THE VOYAGE OF JEAN RICHER TO ACADIA IN 1670: A STUDY IN THE RELATIONS OF SCIENCE AND NAVIGATION UNDER COLBERT

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It hardly seems plausible that a single obscure voyage should epitomize and illustrate most of the relevant aspects and interrelations of French science and navigation in the decades following the accession of Louis XIV in 1660. Yet this is what a little-known voyage to the coast of New England and Acadia in 1670 does, both for France generally, and for the Académie Royale des Sciences, which had been established in Paris in 1666 under the protection of Louis' great minister, Jean-Baptiste Colbert (1619–1683).

Until recently, the accomplishments of the Academy during its early years have characteristically been underestimated or misunderstood. This has been equally true of French science as a whole during the half-century after 1660.[1] Similarly, the decisive importance of the contemporary French contribution to the establishment of scientific cartography has been slow to gain recognition.[2] It is thus not surprising that the related efforts to improve navigation are inadequately known or appreciated. Indeed, the climate of historical opinion has tended, ever since the early eighteenth century, to be unfavorable to a fair evaluation of French work in both the latter areas, just as it has to French science in general. In the case of the Academy this has made for a serious underestimation of the importance of its early work, and an overestimation of that of its rival, the Royal Society of London (1662).

A study of the voyage which one of the Academy's *élèves astronomes*, or assistants in astronomy, Jean Richer (1630–1696), made to the North American coast in 1670 will not automatically set these matters right. Yet such an investigation, embracing not only the voyage but its antecedents as well, may help to place contemporary French science, cartography, and navigation in a more favorable light. In doing so it will not only clarify the role and contribution of the Academy of Sciences, but also suggest the character and scope of the contemporary relationships of science—more specifically astronomy—and navigation.

These interrelations are most clearly revealed in attempts to solve the problem of longitude, not the least of which is the problem of longitude at sea. It is therefore intriguing as well as somewhat ironic that the voyage across the Atlantic to Acadia was more than likely intended to provide concurrent tests of the practicability at this period of *both* the methods by which the riddle of longitude at sea was ultimately solved a century later. Actually, as we shall see, the attempt was premature. For although some of the requisite astronomical tables, optical instruments, and timekeepers existed in 1670, none were as yet adequately refined to make the success of either method a practical possibility. The conditions essential to such success, were, nevertheless, clearly understood.

Another point of interest about the Acadian voyage is that it was the occasion for some careful observations of the height of the tides on both sides of the Atlantic as well as for the determination of the latitude of two points on the North American coast. The latter observations appear to be the earliest in this region made by an experienced observer employing instruments of the best contemporary quality.[3]

[1] The historiographical basis for this situation is of some interest and might warrant investigation.

[2] The nature and extent of the French contribution were shown conclusively by C. Sandler, in *Die Reformation der Kartographie um 1700* (Munich and Berlin, Oldenbourg, 1905), early in the present century. The important study of L. Gallois, L'Académie des Sciences et les origines de la carte de Cassini, appeared soon after in *Annales de Géographie* **18**: 193–204, 289–310, 1909. The slowness with which this information has made its way into the relevant literature in English is surprising—in any detailed way hardly prior to the two works by L. A. Brown: *Jean Dominique Cassini and his world map of 1696*, Ann Arbor, University of Michigan, 1941; *The story of maps*, Boston, Little, Brown, 1949. The latter work includes a categorical recognition of the dominantly French creation of scientific cartography late in the seventeenth century.

[3] No direct information about the instruments Richer actually took to Acadia has been found. Those at his disposition at La Rochelle were certainly representative of the best then available in France, and hence among the most advanced to be had. Presumably the instruments were numerous. An indication of Richer's

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Finally, the voyage constitutes an unrecognized instance of a visit to the North American mainland by men attached to the Royal Academy of Sciences. Although members and associates of this body were to travel widely in the course of the Academy's development and application of the modern scientific expedition—a significant device for extending the range and effectiveness of observation and experiment—few among them ever had any direct contacts with North America.[4] The very singularity of the visit of 1670 might in itself justify the investigation of the history and antecedents of a voyage the traces of which time has largely obliterated.[5]

I

It is a truism that the late fifteenth century marked a new era in the history of navigation. The rapid expansion of oceanic voyaging both posed new problems and rendered old ones acute. More and more two basic conditions for safe and efficient navigation on the high seas, neither easy to fulfill, were recognized. One was the navigator's need to be able to determine with precision his position on the surface of the ocean. The second condition was accurate maps to which to refer this position. The progress of cartography and navigation had thus to go hand in hand.

Because the basic controls were in both instances astronomical, the improvement of maps as well as of navigation hinged on the development of accurate means for determining longitude as well as latitude. The latter presented no great problem: even on shipboard fair results had for centuries been obtained with such instruments as the astrolabe or cross-staff for taking the altitude of the sun by day or of Polaris by night. The refinement or replacement of the instruments and astronomical tables currently in use was in this case all that was required.[6] Longitude posed a more difficult problem.

Even for cartography, dependable knowledge of differences in longitude hardly existed in 1670. The plight of navigation was far worse: anything beyond the approximation of a ship's longitude yielded by dead-reckoning (often surprisingly good in the hands of experienced navigators) was lacking altogether. Nor would this situation be ameliorated for another hundred years. Only when the two alternative methods of "lunar distances," and of differences in local time by means of accurate marine chronometers, had been perfected during the second half of the eighteenth century would the problem of longitude at sea, after centuries of effort, be solved.

Actually, the feasibility of both methods had long been recognized. Hipparchus, the Greek astronomer, at least understood the use of differences in local time two centuries before the Christian era. He had to rely, however, on information gained from simultaneous observations in two or more places of eclipses of the sun or moon, rather than on information supplied by the transportation of a mechanical timekeeper from one place to another. The method of "lunar distances," which involves the measurement of the angular distance from the moon to the sun or to certain fixed stars (accurate tables of the movements of the moon were, of course, presumed), was understood well before 1600.[7]

Late in the seventeenth century an almost revolutionary increase in the accuracy of maps took place. Its basis was the successful determination of longitude by quite another method, a method practicable, as was quickly recognized, only on land. This method involved the determination of differences in local time by means of simultaneous observations of the eclipses of one or another of the four major satellites of Jupiter. As the work of Italian and French astronomers after 1668 was to demonstrate, these were actually

preparation for the accurate observation of latitudes is in C. Wolf, *Historie de l'Observatoire de Paris de sa fondation à 1793*, 10–11, Paris, Gauthier-Villars, 1902. Contemporary interest in the tides was great and widely evidenced.

[4] On the origins of the modern scientific expedition, see J. W. Olmsted, The expedition of Jean Richer to Cayenne (1672–1673), *Isis* **34**: 117–118, 126–128, 1942.

[5] The sources for an early, relatively obscure voyage would tend to be scanty. What specially complicates the reconstruction of the voyage in question is the loss of the manuscript minutes of the Académie des Sciences for 1670–1674, together with the bulk of Richer's correspondence and reports relating to the voyage. Nor has the log of the ship on which Richer sailed been found.

[6] On the general problem of latitude, *cf.* F. Marguet, *Histoire générale de la navigation du XV^e au XX^e siècle*, 104–126, Paris, Société d'éditions géographiques, maritimes et coloniales, 1931; L. A. Brown, *Story of maps*, 180–207.

[7] On the question of longtitude, *cf.* F. Marguet, *op. cit.*, 127–260; L. A. Brown, *Story of maps*, 208–240. A useful recent work on early navigation is E. R. G. Taylor, *The haven-finding art*, London, Hollis, 1956. The standard work of R. T. Gould, *The marine chronometer, its history and development*, London, J. D. Potter, 1923 deals primarily with the post-seventeenth-century period in England.

the only eclipses well suited to the reliable determination of longitude.[8] In the case of lunar and solar eclipses, as well as of the "occultation" or eclipse of a star or planet by the moon, the instant of contact or of immersion in the shadow or emersion from it could not be observed with sufficient accuracy. Moreover, the relative infrequency of lunar and solar eclipses, as well as of occultations, made them less useful than eclipses of the satellites of Jupiter.

The possibility of using the eclipses of the satellites for the determination of longitude had been recognized early in the century concurrently with Galileo's discovery of these "moons" of Jupiter.[9] But it was two generations before relatively accurate ephemerides of the movements of the satellites, published in 1668 by an Italian astronomer, Giovanni Domenico Cassini (1625–1712), made the method practical.[10] Cassini's call to Paris in 1669 to become a resident member of the new Academy of Sciences was not unconnected with this development. His persistent efforts to apply the method were well seconded by those of his colleagues who were astronomers.

In this way, the magnificent new *Observatoire de Paris*, where members of the Academy observed, came to serve as the center of what might appropriately be termed a "bureau" of longitude and cartography. Here observations of the eclipses were arranged and carried on, the cooperation of astronomers in other countries solicited, missionaries with overseas assignments given training in the techniques of observation, and the observations subsequently obtained recorded and entered on a special world map.[11] From the 1670's and 1680's on, an increasing number of observations began to flow in. The results were startling: the longitude of key points in the Far East in error by from 20° to 27°; the length of the Mediterranean seriously overestimated on virtually all maps; the Atlantic coast of France too far to the west by nearly 100 miles; and so on.[12] By 1700, as a result of these activities, a virtual revolution in cartography—a revolution accomplished in France, it should be emphasized—had taken place.

In bringing about this advance, the pendulum clocks developed by the great Dutch scientist, Christiaan Huygens (1629–1695), had contributed notably. As early as 1666, when Huygens was brought to Paris in anticipation of the establishment of the Academy of Sciences, his clocks, after a decade of tinkering and refinement, were capable of a high degree of accuracy.[13] The alert

[8] On the method and its application, *cf.* G. Bigourdan, *L'astronomie. Evolution des idées et des méthodes*, 168–170, Paris, E. Flammarion, 1911; F. Marguet, *op. cit.*, 127–131; L. A. Brown, *Story of maps*, 215–223, based on the fuller discussion in his *Jean Dominique Cassini and his world map of 1696.*

[9] For the first attempts to apply the method to the improvement of cartography and navigation by means of concerted observations, see accounts of the activities of what has been termed a "bureau of longitude" at Aix, in Provence, *circa* 1633 to 1636, centering around the amateur, Nicolas-Fabri de Peiresc, and the philosopher-astronomer, Pierre Gassendi, in P. Humbert, *Un amateur: Peiresc, 1580–1637*, 211–237, Paris, Desclée, de Brouwer, n.d. [1933]; G. Bigourdan, *Histoire de l'astronomie et des observatoires en France* 1: 32–43, 2 pts, Paris, Gauthier-Villars, 1918–1930. The most recent account is Seymour L. Chapin, The astronomical activities of Nicolas Claude Fabri de Peiresc, *Isis* **48**: 23–27, 1957. Whether, as Chapin contends, some of these activities amounted to genuine scientific expeditions of a new type is a point which wants clarification.

