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Michael Rand Hoare, *The Quest for the True Figure of the Earth: Ideas and Expeditions in Four Centuries of Geodesy*. Aldershot, England and Burlington, Vermont: Ashgate, 2005. xii + 275 pp. Preface, appendices, figures, maps, table, notes, reading list, and index. 99.95/£50.00. (hb). ISBN0754650200.

Review by James Evans, University of Puget Sound.

This engaging and well-researched book recounts the battle in the Paris *Académie des sciences* that followed the introduction of Newtonianism into France in the first decades of the eighteenth century. World views were at stake, along with academic reputations. And the whole affair was decided by two scientific expeditions to far-flung parts of the globe — expeditions marked by equal parts of heroism, scientific skill, infighting, farce, and tragedy.

In 1718, Jacques Cassini, director of the Paris Observatory, announced the results of a survey of the Paris meridian from Dunkerque to Collioure. These suggested that the length in *toises* (fathoms, each made up of six Paris feet) of one degree of latitude decreases slightly as one moves from south to north. If the earth were a perfect sphere, as the ancients had believed, a single degree of latitude would correspond to the very same displacement in linear measure, no matter where one did the surveying. Cassini's survey suggested that the earth is slightly *elongated at the poles*, that is, cigar-shaped. French natural philosophers, steeped in Descartes' *tourbillons* (vortices), soon figured out how to account for the non-spherical earth in terms of these standard concepts of French physics.

But there was already trouble with conflicting evidence. In 1672, Jean Richer had made an expedition to Cayenne, on the north coast of South America, sponsored by the *Académie des sciences*. Richer's mission was to make astronomical observations, at a latitude near the equator and at a longitude well removed from the Paris meridian, in order to improve the knowledge of atmospheric refraction and to determine the parallax of Mars (and thus the scale of the solar system). His apparatus included a precision pendulum, made at Paris to beat seconds. But Richer noted that his pendulum ran a little too slowly in Cayenne, as compared with the time defined by astronomical observations. In order to get it to beat seconds properly, he had to shorten its length by 1¼ *lignes*, out of a total length of about 3 feet. (A "line" is one-twelfth of an inch).

Isaac Newton, in his *Philosophiae naturalis principia mathematica* (Mathematical Principles of Natural Philosophy) of 1687, used Richer's observations to underpin his theory of universal gravitation and deduced, moreover, that the earth must not be spherical, but slightly oblate, that is, *flattened at the poles*. Newton reasoned that the strength of gravitation decreases with distance from the center of the earth. If the earth is oblate, it follows that a pendulum at the equator is slightly farther from the center of the earth than is a pendulum at Paris. Thus, the strength of gravity is slightly weaker in Cayenne, and the pendulum will therefore run more slowly. There was important supporting evidence in the shape of the planet Jupiter: seen through a good telescope, the planet shows an obvious flattening at the poles. If the earth is like any other planet that spins on an axis it, too, should be flattened.

In France, Newton's work had a mixed reception. On the one hand, the best geometers could not help but recognize and admire Newton's technical accomplishment: he had deduced Kepler's laws of planetary motion from mechanical and mathematical principles and had shown, moreover, how to apply the new formalism to the motions of comets. But French scientists, trained in the mechanical philosophy of Descartes and his disciples, were troubled by Newton's use of attractive forces. One of Descartes'

greatest accomplishments had been to banish from natural philosophy the "occult qualities" of the medieval scholastics. In the Cartesian view, anthropomorphic qualities such as attraction or affinity were not to be ascribed to inanimate matter. Rather, the world was a giant pinball machine, in which all physical processes were to be explained in terms of the impact of bodies on one another. Newton had postulated that each particle of matter in the universe attracts each other, but he had not explained the mechanism responsible for this attraction. Universal gravitation therefore seemed to be a falling back into discredited way of thinking.

Thus, by 1720 there were two earths: an oblate, English earth, associated with the theories of Isaac Newton, and a prolate, French earth, supported observationally by Cassini's survey, but also buttressed by Cartesian natural philosophy. As Michael Rand Hoare points out, the *Académie des sciences* of the 1720s and 30s was a conservative institution, which had declined from its level of scientific creativity in the late seventeenth century. Its most influential members were all avowed Cartesians (pp. 38-39). The first apostle of Newtonianism in the Academy was Pierre-Louis Moreau de Maupertuis (1698-1759), whose *Discours sur les différentes figures des astres* of 1732 squarely laid the conflict before the French academic community. By July 1734, the King had approved outfitting a geodetic expedition to settle the matter at royal expense.

Indeed, *two* expeditions ultimately were approved. One expedition was outfitted for Lapland and led by Maupertuis. Its members included the French academicians Alexis-Claude Clairaut and Pierre-Charles Le Monnier, as well as the Swedish astronomer Anders Celsius (better known today for his temperature scale). The French group left Paris in April 1736. In spite of some difficulties with terrain, the weather, and insects, the Lapland group completed its survey and returned in triumph to Paris in August 1737, having shown decisively that a degree of latitude is longer in the arctic regions than in France: Newton was right and Cassini was wrong: the earth is flattened at the poles.

