THE *SELENOGRAPHIA* OF WILLIAM GILBERT: HIS PRE-TELESCOPIC MAP OF THE MOON AND HIS DISCOVERY OF LUNAR LIBRATION

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Some time before his death in 1603 the Elizabethan physician and natural philosopher William Gilbert (1544–1603) made astronomical history. He drew the first map of the Moon (Figure 1), and to describe the work he coined the word *selenographia*. More than four centuries later, it remains the only known lunar map made before the telescopic era. The sole surviving manuscript copy does not reproduce well, for which reason we are indebted to Ewen Whitaker for his careful redrawing (Figure 2).[1] Commentators have denied it significance mainly because they find it neither detailed nor accurate. Indeed, several critics question whether it deserves to be called a map.[2] The consequent neglect probably explains why its deeper importance in the history of astronomy has gone unnoticed for over 400 years.

It can now be seen that Gilbert conceived and used the map as an instrument for detecting changes in the appearance of the lunar disc. Remarkably, the change that

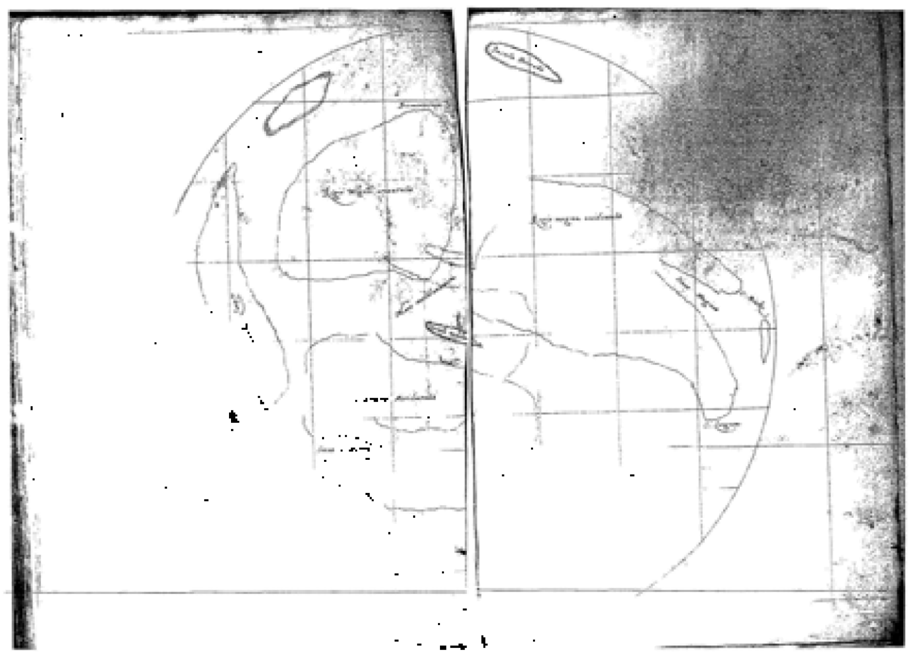

FIG. 1. Gilbert's map of the Moon, from the only extant manuscript of *De mundo* (*c.* 1605), British Library Royal Ms. 12 F. XI, courtesy of the British Library.

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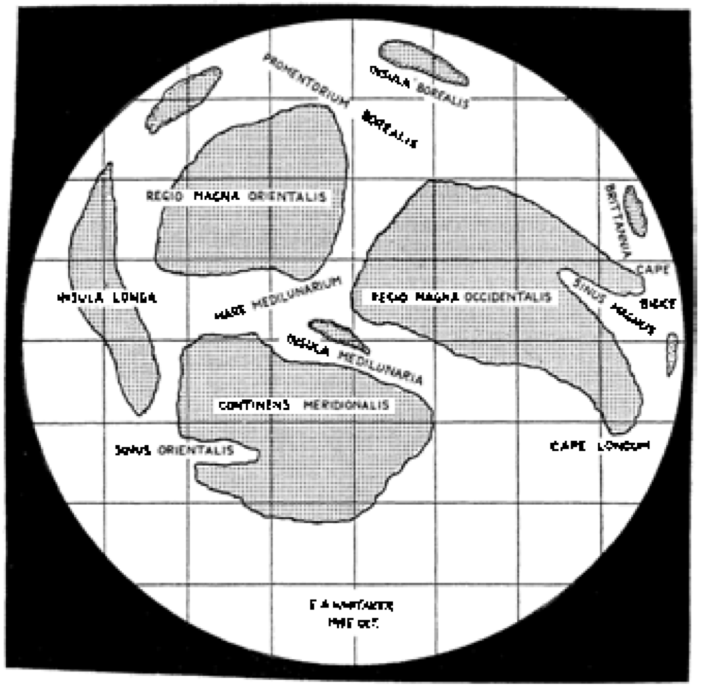