[10] *Ephemerides Bononienses mediceorum syderum, ex hypothesibus et tabulis Joan. Domin. Cassini*, Bologna, 1668.

[11] L. A. Brown, *Jean Dominique Cassini and his world map of 1696, passim* (to be used with caution); C. Sandler, *op. cit., passim.* The standard work on the construction and history of the *Observatoire de Paris* is by C. Wolf, as cited in n. 3, above.

[12] See the works cited in note 11. Observations of the lunar eclipse of 28 August, 1635, had led Peiresc to the conclusion that contemporary maps of the Mediterranean, based on Ptolemy's longitudes, were highly inaccurate as regards its length. According to Chapin, in the article cited in n. 9 above, the conclusion reported by Peiresc in his correspondence is that the accepted length was excessive by 200 to 300 leagues, i.e., 600 to 900 miles. *Isis* **48**: 25, 1957.

[13] Huygens' correspondence, papers, and published writings, especially the *Horologium* (1658), and *Horologium oscillatorium* . . . (1673), constitute the fundamental sources for these developments. All are now available in the great collection, *Œuvres complètes de Christiaan Huygens publiées par la Société hollandaise des Sciences*, 22 v., La Haye, M. Nijhoff, 1888–1950, cited hereafter as *Œuvres complètes*. See esp. vols. **2–8**, **17–18**, 22, *passim*. A reliable short biography of Huygens in English is A. E. Bell, *Christian Huygens and the development of science in the seventeenth century*, New York, Longmans, Green, 1948. Brief suggestions regarding the invention, use, and success of Huygens' astronomical clocks occur in L. A. Brown, *Story of maps*, 211 ff; R. T. Gould, *The marine chronometer* . . ., 27–30. For more extended treatment, see L. Defossez, *Les savants du XVII^e siècle et la mesure du temps, passim*, Lausanne, Édition du Journal suisse de horlogerie et de bijouterie, 1946, and J. D. Robertson, *The evolution of clockwork*, London, Cassell, n. d. [1931], esp. ch. 6, 7, 9. Though dealing less with theoretical, scientific elements, the latter work is more thorough, and based on considerable use of original documents.

astronomers of the Academy, men like Adrien Auzout (1622–1691), and the Abbé Jean Picard (1620–1682), were quick to seize on the clocks as one means of improving the accuracy of a wide range of astronomical observations. An even more pressing application in the eyes of those concerned with the improvement of navigation was the use of clocks on shipboard for the determination of longitude. Had this proved feasible, the application would, of course, have anticipated by nearly a hundred years the success reserved for the marine chronometers perfected in England and in France in the course of the second half of the eighteenth century.

II

During 1667 and 1668, members of the new Academy were busily planning an important program of astronomical observations. To carry out those which needed to be made overseas, proposals to send observers to such places as Madagascar were under consideration.[14] Moreover, it so happened that the Academy's sponsor, Colbert, and its leading member, Huygens, had long been interested in the problem of determining longitude at sea. As a result, from 1667 until well after 1670, numerous attempts to find a solution to this baffling question were made in France, both inside and outside the Academy.

Huygens' interest in the problem arose directly from his invention of the pendulum clock. Within a fortnight of the completion of his first model in December, 1656, he raised the question of the possible service of such a clock to navigation. Two years later, when his recently published treatise, the *Horologium*, was bringing detailed knowledge of the new clock to the learned world, he and a Scottish collaborator, Alexander Bruce, Earl of Kincardine, who had been in exile in the Netherlands, tried their hands at a design suitable for use at sea. In 1662 this first marine clock, employing a short pendulum, was completed and given preliminary tests preparatory to a trial on shipboard.[15]

The first in a long series of such trials was made early in 1663 with clocks Huygens had had constructed for Bruce. The occasion was a voyage made by the latter across the North Sea to England. Weather conditions were quite unfavorable, however, and the trial was unsuccessful. Bruce and his colleague of the Royal Society of London, who had been informed of what was going forward, were not discouraged. During the course of 1663 they managed to have the clocks tested on board the ship of Captain (later Admiral) Sir Robert Holmes of the Royal Navy on a voyage to Lisbon and return.[16] This was followed late in 1663 and 1664 by an even more exacting trial. Again the clocks were sent with Holmes, who was in command of a small naval squadron destined for the Guinea coast and, so Huygens was informed, Jamaica.[17]

The principal political result of this voyage, chiefly through Holmes' high-handed seizure of Dutch trading stations in Africa, was the acceleration of the outbreak in 1665 of the second of England's seventeenth-century commercial and colonial conflicts with the Netherlands. The scientific results of the voyage were entirely pacific and at first seemed quite promising.

The apparent success of the marine clocks during this extended trial, while not conclusive, greatly encouraged Huygens.[18] Previously he had been rather pessimistic about the outlook because of inequalities in the daily rates of going

[14] Olmsted, *Isis* **34**: 118–119, 1942. An early outline of a general astronomical program for the Academy, in Huygens' handwriting, and probably dating from 1666, is in *Œuvres complètes* **19**: 255–257.

[15] *Ibid.* **2**: 5, 109; **4**: 68, 72, 151. For details of the marine clocks, 1662–1670, see *ibid.*, **17**: 164–182; **18**: 7–24; **22**: 174, 579–582, 586, 593–594, 604–608. Numerous original sketches are reproduced. A tentative *mise-au-point*, based largely on the *Œuvres complètes*, is in Defossez, *op. cit.*, 173-178.

[16] *Œuvres complètes*, **4**: 274–275, 278, 281, 284–285, 287–288, 290–291, 296, 304, 306, 318, 426–428, 431–432, 443–451, 458; **17**: 166-167, 193. According to Holmes' journal, the period the clocks were observed was 28 April-4 September, 1663.

[17] *Ibid.*, **4**: 428, 443. Possibly Moray's statement of 29 November, 1663, that the clocks would be sent to Guinea and thence to Jamaica was made in good faith. The secret object of Holmes' voyage, however, was limited to support of English trade and traders in Africa against the Dutch. The widely disseminated statement that it was Holmes' squadron which, presumably after crossing the Atlantic from Africa, captured New Amsterdam from the Dutch in August, 1664, is false, as Holmes' journal proves. See J. C. M. Warnsinck, The legend of Holmes at New York, *Mariner's Mirrour* **22**: 238–239, 1936.

[18] *Œuvres complètes* **4**: 432, 444; **5**: 284–285; **17**: 193-194, 230–234; **22**: 174. On the origins of the Second Dutch War, 1665-1667, the fundamental discussion is H. L. Schoolcraft, The capture of New Amsterdam, *Engl. Hist. Rev.* **22**: 674-693, 1907, which first showed the primary importance of Anglo-Dutch conflicts of interest in West Africa and the contribution to open conflict made by Holmes' seizure of Dutch trading posts on the Guinea coast.

of the clocks both ashore and afloat. Now his confidence in ultimate success returned. Plans were considered for the manufacture and sale of the marine clocks under conditions which would secure his financial interests.[19]

In Paris, meanwhile, knowledge of what Huygens and his English collaborators were attempting had become quite widespread. Indeed, the Dutch scientist himself early informed one of Colbert's influential advisers, the poet Jean Chapelain, of his hopes for the clocks. Subsequently he reported the progress being made. The enthusiasm evinced by Huygens about the performance of the clocks during Holmes' voyage to Africa seems to have determined Chapelain to see that some of their potential advantages were secured for France. By a variety of means, he strove to arouse public interest in the clocks as well as to have their inventor brought to France. In June, 1665, at a time when interest in the new marine clocks was growing in scientific and official circles, negotiations with Huygens were begun.[20]

During the same period, pendulum clocks which Huygens had had made in Holland for the Parisian amateurs, Carcavy and Montmor, were ready for delivery. One was of the marine type. Writing of it to Carcavy on August 20, Huygens noted: "This . . . [clock] will be of no little utility to your Company of the [East] Indies once the use of it has been begun. . . ." And, he added, having apparently come to a vital decision of his own, "this is what I shall work at as soon as I have come to France."[21] In a competition which was to prove important to science as well as to navigation, it appeared that the French had won the first round from their English rivals.

III

The creation in 1664 of a notable overseas trading company, the Compagnie des Indes Orientales, marked the realization of a favorite project of Colbert for the strengthening of French commerce in the region of Madagascar and the Indian Ocean. Huygens' opinion of the potential value of his marine pendulum clocks to the navigations of the Company was not likely to pass unnoticed by Colbert, whose interest in navigation and cartography, as previously indicated, was of long standing. Indeed, Colbert's formation of the Academy of Sciences in 1665–1666 was, in part, a response to the pressing needs of French navigation for the improvement of maps, the development of hydrography, and the solution of the problem of longitude. In this and other ways, Colbert gave an impulsion to nautical science in France which was to be felt long after his death in 1683.[22]

Initially it appears to have been the intention to test Huygens' clocks on a voyage to Madagascar, the East India Company's overseas headquarters during its early years. Thus in 1666, in the course of discussions among members of the nascent Academy about sending an observer to the island in the interests of astronomy, the opportunity this voyage might afford for testing the marine clocks was not overlooked. When, barely three weeks after the first meeting of the Academy (December 22, 1666), more precise plans for the scientific expedition to Madagascar were presented to the members by Adrien Auzout, the trial of Huygens' clocks was specifically recommended. It was perhaps no coincidence that Huygens, having established himself in Paris during the course of the previous year, was at the time supervising the construction of three marine-

[19] *Œuvres complètes* **2–6**: *passim*, contain much correspondence on the latter subject. On the specific steps taken in Holland, England and France, see esp. **17**: 175–177, and notes; **18**: 7–9, 20, and notes.