Voltaire famously addressed Maupertuis as "*aplatisseur de mondes et de Cassinis*." And he also penned a quatrain in honor of his friend:

Le Globe mal connu qu'il a sçu mesurer,
Devient un Monument où sa gloire se fonde;
Son sort est de fixer la figure du Monde,
De lui plaire, et de l'éclairer.

Maupertuis had these lines printed below an engraving of himself, in his Lapp hat of fur, leaning on a globe of the earth and flattening it with his hand. These he distributed to friends and supporters. In a later version, the globe was omitted, perhaps because of the jokes that Maupertuis' self-promotion had elicited. It is the more modest version of the portrait, still accompanied by Voltaire's verse, which appeared in the 1756 edition of Maupertuis's collected works.[1]

The second expedition, which actually left first, in May 1735, was bound for the equatorial regions of Peru. Their story was very different. Some of the members did not return to France for a decade, and some never returned at all. The nominal leader of the expedition, Louis Godin, was unable to control the egomaniacal team members who were often rivals as much as collaborators. The southern expedition was marked by infighting, disagreement over the surveying procedures, and meddling by the local Spanish authorities, as well as the difficulty of doing geodesy in the high Andes. And they had the misfortune to learn of the triumph of the Lapland survey while they had scarcely begun their most important operations. After their own return to Paris, two expedition members, Pierre Bouguer and Charles-Marie de La Condamine, entered into a bitter public dispute.

The story of these expeditions has been told a number of times before, in technical scientific histories, popular books, and even in fiction and drama, for the events and personalities of the South American expedition, particularly, continue to amaze and inspire. Michael Hoare has done a fine job of bridging the gap. He has made full use of eighteenth-century publications in several languages, but has also done a wonderful job of bringing the story to life. He is especially good at explaining the fundamentals of the

geodetic procedures and his book is generously illustrated with period engravings. Moreover, he has brought out some aspects of the story that have received too little attention. The two Spanish naval officers, Jorge Juan and Antonio de Ulloa, who were assigned to monitor the southern expedition warmed to the job and soon became skilled and dedicated members of the survey. Hoare has taken pains to give them due credit and has made use of their own published account of the expedition.[2]
Michael Hoare's book naturally invites comparison with Ken Alder's *The Measure of All Things*, which tells the story of a different episode of French geodesy concerning Delambre and Méchain's survey of the Paris meridian in the 1790s that was used to define the meter.[3] While Alder writes with a more literary flourish, he also focuses on a much more compact story. And it should be said that Hoare is better with the technical details. These two books nicely complement each other, in chronological focus as well as in style, and should satisfy the appetites of most readers for eighteenth-century geodesy.
One important book that Hoare did not use (perhaps it appeared too late) is Mary Terrall's recent biography of Maupertuis,[4] which has a good deal to say about the polemical aftermath of the Lapland expedition, and Maupertuis's career strategies. At times Hoare's documentation is a little uneven. For example, many technical details are precisely documented, but stretches of narrative may run on for pages at a time without a single source note. Of course, in these passages Hoare is relying on the published eighteenth-century narratives, and there are only a few of them, so he perhaps felt it unnecessary to constantly repeat the sources for each major plot development. And there are a few minor slips. For example, in Figure I, illustrating Eratosthenes' method for determining the size of the earth, the rays of sunlight striking Syene and Alexandria should be parallel to one another. Some of the more amusing departures from scholarly reserve occur in the course of Hoares's gleeful telling of the exploits of British navy against Spanish colonial holdings (pp. 188-9).
The title of Michael Hoare's book is needlessly frightening and somewhat misleading. It is true that the introductory chapters give some seventeenth- (and even sixteenth-) century background and that the concluding chapters carry the story into the nineteenth (and even the twentieth) century. But the heart of the book is devoted to the contests in and expeditions of the Paris Academy of Sciences in the eighteenth century. The story of intellectual debates, academic rivalries, and geodetic operations in trying circumstances is told with such verve and in such detail that the book will be far more appealing to readers of H-France than one might guess from the title of the book. It is warmly recommended to anyone interested in Enlightenment history.

NOTES

[1] The original inspiration for these engravings was the oil portrait of Maupertuis painted in 1739-40 by Robert Levrac-Tournières, of which there are versions in the Observatoire de Paris and in the Musée de St. Malo. Hoare reproduces (p. 85) the 1741 engraving by Jean Daullé. The more modest 1755 engraving, also by Daullé, appeared in *Oeuvres de Mr. de Maupertuis*, vol. 1 (Lyon: Jean-Marie Bruyset, 1756).

[2] J. Juan and A. de Ulloa, *Relación histórica del viaje a la América meridional hecho de orden de S. Mag. para medir unos grados de meridiano terrestre y venir por ellos en conocimiento de la verdadera figura y magnitud de la Tierra...* (Madrid: por Antonio Marin, 1748).

[3] Ken Alder, *The Measure of All Things: The Seven-Year Odyssey and Hidden Error that Transformed the World* (New York: The Free Press, 2002).

[4] Mary Terrall, *The Man who Flattened the Earth: Maupertuis and the Sciences in the Enlightenment* (Chicago: University of Chicago Press, 2002).

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