FIG. 2. Gilbert's map, accurately redrawn from the manuscript by Ewen A. Whitaker, reproduced courtesy of Prof. Whitaker.

interested him most was a phenomenon that he predicted and we now call lunar libration. He succeeded in seeing it, without a telescope, forty years before its supposed discoverer, Galileo. In Gilbert's published work *De magnete* (1600) he showed the high value of empirical evidence, and it seems that he wanted his map to provide observational evidence for his belief that the Moon and planets moved through empty space and not in solid geocentric spheres.

The publishing history of the map has not helped its significance to emerge. After Gilbert died, a single copy survived, in the Royal Library in Whitehall in Gilbert's posthumously compiled manuscript work "De mundo nostro sublunari philosophia nova [A new philosophy of our sublunary world]". Few saw it, although it was certainly inspected by Thomas Harriot. Indeed, it is possible that Harriot had Gilbert's map in mind when he recorded his telescopic observations of the Moon. It was also studied by Francis Bacon, who read "De mundo" closely and made specific reference to it; by referring to his "selenographia" Bacon became the first to use Gilbert's neologism in print. [3]

A printed edition of *De mundo* did not appear until 1651. It was prepared by the Dutch humanist Isaac Gruter (1610–80) from two codices he had discovered amid numerous manuscripts belonging to Francis Bacon and given to him by Sir William

Boswell (d. 1650), Bacon's literary executor. Gruter's printed map (Figure 3) also made little or no impact, because by 1651 telescopes had been in use for more than forty years. In that time moon-mapping had emerged as a sophisticated branch of astronomy, culminating in the extraordinary images published by Johannes Hevelius in his *Selenographia* of 1647 — the work that spread the word and idea of selenography.[4]

Set against images of Hevelius's quality, the *De mundo* print of 1651 is very crude indeed. Moreover, it did not fit either of the two main research programmes of the early seventeenth century. The first programme, established by Galileo, was topographical, and aimed to establish the mountainous, Earth-like nature of the lunar surface. Copernicans like Galileo — and Gilbert — regarded this as evidence in their favour. The second and later programme was cartographical, and aimed to plot the Moon's features with the two-dimensional accuracy needed to use the maps during lunar eclipses for the determination of longitudes. Hevelius's work advanced this latter project.[5]

Interest in Gilbert's map took off only in 1965 when *De mundo* was reprinted along with Sister Suzanne Kelly's companion volume *The De mundo of William Gilbert*. A few works subsequently included the map as an illustration, and in recent years copies of Gruter's version have been available on the world-wide web.[6] In 1999 Montgomery and Whitaker independently gave the first extensive discussions of the