[20] H. L. Brugmans, *Le séjour de Christian Huygens à Paris et ses rélations avec les milieux scientifiques français* . . ., 37–39, 50, 56, 59–60, Paris, Impressions P. André, 1935; A. J. George, A seventeenth century amateur of science: Jean Chapelain, *Annals of science* **3**: 222–231, 1938; *Œuvres complètes* **2**: 166, 181, 266; **5**: 110–112, 204–205, 222–223, 375, 397. French interest in Huygens at this time was in no sense narrowly utilitarian. The fact that his work on Saturn aroused quite as much curiosity and emulation as did his marine clocks is worth remarking.

[21] *Ibid.* **5**: 438, 439–440; **17**: 8–9. The importance at this period of Carcavy's position and influence *vis-à-vis* Colbert is shown effectively in the unpublished doctoral dissertation of John Milton Hirschfield, The Académie royale des sciences (1666–1683): inauguration and initial problems of method, University of Chicago, 1957. I am indebted to the author for an opportunity to examine this promising study.

[22] *Cf.* C. de la Roncière, *Histoire de la marine française* **5**: 410–417, 6 v., Paris, E. Plon-Nourrit, 1898–1932; Didier-Neuville, Les établissements scientifiques de l'ancienne marine, *Revue maritime et coloniale* **56**, **57**, **59**, 1878; **62**, 1879; **66**, 1880; P. Clément, ed., *Lettres, instructions, et mémoires de Colbert* **3**^{1}, **4**: *passim*, 8 v., Paris, 1861–1882. R. Mémain, *La marine de guerre sous Louis XIV*, Paris, Librairie Hachette, 1937, is also pertinent.

type clocks which might be used for this purpose.[23]

As yet, however, fortune had not smiled on French efforts to develop maritime and commercial relations with Madagascar. Indeed, the East India Company, struggling to exploit the island's resources, was having to fight for its very existence.[24] To a variety of adversities, those of war had been added. First in point of time and importance was the Second Dutch War (1665–1667) between England and the United Netherlands. This conflict, as already indicated, Captain Holmes' African expedition had helped to precipitate. France, an ally of the Netherlands since 1662, reluctantly declared war on England in January, 1666. Thereafter French maritime relations overseas became quite uncertain, those with Madagascar and the East Indies suffering in particular. Across the Atlantic, local French successes in the West Indies were subsequently offset by English naval action in that area, and by the loss of the colony of Acadia in the north.[25] The belated return of the latter to France in 1670, under the terms of the treaty of Breda of July 21, 1667, which ended the war, was to provide the occasion for the little-known voyage and the scientific observations with which this paper is extensively concerned.

Whether the War of Devolution against Spain, which followed in May of 1667, had any direct or indirect bearing on the delay in the proposed scientific expedition to Madagascar, the documents do not reveal. Possibly the wish to avoid complicating in any way the troubled affairs of the East India Company was, as has been suggested, a more important factor.[26] Or it may have been that the wartime preoccupations of Colbert, whose official approval of any expedition involving members of the Academy of Sciences had to be obtained, served to delay authorization of the voyage to Madagascar, and hence of the related testing of Huygens' clocks. In any case, the best that could be had in the circumstances was a more restricted trial of the clocks shortly before the Treaty of Aix-la-Chapelle of May 2, 1668, ended the war with Spain.

IV

In the course of 1668 and 1669, governmental and scientific groups in Paris were considerably occupied with the question of longitude. One reason was that several "discoveries" asserted to provide practical solutions to the stubborn problem were presented to Colbert during these years.[27] Among them was that of "Sieur André Reusner de Neystett, of the German nation, formerly colonel of a Swedish regiment." Neystett's proposal was referred to a special committee composed of members of the Academy of Sciences, plus a high-ranking naval officer, the famous Abraham du Quesne, and Colbert. Although recognizing some ingenuity in the "discovery," a kind of marine odometer to be installed in a ship's hull, the committee reported it quite unsuitable for use.[28] Fontenelle's often repeated statement that Neystett received 60,000 livres even before the trials took place is unsupported by Colbert's account books and hardly accords with the minister's well-established reputation for shrewdness.[29]

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[23] A. J. George, The genesis of the Académie des Sciences, *Annals of Science* **3**: 385, 1938; Olmsted, *Isis* **34**: 118–119, 122 and note 53, 1942; Huygens, *Œuvres complètes* **19**: 256; **18**: 9; **6**: 129. Notes 7, 8, 9 of the last reference are in error and should be disregarded.

[24] Charles W. Cole, *Colbert and a century of French mercantilism* **1**: 504–509, 2 v., New York, Columbia University, 1939. I owe this reference and the suggestion it supports to Mr. Hirschfield's dissertation, referred to in n. 21, above.

[25] These and subsequent events are discussed in the standard histories of such authors as P. J. Blok, G. N. Clark, E. Lavisse, and D. Ogg. The best general account of French relations with Madagascar is in J. Sottas, *Histoire de la Compagnie royale des Indes Orientales, 1664–1719*, Paris, Plon-Nourrit, 1905.

[26] John M. Hirschfield in the dissertation cited in n. 21, above.

[27] The documents disclose the names of five men either interested in or who put forward various "discoveries" during this period, viz., Van Gangel, Reusner de Neystett, Jacques Graindorge, Nicolas Mercator, and Deshayes, the latter being directly involved in the Acadian voyage of 1670. On the first four, the most convenient source is *Œuvres complètes* **6**: 171–172, 200, 378–379.

[28] The full account is in the manuscript *procès-verbaux* of the Academy, Registres de l'Académie des Sciences (cited hereafter as Acad. Sci., Registres) **2**: 38–53, 1668–1669. It is summarized in part in *Œuvres complètes* **6**: 378, n. 1. The Registres reveal strikingly the extensive discussions of problems relating to longitude and navigation in the meetings of the Academy during this period.

[29] L. A. Brown, *Story of maps*, 214–215, is a recent writer who relies on Fontenelle's somewhat ambiguous account, *Mémoires de l'Académie royale des Sciences depuis 1666 jusqu'à 1699* **1**: 45–46, 11 v. in 14, Paris, 1729–1733. (The paging of the various printings of this set, abbreviated hereafter as *Mém. Acad. Sci., 1666–1699*, varies considerably.) This is Brown's authority for the assertion that Neystett was given a patent (*brevêt*) on his invention, "sight unseen," and paid 60,000 livres in cash. The Academy's minutes, cited in n. 28, are free of any ambiguity: such a payment to Neystett,

For their own part, members of the Academy appear to have been pretty well convinced that one of the best chances of solving the problem of longitude at sea lay in the further improvement of the marine clocks. Thus in March, 1668, probably at Huygens' initiative, one of the Academy's assistants, a M. Delavoye, was sent to test two of Huygens' clocks on board the flagship of an admiral of the French fleet in the Atlantic, M. de Beaufort. When, on March 29, with hostilities against Spain still in progress, Beaufort sailed from Brest with a small squadron for an attack on Corunna, Delavoye, together with his clocks, astronomical instruments, and written instructions prepared by Huygens, was on board the *Saint-Phillipe*.[30]

This time Huygens' hopes for success were high. Heartening news reached him as early as May 11. During a great tempest encountered by the fleet sometime in April, the clocks had not once stopped because of the storm. Writing to Colbert on June 22, a few weeks before the return to Brest, Delavoye expressed confidence in the complete success of the clocks, which in his opinion were destined to prove of great utility both to navigation and in the construction of improved marine and "terrestrial" maps.[31]

In the end, however, careful examination of the records of the voyage produced a different impression. The results, Huygens was forced to admit, were quite unsatisfactory. Mechanical faults in the clocks were partly to blame, he concluded. But, he alleged, Delavoye had handled the clocks badly and thus contributed to their failure. For a time Delavoye was under a cloud.[32]

Huygens was not seriously discouraged. To protect his invention against encroachment, he pleaded with Colbert for a trial of the mechanically improved clocks by a genuinely competent person on a long oceanic voyage. This plea was only partially successful. What was authorized was not an extended voyage in the Atlantic, but rather one in the Mediterranean from Toulon to Crete with a French expeditionary force under Beaufort for raising the twenty-year-old Turkish siege of the Venetian stronghold of Candia. Moreover, custody of the single clock employed was confided to Delavoye. Having been reinstated in Colbert's good graces, he was apparently on board Beaufort's flagship, *Le Monarque*, when the expedition weighed anchor on or about June 5, 1669. At the end of September—possibly a little later—Delavoye returned to Toulon.[33]

The results of this second voyage seemed encouragingly good. The clock had stood up well against the vibration caused by the ship's gunfire; even under the shock of the explosion of a near-by vessel, the *Sainte-Catherine*, it had not stopped. Further ground for Huygens' optimism was provided by the determination of the difference in longitude from Candia to Toulon with an apparent error of not over five or six leagues. Such an error was normally made by pilots in their reckoning of position after two days' sailing. Yet, on the return voyage, Delavoye's ship had been at sea from 22 July to 29 September without sight of land. Everything hinged, of course, on the accuracy of Delavoye's observations

or the issuance to him of letters-patent, is conditional upon the successful demonstration of his device before the royal commissioners. This is the import of the less explicit statement made by the contemporary secretary and historian of the Academy, J. B. Duhamel, *Regiae scientiarum Academiae historia*, 42–44, 2nd ed., Paris, 1701. The only payment to Neystett recorded in the official accounts of Colbert's office, *Comptes des bâtiments du roi sous le règne de Louis XIV*, ed. J. Guiffrey, **1**: 279, 5 v., Paris, 1881-1901, is dated 27 August, 1668, about three months *after* the rejection of the invention. The entry reads: "To M. Reusnier [*sic*] for having come here from Germany and Holland bringing various machines . . . 3000 [livres]"—a considerable sum for that day, and indirect evidence of the high valuation placed by Colbert on the solution of the problem of longitude.

