscher*., **99**(1), 1–99 (1913)

19 M. A. Blagg & K. Müller, *Named Lunar Formations,* London, 1935

20 P. Götz, 'Tabulae Caelestes Continentes Omnes Stellas Caeli', *Richard Schurigs Himmels Atlas*, Gaeblers Geographisches Institut, Leipzig, 1909

21 E. Debes, *Kleiner Mond Atlas,* H. Wagner & E. Debes, Leipzig, 1922

22 W. Goodacre, *J. Brit. Astron. Assoc.,* **48**(2) (1938), 81–82. Note added to the paper by H. Percy Wilkins cited in Ref 24.

23 Patrick Moore, 'Obituary: Hugh Percival Wilkins', *J. Brit. Astron. Assoc.*, **70**(5) (1960), 237–238

24 H. Percy Wilkins, 'The Lunar Mare X', *J. Brit. Astron. Assoc.,* **48**(2) (1938), 80–81

25 *ibid.*, 81–82

26 T. L. MacDonald, *J. Brit. Astron. Assoc*., **48**(7) (1938), 270–271

27 T. L. MacDonald, 'Obituary: Samuel Morris Green', MNRAS, **105**(2) (1945), 91–92. Dr Green, an observer who showed considerable promise as a selenographer, was killed in action with the British Liberation Army on 1944 June 6 – D-Day. Harold Hill obtained Dr Green's 12-inch mirror. H. P. Wilkins reports Green's observations of the Mare Orientale in some detail in the eleventh Report of the Lunar Section, *Mem. Brit. Astron. Assoc.* **36**(3), (1950 July), 27–29, and refers to the observations by Abineri and Moore.

28 *Trans. IAU*. **7**. (1948), 166 & 169. Schröter's 'Malvasia' was renamed 'Lowe' by Wilkins, but the name became just another casualty of the resolution.

29 *Trans. IAU*. **9**. (1955), 263

30 G. P. Kuiper (ed.) *et al.*, *Photographic Lunar Atlas*, Chicago, 1960

31 E. A. Whitaker *et al., Rectified Lunar Atlas*, Tucson, 1963

32 W. K. Hartmann & G. P. Kuiper, 'Concentric Structures Surrounding Lunar Basins', *Communications of the Lunar and Planetary Laboratory*, **1**(12) (1962)

33 N. S. Shaler, *Annals of the Astronomical Observatory of Harvard College*, **8**. Pt. 1., 50–53 (1876). For a biography of Shaler, see David N. Livingstone, *Nathaniel Southgate Shaler and the Culture of American Science*, Tuscaloosa, The University of Alabama Press, 1987. In addition to a popular article entitled 'The Moon' in *Atlantic Monthly* **34,** (1874), 270–278, Shaler produced 'A Comparison of the Features of the Earth and the Moon', *Smithsonian Contributions to Knowledge,* Part of Vol. **XXXIV** (No.1438), Washington DC, Smithsonian Institution, 1903, and a *General Description of the Moon* (Smithsonian, 1903), an introductory chapter taken from the former work.

34 N. S. Shaler, 'A Comparison of the Features of the Earth and the Moon' (1903). Footnote page 59.

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