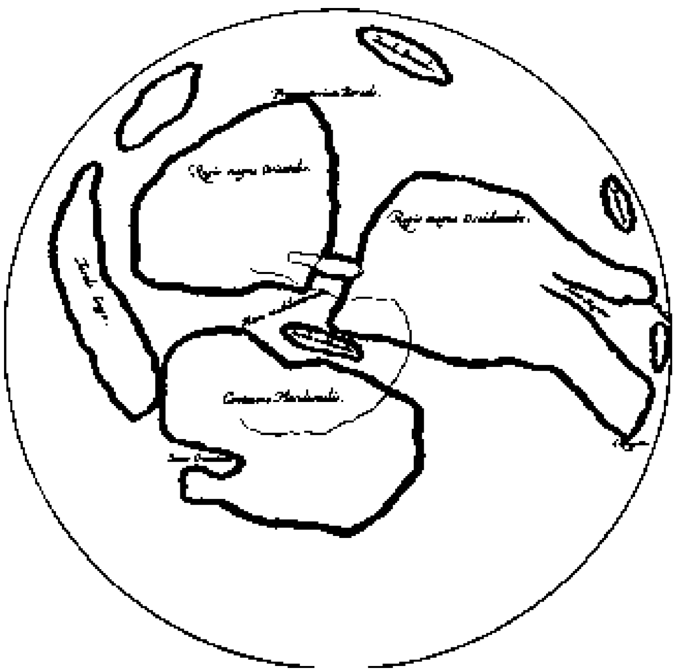

FIG. 3. Gilbert's map as it appeared in the printed edition of *De mundo* (Amsterdam, 1651).

image. They concurred in calling it a map, and therefore different from earlier images such as those of van Eyck and Leonardo.

In his fascinating study, *The Moon and the Western imagination*, Scott Montgomery argued convincingly that, in order to establish that the Moon and the Earth had similar natures, the lunar surface had to be "made the subject of cartography, not just picturing. Epistemologically, it was this tiny yet bold stroke that marked the great break with the past: Gilbert seems to have been the first to codify perception of the Moon as 'territory' and 'place' into the form of an actual map".[7] In his masterly *Mapping and naming the Moon*, Ewen Whitaker also judged that Gilbert's drawing "qualifies as a map rather than an image". He cited Gilbert's nomenclature and effort at accuracy, and he produced a table that correlates seven of the thirteen features named by Gilbert with modern names.[8]

Answers to the questions of what counts as a map and what features a map should possess are notoriously diverse, and even more so if one includes opinions from the seventeenth century.[9] Definitions vary from the general to the specific. The more specific insist upon a clear scale, orientation, projection and scheme of symbols or labels, by which criteria Gilbert's drawing (and many other historical representations accepted as maps) would fail the test. However, a looser but widely respected definition, very similar to that adopted by the International Cartographic Association (ICA), is that of Norman Thrower. He defines a map as "a representation, usually on a plane surface, of all or part of the earth or some other body [*sic*] showing a group of features in terms of their relative size and position".[10] On this definition Gilbert drew a map.

It is true that he recorded only fifteen features and twelve labels,[11] but in all maps the data are selected according to purpose. One must also concede that Gilbert's delineation of the Moon's features does not readily fit modern schemata. Nevertheless, we can be confident that he represented their relative size and position as accurately as his naked eye observation permitted; he had to believe that his representation was accurate (or accurate enough) if it was to fulfil the purposes he had for it. We now examine those purposes.

One finds the map folded within a section of seven chapters in "De mundo", seemingly forming what the manuscript (but not the printed edition) refers to as a "treatise on the Moon".[12] If Gilbert's map has received scant attention, his little treatise on the Moon has received almost none. This is surprising given that it contains original ideas and, on the folio preceding the map, a clear description of the scientific purposes Gilbert had for it. Analysts have denied that Gilbert's drawing served any obvious purposes, and so I reproduce the passage in full.

> We are giving a Selenography, or description of the Moon. Antiquity entirely neglected to give one, from which we could have perceived whether the spots visible in it had changed. Moreover, such a description is required of necessity in observation of the lunar body in order to perceive whether it absolutely does not revolve, as was argued by Aristotle and accepted, or whether to some extent

> it does turn itself. Then it is required to perceive how it inclines in its monthly motion, with its poles (that is, its body's poles) [inclined] towards some fixed parts of the heavens; and then how it has been conjoined with the Earth, and is in harmony with the Earth's position. All these cannot be properly observed, or known in any other way, without differentiating the parts of the Moon itself through these spots. It is because we think the Moon is indeed a second, smaller Earth, or some other body which has been arranged in the manner of the Earth (as we shall prove afterwards), that we now give a description of the visible disc, like a second geography, labelled with some geographical names so that anyone might understand it better and more easily and remember it more securely.[13]