30 Auzout to Oldenburg, 17 March, 1668, Royal Society of London, Guard Books, A, 21; *Œuvres complètes* **6**: 200; La Roncière, *op. cit.* **5**: 474-475; G. P. Depping ed., *Correspondence administrative sous le règne de Louis XIV* **4**: 567, 4 v., Paris, 1850-1855. Delavoye (? – 1684), sometimes referred to as La Voye-Mignot, and described as an astronomer and engineer, was named an *élève* of the Academy of Sciences in 1666. Although details of his first voyage with Beaufort are scarce, it need not be confused with that to Candia as is done by Huygens' editors, *Œuvres complètes* **6**: 187, n. 8; 281, n. 12. The instructions prepared by Huygens were presumably those of 1665 first issued in Dutch, and later published in Royal Society, *Philosophical Transactions*, 10 May, 1669. These instructions are reprinted in *Œuvres complètes* **17**.

31 *Œuvres complètes* **6**: 218, 226. Delavoye's letter, written from "Vignes" (Vigo?), is known only from the copy in Huygens' hand printed in this work.

32 *Ibid.* **6**: 379; Depping, *op. cit.* **4**: 567–568.

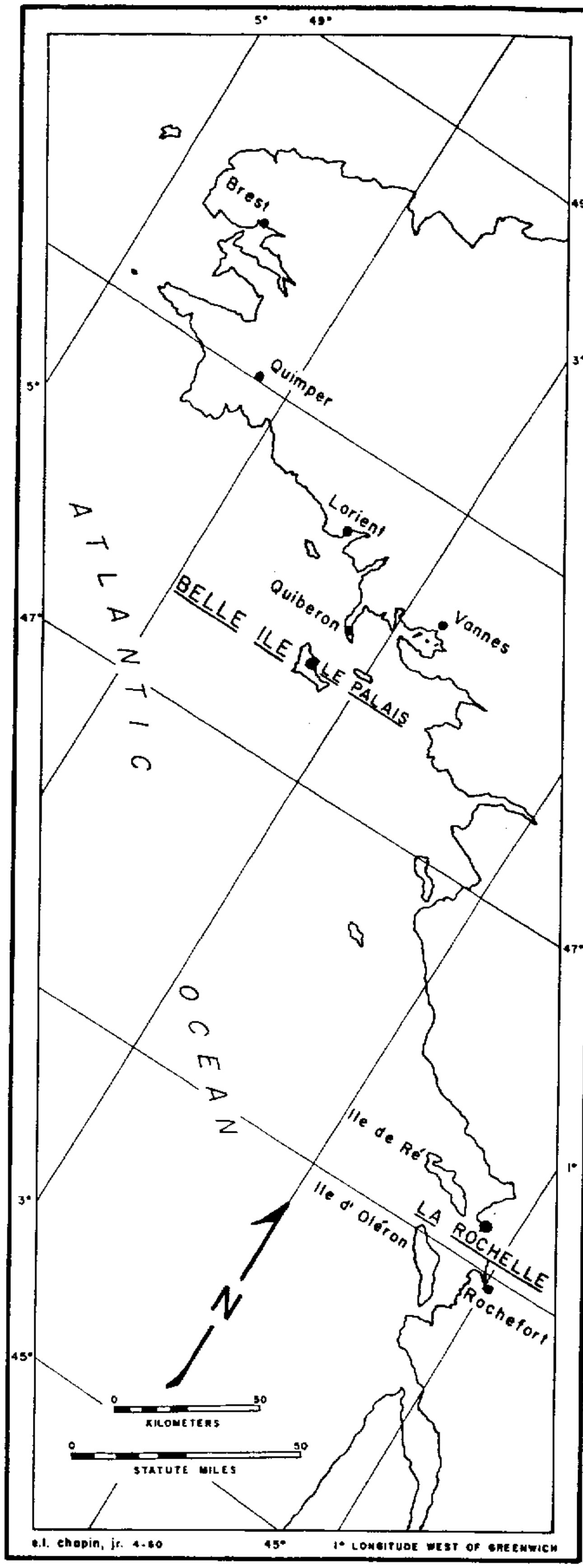
33 Depping, *loc. cit.*; *Œuvres complètes* **6**: 378–379, 501; La Roncière, *op. cit.* **5**: 280–295, the latter a clear general account of the history of the expedition. The single clock employed was apparently one Delavoye had arranged to have made for Beaufort at the latter's request sometime after the expedition of 1668. Presumably the mechanically modified clocks Huygens was preparing in Paris were not ready in time.

and the integrity of his journal. Huygens did not see how the latter could have been falsified although he did raise the question.[34] Late in October, with his doubts on this score apparently satisfied, he reported that the news of his clock since its return from Candia continued to be very good. Delavoye was completely rehabilitated and roundly praised. To Huygens, the long oceanic voyage he had previously urged Colbert to authorize now seemed even more necessary than before.[35]

V

For more than two years the astronomers of the Academy of Sciences had been busily formulating plans for various overseas scientific expeditions, that were originally intended for Madagascar being the earliest in point of time.[36] Quite possibly the recommendation of suitable occasions for the testing of Huygens' marine clocks had, during this period, been requested of them. The fact that the official report of the Acadian voyage of 1670 was made directly to the Academy strongly suggests such a relationship.[37] Conceivably it was one which existed at the time of the trials made with Beaufort in 1668 and 1669. Unfortunately, the scanty records which have survived permit no unequivocal answer. This is equally true of the more important problem of the origin and history of plans which called for sending Huygens' clocks on *two* long voyages, the one presumably westward to Cayenne, the other south and east to Madagascar and the Indian Ocean.[38]

Plans for testing the clocks on an eastern voyage were rapidly perfected at the end of 1669. Royal policy, it so happened, provided a unique opportunity. A large naval squadron under Jacob Blanquet de la Haye, "Lieutenant General of the King in Madagascar and the Indies," was on the point of sailing on a three-year cruise in the region of Ceylon, India, and the Dutch East



MAP 1. The Atlantic coast of France. To illustrate the movements of the *Saint-Sébastien*, May 1–14, 1670.

[34] *Cf.* Huygens' memoir, Sur l'Essay des Horloges sur Mer par Monsieur la Voye dans le Vaisseau de Monsieur de Beaufort au voiage de Candie en 1669, *Œuvres complètes* **6**: 501–503: also **6**: 500; **18**: 633–635. The account of this voyage published in the *Horologium oscillatorium* (1673) has been reprinted, with French translation, in *Œuvres complètes* **18**. For the text and translation of the relevant passage, see pp. 116–119.

[35] *Ibid.* **6**: 379, 486, 514–515.

[36] For these and other developments from which the expeditions of 1671–1672 to Uraniborg and 1672-1673 to Cayenne ultimately emerged, see Olmsted, *Isis* **34**: 117–121, 1942.

[37] For the details of the report, see below, sec. XI.

[38] See below, p. 621 and n. 47.

Indies as one phase of French strategic dispositions in anticipation of future hostilities with the Dutch. Since May, 1669, the squadron had been fitting-out at Rochefort (map 1). Subsequently, on 3 December, De la Haye was officially named to the command of this "escadre de Perse." The same day, at Colbert's order, Delavoye, described in the official entry as a "scientist ordered to the East Indies for the trial of the pendulum clock for the [determination of] longitudes," was paid a stipend of 600 livres for the next four months, plus an additional 300 livres to cover the costs of transporting himself and his instruments to La Rochelle. Huygens' wish for the rigorous and sustained testing of his clocks on a long voyage at last seemed on the point of fulfillment.[39] (It is surprising, in view of previous mechanical difficulties with the clocks on shipboard, that a competent horologer familiar with the construction, maintenance, and repair of such instruments was not assigned to this voyage or to any of the later voyages on which the clocks were to be tested.)

Delavoye, however, seemed unable to stand his new prospects and temporary prosperity. His funds he complained were quickly "eaten up"; shortly he was dunning Huygens for more. The previous intimations of personal instability and untrustworthiness became unmistakable. As a result this *fripon*, as Huygens described him, was relieved of his assignment.[40]

With the departure of De la Haye's squadron imminent, a replacement had to be found at once. Although the evidence is inconclusive, the collaboration of the Academy of Sciences in meeting this situation was apparently requested. In any case, on March 10, 1670, Colbert could inform his cousin, Colbert de Terron, the royal intendant at Rochefort, that "the Academy of Sciences" had chosen one of its assistants to go to the East Indies "to make various astronomical observations in connection with others which are to be made here [in Paris], and to test the clocks which have been constructed for the determination of longitude at sea. . . ."[41] It was the King's wish Colbert added, that the assistant, Jean Richer, and his aide, Meurisse, make the voyage on board a ship of the royal squadron which was soon to sail for the east. Thus the Academy's earlier plan for a scientific expedition to Madagascar was not only suddenly revived but seemed on the verge of being carried out. The replacement of Delavoye as custodian of Huygens' clocks by a rising young astronomer, Richer, was apparently the decisive factor in this development.[42] At the last moment, however, something went awry: instead of Madagascar and the Indian Ocean, we shall find Richer and Meurisse journeying in obscurity westward to New England and Acadia. Small wonder that an occasional scholar should express annoyance with a voyage to the East Indies which somewhat incomprehensibly winds up in Acadia.[43]

VI

Richer and Meurisse were apparently able to prepare for the journey quickly. According to Colbert, their luggage and instruments had left Paris about a week prior to his message of March 10 to Colbert de Terron. Not later than 21 March the two observers were themselves at La Rochelle. On the day of the vernal equinox Richer found time to measure the height of the tides in the harbor. Just eight days later, the "Persian squadron" sailed from La Rochelle on its long and dangerous mission.[44] Despite all the

[39] Sottas, *op. cit.*, 43; Clément, *Lettres . . . de Colbert* **3**: 442 and n. 1, 461–470; **5**: 478; Guiffrey, *Comptes des bâtiments* . . . **1**: col. 379.

[40] *Œuvres complètes* **7**: 26–27.

[41] Clément, *Lettres . . . de Colbert* **5**: 294. The phrase "horloges et pendules" in the text is probably an error in writing "horloges à pendule." Charles Colbert, seigneur de Terron (1618–1684), a man of influence, was from 1666 to 1674 the *intendent général* in charge of all naval affairs relating to the Atlantic coast of France and to French fleets in Atlantic waters.

[42] Guiffrey, *Comptes des bâtiments* . . . **1**: col. 470, contains the interesting entry: "5 April 1670. To Sevin, maker of mathematical instruments, for various instruments which by our order he has furnished M. Richer, whom we are sending to the [East] Indies to make some astronomical observations. 70# [livres] 10^s." Meurisse (or Meurice) has been identified only as Richer's assistant from 1669 to 1673. He died at Cayenne in the latter year. On 20 February, 1670, Richer had been paid 336 livres as compensation for experiments and astronomical observations made on behalf of the Academy of Sciences during the latter part of 1669-1670. *Ibid.* **1**: col. 270.

[43] E.g., by C. Wolf, *Histoire de l'Observatoire de Paris* . . ., 142–143, after quoting various seemingly contradictory statements found in contemporary documents.

[44] Clément, *Lettres . . . de Colbert* **5**: 294–295; Jean Richer, *Observations astronomiques et physiques faites en l'isle de Caïenne*, 89 (separately paged), in *Mém. Acad. Sci., 1666–1699* **7** (1), edition of 1729–1733; Sottas, *op. cit.*, 43. Subsequent citations of Richer's memoir will appear as *Observ. de Caïenne,* as found in the edition and volume of the Academy's *Mémoires* given above. De la Haye's squadron reached Madagascar 23 November, 1670.

preparations which had been made, Richer and Meurisse were not aboard. The scientific expedition to Madagascar was off again. What had happened to prevent it?

One ostensible explanation is provided by a report which Colbert de Terron sent to Colbert on 3 April, five days after the departure of De la Haye's squadron. After discussing a variety of matters, the intendant laconically informed his chief of Richer's situation in these terms:

> M. Richer's clock [clocks?] arrived here after the departure of the Persian squadron. I think it will be decided to send him to Acadia. It is a voyage from east to west during which he will be able to make his experiments; and, if he returns in time, it will be possible for him to embark on *Le Breton* [for the East Indies] in October.[45]

Yet it is possible this statement conceals more than it discloses. We know nothing of the clock or clocks which were late in arriving. We wonder whether Richer's equipment, which had arrived in ample time, did not include others which could have been made to serve on the outward voyage, the clock(s) in question being forwarded by a later ship, such as *Le Breton*. Further, what delayed the arrival at La Rochelle of this particular clock, and what made it so vital to Richer's mission? Finally, why should Richer's destination be a matter at this late stage for De Terron to decide? What lies behind this statement to Colbert?

Certain elements in this situation can be discerned, though not as clearly as one would like. Most important are the indications that various persons of influence, De Terron among them, had reasons to prefer that Richer be sent on a shorter, westerly voyage, rather than on the voyage to the Indian Ocean in replacement of Delavoye. A voyage from east to west would, for one thing, immediately provide substantial, cumulative differences in longitude. In testing Huygens' marine clocks, this would be an obvious advantage as against a voyage whose orientation would be primarily from north to south.[46] Furthermore, the results obtained would be known nearly a year sooner than those from a voyage to Madagascar which would require nearly eight months for the outward passage alone.

These or comparable reasons for sending Richer on a voyage west were bound to appeal strongly to the astronomers of the Academy. For some time past, Cayenne, rather than Madagascar, had been emerging as the preferred destination for the major overseas astronomical expedition deemed necessary to the furtherance of their observational program. As early as May, 1669, Huygens was writing of observers about to be sent to "America." But by September of that year, Cayenne is the specific destination he mentions to his correspondent in England. Furthermore, by January of 1670 it has become a question of "our voyagers for the trial of longitude in east *and* west . . ." (my italics). Richer and Meurisse, moreover, are officially described at this time in Colbert's account books as "mathematicians designated to go to Cayenne to make astronomical observations of utility to navigation."[47]

In order to make the specific observations envisaged by G. D. Cassini and others concerned in planning this "Brazilian expedition," Richer and Meurisse would need to sail from France during the autumn of 1671 or early in the winter of 1672.[48] If they accompanied De la Haye's squadron to Madagascar and the Indian Ocean what assurance was there that they would be back in time? Given the recent state of communications with this remote region, the prospects must have seemed slim at best.

Clearly, the astronomers of the Academy had grounds for intervening in the matter of Richer's destination. That they did so, either directly or indirectly, there is no evidence. The prestige of Cassini was already sufficient to enable him, had he so decided, to make representations personally to Colbert. And, indirectly, there was the matter of the readying in Paris of one or possibly

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[45] Colbert de Terron to Colbert, 3 April, 1670, Bibliothèque Nationale (hereafter given as B. N.), Mélanges de Colbert **176**: fol. 57 *verso*. The photostats of this correspondence were obtained from the collections of the Library of Congress. Their loan is gratefully acknowledged. Whether De Terron meant one clock, or more than one (he writes "la pendule de M. Richer") is not certain in the light of statements he makes elsewhere. See below, n. 50.

[46] This aspect of the question was first called to my attention by a geographer and colleague, Professor Homer Aschmann. I am indebted to him for a number of helpful suggestions about some of the later portions of the paper.

[47] *Œuvres complètes* **6**: 427–428, 440, 486; **7**: 4; *Comptes des bâtiments* . . . **1**: col. 476.

[48] Greatest urgency attached to the proposed observations of Mars, which in the fall of 1672 would, after an interval of about fifteen years, be at the point in its orbit nearest the earth. *Cf.*, Olmsted, *Isis* **34**: 121–122, 1942.

two of Huygens' marine clocks for Richer to use. It is tempting to infer that members of the Academy had a hand in making certain that "unavoidable delays" kept "M. Richer's clock" from reaching La Rochelle until after the departure of De la Haye's squadron. Had Huygens, for his part, wished to prevent any such machination—assuming there was one—he could have done nothing personally to counter it. Late in January or in February, he had become seriously ill and for many months thereafter could accomplish virtually nothing. Indeed, sometime during September or October, he returned to Holland to convalesce for an additional nine months.[49]

De Terron, being on the scene at La Rochelle, was obviously in the most favorable position to encourage or to effect a last-minute change in the plan to send Richer to Madagascar. He appears, moreover, to have had a specific reason for favoring such action. This is at least implied in a letter of 14 April written to Colbert:

> I have already had the honor to write you that Richer will embark with his clock [clocks]? on the *Saint Sébastien* for Acadia. Deshayes will also sail on the same vessel with the instrument that he has made in Paris. It is to be hoped that from the contact of these two men, who are embarking on good terms, knowledge will result with which you may be satisfied.[50]

To what extent, one wonders, was the situation revealed in this communication purely fortuitous? Colbert, to be sure, must have had some idea of what was impending and evidently interposed no objection; possibly he had some part in the arrangement. Yet, in view of De Terron's previous relations with Deshayes, it seems probable that any initiative would be likely to come from the intendant rather than the minister.

Deshayes is a distressingly obscure figure.[51] He has been described as an impoverished professor of *mathématiques* at Rouen who grew tired of trying to conduct courses to which no one came, and instead attempted to find a market for a "discovery" which he claimed to have made concerning the determination of longitude. To this end he apparently informed De Terron quite fully of his proposed method sometime during 1669. De Terron, who was himself interested in the improvement of navigation, and well aware of his cousin's preoccupation with the subject, must have been favorably impressed.[52] At least he sent his new protégé to Paris to wait on the minister. Colbert in turn passed Deshayes on to the Academy of Sciences for interrogation.

At the first autumn meeting of the Academy for the discussion of questions of *mathématiques*, on October 16, 1669, Charles Perrault, *Controleur des Bâtiments*, informed the members of the matter. Deshayes, he said, had represented to M. Colbert that he had found an exact method for the determination of longitude at sea. The minister had therefore asked Deshayes to present his method to the Academy. Recalling their experience of the preceding February with a certain Jacques Graindorge, the prior of Culey in lower Normandy, who was likewise a legacy from Colbert, the members must have been prepared for the worst. What they heard from Deshayes was probably better than they had anticipated.[53]

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[49] *Œuvres complètes* **7**: 9-10; Brugmans, *op. cit.*, 67. No letter written by Huygens between 22 January and 15 October, 1670, is known.

[50] Colbert de Terron to Colbert, 14 April, 1670, B. N., Mélanges de Colbert **176**: fol. 91 *verso*. Again, as in the letter of 3 April quoted above, Colbert de Terron writes "la pendule," a further use of the singular form which adds to our uncertainty since, as we shall see, Richer unquestionably carried *two* clocks with him on the Acadian voyage.

[51] Careful inquiry has failed to elicit any biographical details concerning Deshayes. Until specific information can be found, the temptation to identify him with or relate him to the Jean Deshayes who was a member of a French scientific expedition of 1681–1682 to Gorée and the West Indies, and who between 1685 and his death at Quebec in 1706 was twice in Canada, where he did important cartographical work, must be resisted. However, dates alone do not rule out either the possibility that Deshayes and the better known Jean Deshayes were one and the same man, or that they may have been closely related, e.g., father and son.

[52] Didier-Neuville, Les établissements scientifiques de l'ancienne marine . . ., *Revue maritime et coloniale* **62**: 459-460, 1879. In a letter of 21 April, 1670, to Colbert. B. N., Mélanges de Colbert **176**: fol. 105 *verso*, De Terron indicates a hope to see a school of "hydrographie et pilotage" established at La Rochelle, in part to maintain the morale of young naval officers by keeping them busy while in port. *Mathématiques* at this period embraced astronomy, navigation, mechanics, optics, etc., as well as geometry and the other branches of mathematics, narrowly defined.

[53] Acad. Sci., Registres **5**: 184 ff., 1669, under date of 16 October. The rumor which had reached Oldenburg in England as early as 6 May, 1669, that the Academy, on behalf of the king, had already offered Deshayes 160,000 livres for his discovery, *Œuvres complètes* **6**: 427, is reminiscent of the exaggerations which gathered around Neystett in this same period. It reinforces previous indications of the seriousness of official and popular interest in the problem of longitude and of the large rewards currently talked about. Graindorge was one

The method proposed was in no sense original. It consisted of finding the longitude of a given point by means of the observation of the distance from the moon to the sun by day, and from the moon to a star by night; in short, by the method of "lunar distances." However, as the members of the Academy rightly insisted, the state of astronomical knowledge in 1669 did not permit the construction of sufficiently accurate tables of the movements of the moon. In consequence, any longitudes determined by this method would be seriously in error. Huygens' opinion, moreover, was that Deshayes knew less about the method he was putting forward than others who had previously proposed its use.[54]

To the objections formulated against his proposal, Deshayes returned written answers which were discussed by the Academy at the meeting on 23 October. Thereafter an unfavorable report on the practicability of Deshayes' proposition was submitted to Colbert.[55]

The matter evidently did not rest there. For one thing, while still in Paris, Deshayes had ordered "two large instruments, each of a diameter of two feet, and made by a certain Rousselot who lives in the faubourg Saint-Germain"—at whose suggestion and at whose expense it is impossible to say.[56] In the second place, De Terron could hardly have announced to Colbert in April, 1670, that Deshayes was soon to embark for Acadia unless tacit consent to a trial of his method had previously been given. The idea of having Richer and his assistant sail on the same vessel seems most likely to have been De Terron's. Could this have been the decisive element in the "delay" in the arrival of Richer's clock at La Rochelle the previous month?