The passage shows that Gilbert had four purposes for his map. The first was to reveal changes on the lunar surface. These would be slow mutations, such as erosion at the edges of the landmasses, which would take very many years to become noticeable from Earth. He believed that there were other changes, perhaps in lunar vegetation, but that these were probably not observable given the distance of the Moon from the Earth.[14] Gilbert defended his heterodox opinion with a rhetorical question: "If there were an observer above the Moon, would they have discovered change in the Earth's plant life, and in its other generations and corruptions?"[15] Since the ancients had made no map, and the detection of changes in the spots was a long term project only just begun, it seems clear that Gilbert intended his map to be copied and used by others in collaborative research that would extend over many years. This first purpose foreshadowed the topographical programme developed by Galileo of showing the Earth-like nature of the Moon, and is remarkable mainly for having been formulated in the post-Copernican but pre-telescopic decades.

Gilbert's second and third reasons are, however, truly remarkable. His selenography was necessary "in order to perceive whether the Moon absolutely does not revolve (as was argued by Aristotle, and accepted) or whether to some extent it does turn itself. Then it is required to perceive how it inclines in its monthly motion, with its poles (that is, its body's poles) [inclined] towards some fixed parts of the heavens".[16] These research questions reveal that Gilbert was investigating whether or not the Moon exhibits the phenomenon we call libration. Gilbert was intrigued by his realization that if the Moon moved through empty space, which as a radical Copernican he believed it did, then libration was possible. Libration was impossible, even unthinkable, according to the conventional cosmology he wanted to disprove.

As I have argued elsewhere,[17] Aristotle's immensely influential cosmological doctrine of the heavenly spheres depended for empirical confirmation upon his statement that "the face of the Moon is always seen". From this he inferred, as Gilbert put it, that "the Moon absolutely does not revolve". [18] The constant appearance of the face of the Moon confirmed for Aristotle that it was a passive body, incapable of self-motion. Consequently it could not move itself around the Earth, which in turn proved that it was moved by and within a solid celestial sphere. From Aristotle's era until the mid-sixteenth century the Moon was held to be one of the seven planets, and this allowed cosmologists to argue by analogy from the appearance of the Moon that all planets and stars were moved in and by spheres.

Aristotle's assertion that "the face of the Moon is always seen" accords with inexpert assumptions and everyday observations of the Moon. Many accept that we always see the same half of the Moon, and that "the man in the moon" always looks the same. Readers of this journal will know that is wrong, because of the existence of lunar libration. The libration or wobble allows us to see more than half (59%) of the Moon as it travels its monthly course.

Libration manifests itself as a complex rocking motion, which is the resultant of two principal factors. The first and larger is the libration in longitude. It is caused by the dynamical fact that the Moon rotates on its axis with a constant angular velocity, whilst it orbits the Earth elliptically with an angular velocity that varies according Kepler's second law. Since our Moon is tidally locked, both motions have exactly the same period of one lunar month, and the Moon keeps the same face turned towards the Earth. However, in one half of the orbit the Moon's axial rotation is in advance of its orbital rotation and we get to look round one side of its disc, while in the other half the axial rotation lags behind and we get to look round the other side. In total the effect allows us to see not 180 but 188 degrees of lunar longitude.

The second libration, in latitude, allows us to see an extra 7%. It is an optical effect, the result of the Moon's axis of rotation being inclined by 5 degrees to the plane of its orbit around the Earth, and is analogous to the inclination of the Earth's own axis by $23\frac{1}{2}^{\circ}$ to the plane of its orbit in the ecliptic. For half of the Moon's orbit we are able to see beyond its north pole, while in the other half we can see beyond its south pole.

A third, much smaller and trivial cause of libration is also an optical one, and caused by parallax. Since we observe the Moon from various positions on the surface of the Earth and not from its centre or from the centre of the Moon's orbit, the diurnal motion of the Earth and the monthly orbit of the Moon produce respectively the topocentric libration in longitude and the topocentric libration in latitude. These are very small librations, no more than one degree at any location on Earth.

Overall, libration in longitude makes the Moon perform a small nod of 'Yes', while libration in latitude produces an even smaller nod of 'No'. Each nod takes one month to complete and results in a slow diagonal wobbling motion. It is almost impossible to track with the naked eye unless one is looking for it. It is no surprise that the assumption of the Moon's unchanging face satisfied expert observers from ancient times until the 1630s, and still satisfies lay observers today.

It is generally accepted that libration was discovered by Galileo. He presented it as another discovery that demonstrated the power of the telescope. "Will the new observations and discoveries made with this admirable instrument never cease?", says the character Sagredo in the *Dialogue concerning the two chief world systems* of 1632. Galileo's typically clear account describes well his observation of libration.

> [T]here are two special markings on the Moon, one of which is seen to the northwest when the Moon is on the meridian, and the other almost diametrically

> opposite. The former is visible even without a telescope, but not the latter. The one towards the northwest is a small oval spot separated from three larger ones. The opposite one... In both of these the variation mentioned already is quite clearly observed; they are seen opposite to one other, now close to the edge of the lunar disc and now farther away. The difference is such that the distance between the northwesterly spot and the edge of the disc is at one time more than twice what it is at another. As to the other spot, being much closer to the edge of the disc, the change is more than threefold from one time to the other.[19]

As astronomers and other skilled observers know, libration is visible to the naked eye. Experts agree that the best features visible to the naked eye to be tracked are *Mare Frigoris* and *Mare Crisium*, together with the western edge of *Oceanus Procellarum*.[20]

Now that we are aware of the purposes Gilbert had for his map, and of which features are best for the naked eye observation of libration, we should look again at the map itself. Gilbert had no plan to record topographical details of the kind we call craters; that project only became possible with the invention of the telescope. Gilbert seems to have been necessarily but purposefully selective and schematic. The centre of his map delineates three large and central regions or continents clustered around a small central island. Not being foreshortened, these would have been useful for his first purpose of tracking changes in the boundaries or interiors of the Moon's large spots, which he thought were continents. This leaves five other features, each of which Gilbert drew as long, thin, foreshortened islands very close to the limb of the lunar disc. As such they were not suitable for Gilbert's first purpose, but excellent for the detection of libration.

Gilbert gave memorable names to three of these liminal islands: "Insula Longa", "Insula Borealis" and "Britannia".[21] Whitaker identified these three with the regions we today call *Oceanus Procellarum*, *Mare Frigoris* and, in the case of "Britannia", *Mare Crisium*. In short, Gilbert's simple map located and named features on the limb that are ideally suited for observing libration with the naked eye. He even named the best feature of all after the island on which he lived!

We can, then, reasonably conclude that the main purpose of Gilbert's map was to locate the features with which he and, he hoped, subsequent selenographers might observe libration as accurately as possible. It would enable him to show that the Moon librated in latitude because it inclined in its monthly orbit, and also that it did "turn itself to some extent" as it librated in longitude. With reason he interpreted the phenomenon as proof that the Moon orbited the Earth freely and actively, and was not moved passively embedded in a sphere. In short, libration provided Gilbert with observational evidence against the pre-modern cosmology of solid spheres, and in favour of his cosmology of planets moved by attractive forces through a vacuum. These were cosmological ideas that Kepler used as he developed his elliptical astronomy.[22]

Gilbert could not have foreseen that the development of the telescope would soon turn libration from an almost invisible movement into a big one that could hardly be missed. But did he actually see it himself? The manuscripts posthumously collected as "De mundo" preserved from among his doubtless numerous lunar observations the following crucial example. It shows that he did indeed beat Galileo by forty years to the discovery of libration. He did not have the aid of a telescope, but he had the predictions from his radical cosmological theory — and his map of the Moon. Gilbert recorded that

> Observation of the full moon in [the constellation of] Capricorn shows that the distance of the Moon's southern spot from the outer edge of shining light of the orb is greater than when the Moon is in Cancer. The opposite would happen if there were not an inclination of the Moon's poles towards the pole of its deferent, or toward the pole of the Zodiac, since we see more of the lower part of the Moon.[23]

APPENDIX: THE EXTANT COPIES OF GILBERT'S MAP

One manuscript copy of "De mundo" survives, dedicated to Henry, Prince of Wales. The map, forming ff. 75 and 76 of the British Library volume, cannot have been drawn by Gilbert because the manuscript was a presentation copy made after his death.[24] All the diagrams were copied with care but not always with understanding. Whitaker drew attention to the 8 × 8 grid superimposed on the map. He also noted that the map replicated "some outlines one square too far north". [25] It is possible that the maker of the extant drawing was working from a prior copy that already possessed the rogue outlines, but which he lacked the confidence to remove.