An additional factor in determining the intendant's action may have been the attitude of the commander of "the Persian squadron," who was openly contemptuous of Richer's mission and reluctant to accord this accredited representative of the Academy the facilities and personal recognition stipulated by Colbert in his letter of 10 March. If the reports of the naval engineer, Massiac de Sainte-Colombe, based on conversations with Richer at La Rochelle are to be trusted, De la Haye's attitude and actions boded ill for the trial of Huygens' clocks. How far this situation influenced De Terron in substituting the Acadian voyage, we should like to know. Possibly one of the functions of this brief journey to North America was, in De Terron's eyes, to keep Richer suitably employed until he could be sent to Madagascar with a more sympathetic and cooperative commander. For, as he indicated to Colbert on 3 April, if Richer got back from Acadia in time, he could proceed to the east on board *Le Breton* in October. A "delay" in the arrival of Richer's clock(s) until after the departure of the East Indian squadron may, for the added reason of De la Haye's attitude, have appealed to De Terron as serving the legitimate interests of all parties.[57]

VII

However informative the apparent reasons for Richer and Meurisse not being aboard when De la Haye sailed in March, 1670, the change in their destination is not what gives the episode its

of the "longitudinaires" of 1668–1669 referred to above, n. 27. The *procès-verbaux* of the Academy deal at length with the episode in which he was involved: Registres **3**: 261–272 (20 February, 1669), 273–278 (27 February, 1669), 279–282 (6 March, 1669), 1668–1669. A Latin memoir of 39 pages submitted to the Academy contained not only a method for longitude which, according to Huygens, was based on the assumption of the thing sought, but also a "perfect meteorology," the true cause of the wind and tides, whether the earth or the sun turns, etc.—views which Huygens alleged were all drawn from Graindorge's "astrology."

[54] *Œuvres complètes* **7**: 4.

[55] Acad. Sci., Registres **5**: 184–190 (16 October), 194–197 (23 October), 1669; and *cf. Œuvres complètes* **6**: 533, 534.

[56] Quoted by Didier-Neuville, *loc. cit.*, n. 52, above, from a letter of 14 April, 1670, by a naval engineer, Massiac de Sainte-Colombe, who saw Deshayes—as well as Richer—at La Rochelle, and judged him a very sensible person, though doubting the probable success of his method for determining longitude. The nature of Deshayes' "instruments" is entirely unknown. That they represented a crude form of sextant or octant of two-foot radius is not impossible. But why should this have made them "large"?

[57] *Cf.* Didier-Neuville, *loc. cit.*, n. 52, above, who bases his conclusions on the extant letters of Sainte-Colombe; Clément, *Lettres . . . de Colbert* **5**: 294; De Terron to Colbert, 3 April, 1670, *loc. cit.*, n. 45, above. Colbert's stipulation regarding Richer was that he should not only receive all the *commodités* which his mission required, but be given a place at the captain's table as well—a source, perhaps, of some of De la Haye's apparent resentment. The continued resolution to send Richer to Madagascar, despite the possible consequences for the projected 1671–1672 scientific expedition to Cayenne on which the Academy planned to send him, is a point of some interest. One would like to know the source of the apparent pressure. Did it result from an inclination on the part of Colbert and/or his cousin, to give top priority at this point to scientific enterprises which were centered narrowly on the solution of the problem of longitude at sea?

primary interest for the history of navigation. Rather it is the decision to send Deshayes *with* Richer on the same vessel. An early voyage during which it was intended to test the two principal methods by which the riddle of longitude at sea was ultimately resolved would, by its very singularity, command the historian's attention. This would still be the case even if chance had played a larger part than we now think in bringing Richer and Deshayes together at La Rochelle.

De Terron, once the decision revealed in his letter of 14 April to Colbert had been reached, was inclined to gloat at the prospect of having the two men test their respective methods on board the same vessel. For, as he subsequently wrote the minister, "one will provide the best possible check upon the other." [58]

Just what considerations had determined De Terron's choice of ship and destination for his two "longitudinaires" is not clear. As it happened, other posibilities than the *Saint-Sébastien* and Acadia were open to him. Three royal ships were at La Rochelle awaiting favorable weather before sailing for destinations in French North America. The *Gédéon* was for Quebec, carrying back to Canada the famous intendant, Talon. *Le Sigournois* was sailing for Plaisance with the governor-designate of Terre Neuve (Newfoundland) aboard. Lastly, the *Saint-Sébastien* was scheluled to go to New England and Acadia with some infantry, a military engineer, and—most important of all—Hector D'Andigny, Sieur de Grandfontaine, a naval captain who had recently been named plenipotentiary of Louis XIV for the belated surrender of Acadia by the English under the treaty of Breda of 1667, and civil and military commander in the province as well.[59] Possibly the date at which the last-named vessel was expected to return to La Rochelle was a factor in De Terron's decision.

Stormy and changeable weather held the *Saint-Sébastien* at La Rochelle all through April. On the first day of May, however, De Terron was able to inform Colbert that her captain, La Clochetrie, expected to sail at once. Ten days later word had been received that the ship had put in at Belle-Île (map 1) after a heavy storm "without further incident." [60] What mischance was thus alluded to we do not specifically know.

In all probability Richer observed the latitude of Belle-Île on this occasion.[61] Assuming the observation(s) to have been made at the island's principal town and port, Le Palais, whose latitude is approximately 47° 21′ 35″, Richer's figure of 47° 21′ is surprisingly good—well within the limits of accuracy of ± 1′ characteristic of the best work during the early 1670's—the period of the gradual introduction of "telescopic sights" and of noteworthy improvement in the knowledge of refraction and parallax.[62]

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[58] Colbert de Terron to Colbert, 1, May, 1670, B. N., Mélanges de Colbert **176**: fol. 127 *verso*.

[59] The details are in the dispatches of Colbert de Terron to Colbert, B. N., Mélanges de Colbert **176**: *passim*, and, to a lesser extent, in Colbert's letters to the former in Clément, *Lettres . . . de Colbert* **3**[1]: *passim*. The King's order to Grandfontaine to command for three years in Acadia under the royal governor and lieutenant-governor in Canada, at the time the Sieur de Courcelles, was dated 20 February, 1670. Paris, Archives de la Marine, B[2], **10–12**: fol. 10–11. Grandfontaine remained in Acadia until 1675, when he was recalled.

[60] Colbert de Terron to Colbert, 1 May, 1670, 11 May, 1670, B. N., Mélanges de Colbert **176**: fol. 127 *verso*, 153 *verso*; *Œuvres complètes* 7: 27. Chadeau de la Clochetrie (the orthography of the name varies considerably) was a "capitaine de frégate" from 1666 to 1671, becoming "capitaine de vaisseau" in the latter year. He died in 1696. The *Saint-Sébastien*, which he commanded in 1670, was listed as 250 tons burden and 16 cannon. In 1664, when she served as vice-admiral's ship in a fleet which went to the West Indies, the *Saint-Sébastien* carried a total of 153 crew members, soldiers, and passengers. On a voyage to the same area in 1671 the total "équipage" was 120, viz., 20 "officers mariniers," 60 sailors, and 40 soldiers. S. L. Mims, *Colbert's West India policy*, 86, New Haven, Yale University, 1912, Yale Historical Studies **1**; Mémain, *op. cit.*, 920.

[61] This observation is known to me only by a letter of 16 December, 1679, from Jean Picard to J. D. Cassini, Observatoire de Paris, Manuscrits, B. 4. 12, in which there is a reference to "the elevation of the pole observed at Belle Isle [*sic*] by M. Richer of 47° 21′." Possibly Richer was at Belle-Île on some occasion after 1670; yet no reference to astronomical observations made by him subsequent to 1673 has been noted. In that year he returned from his two-year expedition to Cayenne, and, indicative of changing times, was shifted from the service of the Academy of Sciences to that of fortifications and military engineering under the celebrated Vauban. That he visited Belle-Île in this capacity, and made an astronomical observation or two on the side, is a possibility, but only that.

[62] Surprising accuracy was achieved at this time in observations made by astronomers of the Academy, an accuracy twentieth-century commentators sometimes find hard to accept. (This accuracy was likewise typical of the work of certain conservative astronomers like Hevelius, who continued to use large quadrants which did not have the advantage of "telescopic sights.") Apparently the nature of traditional instruments and the conditions of observation had long required and been productive of greater keenness of vision and observa-

On May 14 La Clochetrie wrote De Terron from Belle-Île that all was well and he was ready to put to sea again.[63] Nevertheless, in one respect disaster had already struck. The heavy storm encountered by the *Saint-Sébastien* out of La Rochelle had resulted in serious damage to the clocks with which Richer had been entrusted. Before the storm abated, both had stopped. In addition, one clock seems to have suffered a fall and been more or less ruined. Neither was again in operation at any time during the outward or the return passage.[64]

De Terron's great hopes for the voyage had thus in part been dashed almost within sight of the French coast. His expectations in regard to Deshayes' success must in the end have proven equally illusory. But here the sources afford us no further aid, no trace of Deshayes or of the observations he may have made. Indeed there is no positive evidence that he was actually on board when the *Saint-Sébastien* sailed; but neither is there evidence that he was not. The curtain is simply rung down. The drama of the two "longitudinaires" and of the trial of their rival methods ends in a conspiracy of silence almost before it has begun.