The manuscript map is unsuitable for reproduction, which is why Whitaker's careful redrawing (Figure 2) is so valuable. However, most people familiar with Gilbert's map know it through reproductions of the plate from the first (Amsterdam, 1651) edition (Figure 3). The Dutch editor Isaac Gruter worked from two codices of "De mundo", which were apparently copies of the Royal Library manuscript made for Francis Bacon and discovered among his own manuscripts long after his death. Gruter complained that both copies were badly defective, especially with respect to the diagrams.[26]

Gruter's version is remarkably close to the map in the extant manuscript, but his plate improved on the manuscript in two ways, arguably fulfilling the intentions of the original drawer. First, it gave to every feature the hatching one can see applied in the manuscript only to the *Insula Borealis* and *Insula medilunaria*. This makes the boundaries look more like the coastlines Gilbert had written about. Secondly, it removed the 8 × 8 square grid. The only significant discrepancy is that the two capes of the *Regio Magna Occidentalis* are extended further towards the edge of the disc. Given that the distance of these marginal features from the edge was crucial to the map's purpose of observing libration, Gilbert might have been disappointed.

Nevertheless, the printed map preserved two errors present in the extant manuscript. First, Gruter did not remove the erroneously duplicated outlines: he retained the double appearance of the eastern coast of the *Continens Meridionalis* and of the *Insula medilunaria*, which was turned by its hatching into a central isthmus! Some doubt about status might be signalled by the sections left unhatched. Secondly, his map replicated the uniquely non-Latinate label "*C. Bicke*" [Cape Bicke] for the northern cape of Gilbert's *Regio Magna Occidentalis*. Given that the larger southern limb is called *C[aput] Longum*, we should, *pace* Montgomery, read "Bicke" as a copyist's misreading of the minims forming *Breve*. This leaves us with the memorable and pseudo-geographical name "Short Cape" to pair with the "Long Cape".[27]

REFERENCES

1. The sole extant manuscript map forms ff. 75–6 of William Gilbert, "De mundo nostro sublunari", British Library Royal Ms. 12 F. XI. The redrawn map is in Ewen Whitaker, *Mapping and naming the Moon: A history of lunar cartography and nomenclature* (Cambridge, 1999), 13. It is reproduced here by permission as Figure 2; see also Ewen Whitaker, "Selenography in the seventeenth century", in R. Taton and C. Wilson (eds), *The general history of astronomy*, ii: *Planetary astronomy from the Renaissance to the rise of astrophysics.* Part A: *Tycho Brahe to Newton* (Cambridge, 1989), 119–43, p. 121.
2. I am indebted to an anonymous referee who required a defence of the label, because if he were to "compare Gilbert with what Leonardo drew, a century earlier..., Gilbert's 'map' is a very poor representation indeed". Leonardo's work can be seen in Gibson Reaves and Carlo Pedretti, "Leonardo da Vinci's drawings of the surface features of the Moon", *Journal for the history of astronomy*, xviii (1987), 55–8. This article supports Whitaker's view that da Vinci's made "crude sketches" but Gilbert "may perhaps be thought of as the first selenographer". See Whitaker, "Selenography" (ref. 1), 118. As the referee noted, the answer depends upon what one means by a map, and I address the issue briefly below.
3. For evidence that Harriot saw the map see Stephen Pumfrey, "Harriot's maps of the Moon: New interpretations", *Notes and records of the Royal Society*, lxiii (2009), 163–8. For Bacon see James Spedding, Robert Leslie Ellis and Douglas Denon Heath, *The collected works of Francis Bacon* (15 vols, London, 1857–74), iv, *Novum organum*, Part II, aph. XXXIX, 308; Bacon's first manuscript use, and specific mention of Gilbert, occurs in Bacon, *Works*, v, "Descriptio globi intellectualis", 760: "et selenographia illa sive typus lunae, quem animam agitabat Gilbertus iam ex Galilaei et aliorum industria praesto esse videatur." It has been claimed that Galileo picked up his neologism from Bacon. See Bruno Migliorini and Ghino Ghinassi, *Storia della lingua italiana* (Bompiani, 1994), 443.
4. William Gilbert, *De mundo nostro sublunari: Nova physiologia contra Aristotelem* (Amsterdam, 1651); for Hevelius see Janet Vertesi, "Picturing the Moon: Hevelius's and Riccioli's visual debate", *Studies in the history and philosophy of science*, xxxviii (2007), 401–21.
5. For the two programmes see Whitaker, *Mapping* (ref. 1), chaps. 1–3.
6. Sister Susanne Kelly, *The De mundo of William Gilbert* (Amsterdam, 1965). Two sites that reproduce the image are Charles Wood, "Timeline of lunar exploration", *Chuck Wood's Moon: Compendium of lunar science and history*, url: http://www.lpod.org/cwm/Timeline/1600s/1603-Gilbert.html, last accessed 11 August 2010, and (in higher resolution) "Early lunar map", European Space Agency: Science and Technology, url: http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=21885, last accessed 13 August 2010.
7. Scott L. Montgomery, *The Moon and the Western imagination* (Tucson, 1999), 99, 220. Montgomery added that Gilbert "did something utterly remarkable: he named [the spots], even portions of them, all after earthly geographic forms" such as seas, continents and even "Britannia". As a result, he suggested, the map encoded colonialist aims. Without denying that, I argue that the aims were primarily astronomical. On pp. 103–4 Montgomery also discusses the name "Cape Bicke", concerning which see the appendix to this article.
8. Whitaker, *Mapping* (ref. 1), 13, 15. He wrote that "Gilbert used an 8 × 8 grid square to better position the features", but we should remember that the surviving manuscript is a copy prepared after

Gilbert's death and the grid could have been a device introduced by the copyist. The correlations are sometimes loose, and one has some sympathy with the lunar astronomer, Charles Wood, who has written that "Gilbert's drawing is about the minimum a careful observer would notice! The locations and sizes of the *maria* are poor, and no craters — not even Tycho — are shown. This drawing is famous for being the only pre-telescopic drawing, but it is not a careful rendition of what is visible". See Wood, "Timeline of lunar observation" (ref. 6).