VIII

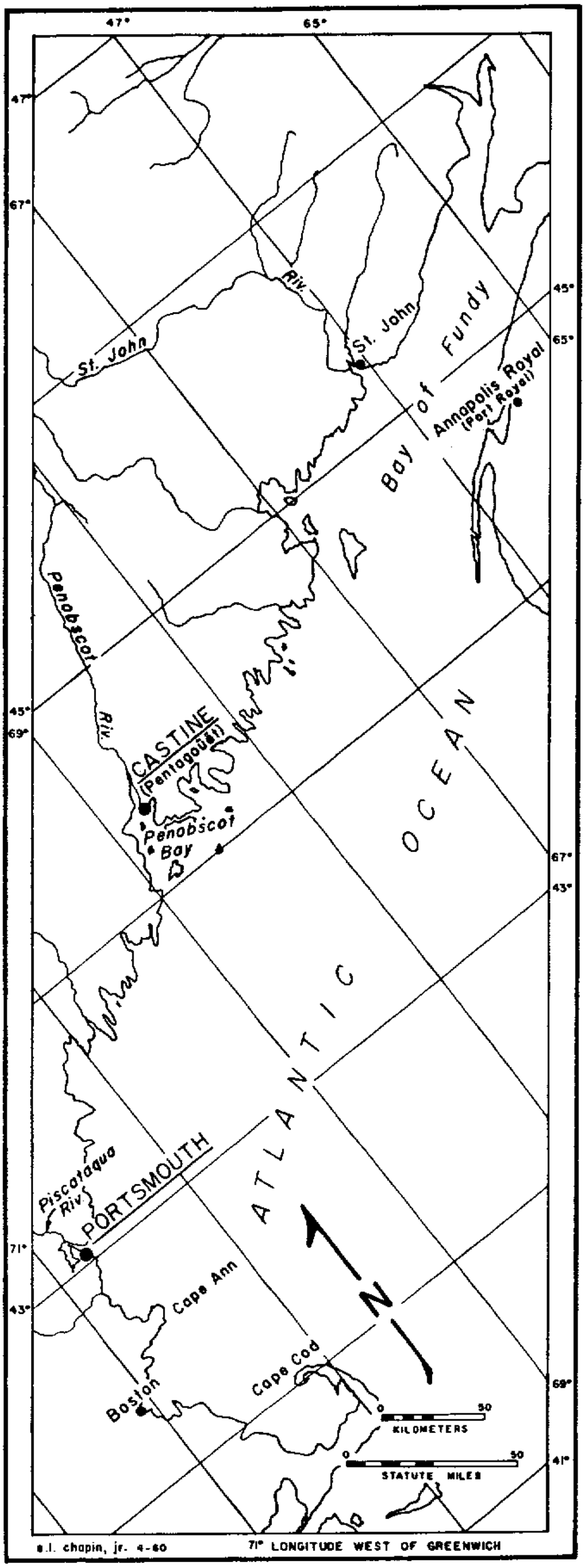
If nothing further can be learned regarding the attempts to determine longitude during the expedition to Acadia, the same is not true about observations of latitude. In addition, a number of details about the voyage itself can be gleaned. Thus we know that by July the *Saint-Sébastien* was at or near Boston. There, on the seventh day of the month, Grandfontaine signed a treaty with the British governor of Acadia, Sir Thomas Temple, providing for the full restitution of the colony to the French crown.[65] To complete the

tional skill than is assumed or achieved now that mechanical and optical advances in instruments have made them unnecessary. This general fact, plus Richer's prior experience, the quality of his instruments, and the standards of accuracy he later achieved at Cayenne, make a strong case for placing considerable reliance on the determinations of latitude he made in 1670. (See below, sects. VIII, IX.) It would be superficial to hold that he was merely lucky in certain random observations.

[63] Colbert de Terron to Colbert, B. N., Mélanges de Colbert **176**: fol. 155.

[64] *Loc. cit.*, n. 63, above; *Œuvres complètes* **7**: 54–55.

[65] The text of the treaty is in *Collection de manuscrits . . . et autres documents historiques relatifs à la Nouvelle France* **1**: 198–199, 4 v., Quebec, 1883–1885. On the background of the surrender, *cf. ibid.* **1**: 187–195, 197–198; *Recueil des instructions données aux ambas-*



MAP 2. The New England and Acadian coast. To illustrate the movements of the *Saint-Sébastien* and the related events of July and August, 1670.

transfer, Grandfontaine and his party then sailed northward (map 2).

By July 16 the *Saint-Sébastien* had either reached or passed the general vicinity of the estuary of the Piscataqua River, site of modern-day Portsmouth. This we learn from Richer's report on his scientific expedition to Cayenne in 1672–1673, a voyage on which he was again the designated agent of the Academy of Sciences. In his account of this expedition, published in 1679, Richer recapitulates observations of the tides which he made at Cayenne, as well as in North America in 1670.

> I shall add to these observations of the flux and reflux of the sea made at Cayenne, those which I made in the year 1670 on the coast of Acadia in Canada, and on the coast of New England. . . . On the coast of New England, in the harbor of a place called Piscataway [Pescatoué], on the open ocean, whose latitude is 43° 7′ N., I observed that the tide was high at 11:15 A.M., 16 July 1670, the day of the new moon.[66]

This statement warrants an attempt to fix more precisely the point on the New England coast near which the *Saint-Sébastien* was presumably at anchor on July 16 (map 3). Unfortunately, numerous difficulties stand in the way. First, none of the early maps which have been examined provides a clue to the location of a settlement which a contemporary Frenchman would know as Pescatoué, Pescadoué, or possibly Piscatewai; an Englishman presumably as Piscataway.[67] Moreover, there is some evidence that, during the seventeenth and even the eighteenth century, these early forms of Piscataqua were used quite indifferently to refer to a large, undefined area lying to the north of the estuary.

A more reliable guide in interpreting Richer's figure of 43° 7′ N. for the latitude of the harbor in question is provided by the qualifying phrase which tells us that the harbor of Pescatoué is "sur le bord de la grande mer." This statement, made by an experienced scientific observer, must be considered virtually decisive. Thus any of the inland harbors, between, say, 43° 3′ latitude on the south and 43° 11′ on the north, in which Richer's observations might conceivably have been made, can hardly be considered to lie "on the open ocean" and must be ruled out.[68] This includes the large number of points in the estuary of the Piscataqua itself lying between 43° 3′ and 43° 6′ N. latitude. The estuary of the York River, whose mouth is at roughly 43° 8′ N., seems similarly excluded, as does that of the Cape Neddick River at 43° 11′ N. In the latter case, it is doubtful whether the region designated by contemporaries as Piscataway can properly be considered to have embraced the territory lying to the north of the York River. This would be additional reason for rejecting both the York and Neddick estuaries as possibilities. Nor is it likely Richer's figure for the latitude of the site of his observations was in error by as much as the 3 to 4′ necessary to make either the Piscataqua or the Neddick serious possibilities.

Three points "on the open ocean" appear to remain (map 3). From south to north these are: the cove at Seapoint, whose latitude is roughly 43° 5′ 25″ N.; what is now known as Brave Boat Harbor at 43° 6′ N.; and Godfrey's Cove at 43° 7′ 10″ N.[69] The difference in latitude between the first and third of these sites is 1′ 45″;

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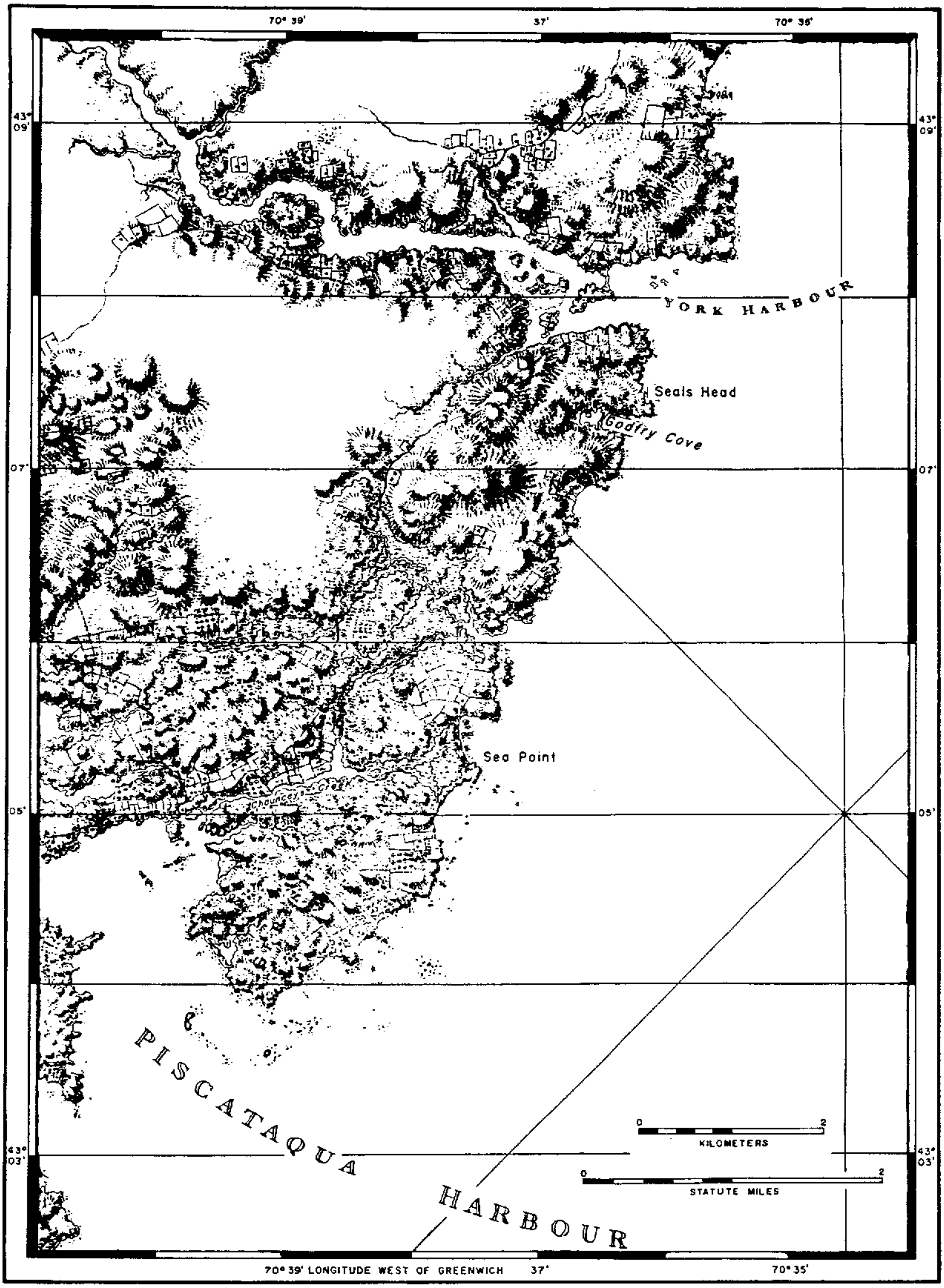
sadeurs et ministres de France depuis les traités de Westphalie . . . **25**: 19–20, 23–28, 86–88, 454–455, Angleterre, 2; Calendar of State Papers, *America and West Indies*, 1661–1668: nos. 1598–1600, 1635–1638, 1641, 1643, 1654, 1669–1701, 1709, 1808, 1815, 1868, 1877, 1898; 1669–1674: nos. 4, 23, 32, 69, 95, 384. On Sir Thomas Temple (1614–1674), consult *Dictionary of national biography* **19**: 520. The interrelationship between the *détente* over Acadia and the West Indian island of St. Christopher, the move for a commercial treaty, and the negotiations which in May and June, 1670, culminated in the celebrated secret treaty of Dover between Louis XIV and Charles II should not be overlooked. The best general history of the French in Acadia is E. Lauvrière, *La tragédie d'un peuple: histoire du peuple acadien* . . ., nouv. edn., 2 v. Paris, H. Goulet, 1924.