9. J. H. Chalmers notes that more than 300 definitions in English have been collected for the period 1649–1996. See Chalmers, "What was a map? The lexicographers reply", *Cartographica*, xxxiii (1996), 1–12. For the list itself see J. H. Andrews, "Definitions of the word 'map', 1649–1996", *MapHist discussion papers*, url: http://www.maphist.nl/discpapers.html, last accessed 17 May 2010.
10. Norman J. W. Thrower, *Maps and civilization: Cartography in culture and society* (Chicago, 1996), 254. The ICA definition is reproduced as no. 187 in Andrews's list above (ref. 9).
11. One sea, two bays, two headlands, a promontory and nine landmasses (six of them labelled).
12. Gilbert, "De mundo" (ref. 1), I.4, f. 7: "Quere plura in tractatu de luna"; *cf.* Gilbert, *De mundo* (ref. 4), 9. The treatise seems to form Book II, chaps. 13–19.
13. Gilbert, "De mundo" (ref. 1), f. 74v. Translations are by me and Ian G. Stewart, my co-editor of a forthcoming edition and translation of the manuscript "De mundo". We transcribe the Latin thus: "Selenographiam sive Lunae descriptionem damus, quam male antiquitas omnis praetermisit: qua post tot annorum curriculum intelligeremus, num in illa maculae apparentes immutatae fuissent praeterea talis descriptio necessario requiritur, in observatione corporis lunaris ut intelligatur num omnino non volvatur, ut ab Aristotele persuasum est et acceptum, aut reliqua ex parte convertat se, Tum quomodo in motu suo menstruo inclinat polis eius polis scilicet corporis, versus mundi partes aliquas certas; Tum etiam qua ratione telluri coniuncta sit, et cum telluris positione consentiat; Quae omnia recte observari, aut aliquo modo cognosci non possunt sine partium ipsius Lunae per maculas illas distinctione. Quod vero Lunam tellurem alteram, minorem, aut corpus aliud telluris modo ordinatum existimamus, id postea confirmabimus, Damus iam apparentis orbis graphiam tanquam geographiam alteram, quibusdam nominibus geographicis discretam, ut melius quisquam et facilius, illam mente compraehendere possit firmiusque retinere." See Gilbert, "De mundo" (ref. 1), f. 74r. In the 1651 printed edition (ref. 4), the reasons appear in almost identical words on p. 172. The map is inserted between p. 172 and p. 173.
14. This purpose alone was reported in 1969 by Kopal but he seems to have been ignorant of the three more remarkable purposes. See Ždenek Kopal, "The earliest maps of the Moon", *The Moon*, i (1969), 59–66, p. 61.
15. Gilbert, "De mundo" (ref. 1), f. 78r. "Si enim supra lunam oculus foret, anne discerneret mutationem telluris in vegetabilibus, aliisque generationibus et corruptionibus?" *Pace* Kopal (*op. cit.* (ref. 14), 61), it would not have "consoled Gilbert if he knew that no such changes have been noted since the advent of the telescope".
16. Gilbert, "De mundo" (ref. 1), f. 74r.
17. Stephen Pumfrey, "The astronomer's role and the natural philosopher's role in the sixteenth century reconsidered: The case of William Gilbert", paper presented at the Annual Conference of the British Society for the History of Science, Aberdeen, 23 July 2010.
18. Aristotle, *The works of Aristotle*, ed. by W. D. Ross, transl. by J. L. Stocks (12 vols, Oxford, 1930), ii, *De Caelo*, Book II, chap. 8, 290a8–290a29.
19. See Galileo Galilei, *Dialogue concerning the two chief world systems*, transl. by Stillman Drake (Los Angeles, 1962), 66, 67. Galileo was driven by his conservative celestial mechanics to assert incorrectly that all libration was topocentric, so that "anyone looking from the centre of the Earth would always see the same lunar disc bounded by exactly the same circumference". Gilbert considered the geometry of topocentric libration in "De mundo" (ref. 1), Book II, chap. 19, f. 83v, and thought that it was too small to account for the observed libration.
20. See, for example, Ernest H. Cherrington, Jr, *Exploring the Moon through binoculars and small telescopes* (New York, 1984), 36. "The effect of the libration in longitude may be observed by

simply noting the position of *Mare Crisium* with respect to the eastern limb from night to night" and the "libration in latitude may be checked by observing the changing position of the long narrow *Mare Frigoris* with respect to the northern limb".

21. I.e. Long Island, North Island and Britain. The manuscript has the label "Brittannia" which is corrected to Britannia in the printed edition.
22. See Stephen Pumfrey, "Magnetic philosophy and astronomy", in Taton and Wilson (eds), *op. cit.* (ref. 1), 45–53.
23. Gilbert, "De mundo" (ref. 1), f. 82v. "Observatio plenilunii in capricorno, quod maior sit distantia meridionalis maculae lunae, ab extremitate orbis luminis quam in Cancro, quod esset contrarium, si non esset inclinatio polorum lunae versus polum deferentis sui, sive polum Zodiaci, quia plus videmus in inferiore parte lunae."
24. Gilbert, "De mundo" (ref. 1).
25. Whitaker, *Mapping* (ref. 1), 13. He assumed that it was Gilbert who had "mislocated some outlines one square too far north before realizing his error".
26. See ref. 4, and Gruter, "Ad Lectorem" in Gilbert, *De mundo* (ref. 4).
27. See Montgomery, *op. cit.* (ref. 7), 103–4.