[66] Richer, *Observ. de Caïenne,* 89. The name "Pescadoué," using a "d" in place of Richer's "t," appears on a French manuscript map of 1650, but without any geographical detail. The map is reproduced in Justin Winsor, *Narrative and critical history of America* **3**: 382, 8 v., Boston, 1884–1889. Interest in the tides, as previously suggested, was widespread during the seventeenth century. Auzout's proposals to the Academy of Sciences in 1667 for a scientific expedition to Madagascar included careful observation of the tides and of ocean currents. See above, p. 616, and n. 23.

[67] The form, Piscatewai, appears on a map from the 1688 edition of Blome's *Amérique*, reproduced in Justin Winsor, *Cartier to Frontenac* . . . , 346, Boston and New York, 1894. The variant spelling, Pescadoué, rather than Richer's Pescatoué, has been encountered in two or three documents of the post-1670 period, as well as on the map of 1650 referred to in n. 66.

[68] For more detailed information about this portion of the Maine-New Hampshire coast, see the United States Geological Survey topographic map of the York Quadrangle, used in the edition of 1920.

[69] For additional detail on the places and latitudes indicated, see the map of the York Quadrangle referred to in n. 68, above.



MAP. 3. The New England coast from *circa* latitude 43° 2′ N. to 43° 10′ N., after a map of 1779 by J. F. W. Des Barres.

the greatest deviation from Richer's figure of 43° 7′ is in turn 1′ 35″ in the case of Seapoint. Both differences are in excess of the error of less than 1′ attained by Richer's values for the latitude of Belle-Île and that of Pentagoûët in Acadia, the latter of which will be discussed hereafter. Moreover, in both instances Richer's value for the latitude makes it too small rather than too large. Thus, if a systematic error were involved, through use of the same instrument at each of the three places, then the latitude of Pescatoué—particularly if it is the mean of two or more observations—should also be too small rather than too large. Yet, as we have seen, any point north of Godfrey's Cove, at 43° 7′ 10″ N. latitude, can hardly be made to fit either Richer's description of the harbor or the name of the place at which his several observations were made. In this case we must apparently admit the possibility of an error of ± 2′—possibly more—in the latitude which Richer reports for Pescatoué. If he made only a single observation, as seems probable, or used a different instrument, such a limit of error would be altogether normal. Thus, in terms of latitude alone, we can only conclude that any one of the three points named might have been the place known to Richer as Pescatoué.[70] On other grounds than latitude, either Seapoint or Godfrey's Cove appears the more likely location.

Seapoint, particularly as shown on a 1779 map by J. F. W. Des Barres in the *Atlantic Neptune* (map 3), has several claims to be considered the site in question.[71] First, there is the question of proximity to the estuary of the Pescatoué, a good reason for the application of the name to a nearby settlement. Further, in the seventeenth century the cove was pretty certainly larger than now. It would accordingly provide better protection for ships of the size of the *Saint-Sébastien.* A further argument in Seapoint's favor is its closeness—not much more than half-a-mile—to an east-west arm of the Piscataqua estuary now known as Chauncey's Creek. If the captain of the *Saint-Sébastien* preferred the greater shelter of the estuary, a trip by small boat along the Creek, followed by a walk overland to Seapoint with the requisite instruments, might conceivably have been managed. The fact that there is today some settlement proximate to the "harbor" at Seapoint is a tenuous added argument in its favor.

The case for Brave Boat Harbor is weakened by its topography. The harbor consists of a fairly narrow entrance behind which lies a small estuary in which a ship might drop anchor. Possibly, merely by contrast to the magnitude of the estuary of the Piscataqua, with its numerous inland havens, the Harbor might on a first visit to this coast have been considered to lie "on the open ocean." Yet the settlement of Pescatoué, if situated here, would pretty certainly have lain somewhere on the inner reaches of the estuary. How then could the phrase, "on the open ocean," properly have been applied to it? In this respect Brave Boat Harbor appears to fit Richer's basic condition somewhat less well than either Seapoint or Godfrey's Cove.

The latter offers us the third and presumably final possibility. As a harbor, the cove was doubtless larger and capable of providing better shelter in 1670 than it could today after almost three centuries of wave action on Seal Head Point, plus the attendant silting of the Cove itself. On the other hand, Godfrey's Cove is still farther removed than Brave Boat Harbor from the Piscataqua River and from the contiguous region which might most readily lend its name to the settlement. Possibly this consideration tilts the balance, however, slightly, in favor of Seapoint as the most likely site for Richer's observations on July 16, 1670—observations made "on the coast of New England, in the harbor of a place called Pescatoué, on the open ocean. . . ."

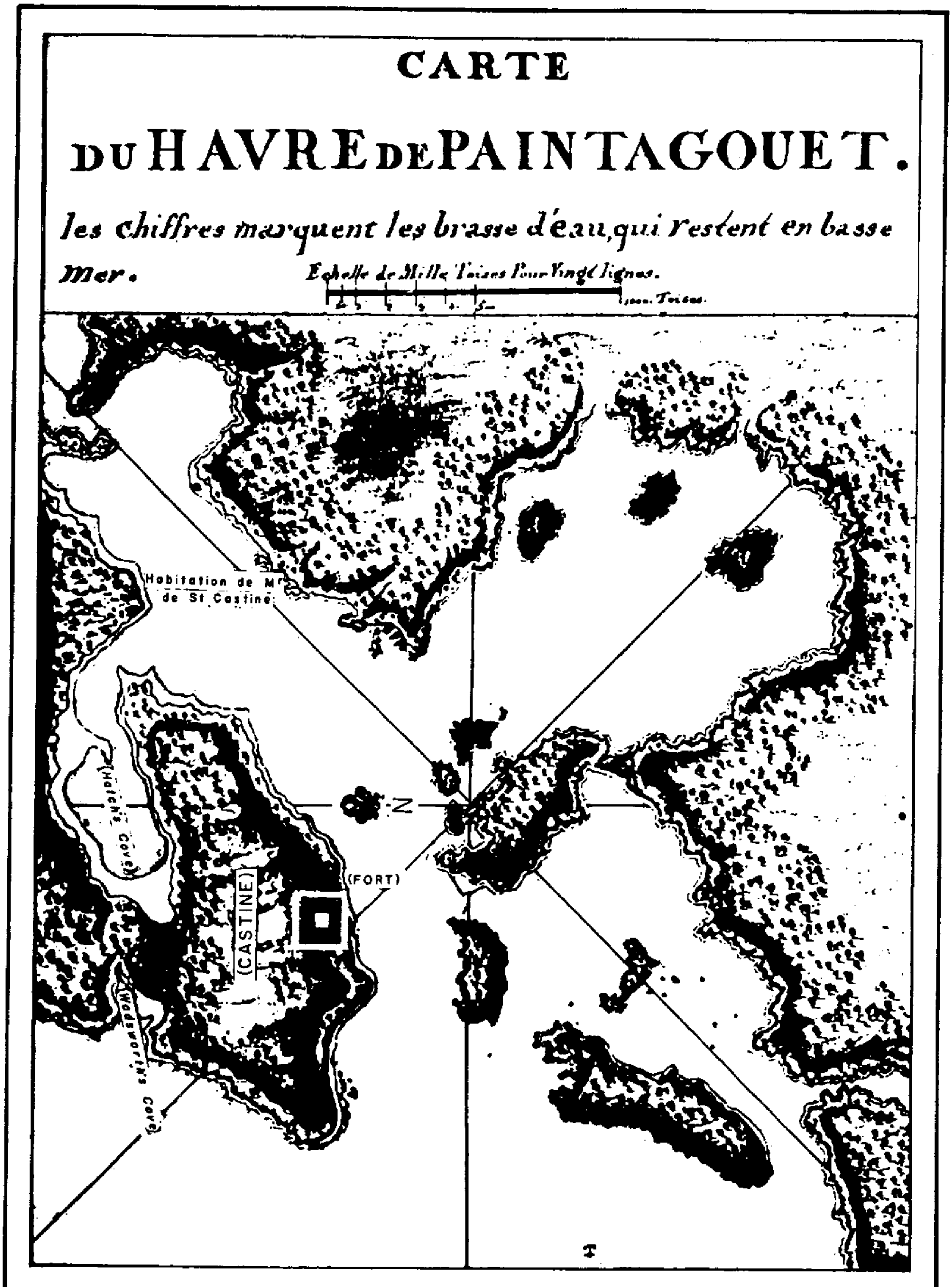
IX

Before the end of July, Richer's ship had reached Penobscot Bay (map 2). There the French had a small fort called in this period Pentagoûët, "on the river of the same name," as Richer later wrote.[72] The fort occupied a site,

[70] The time of high tide observed by Richer can apparently offer no help in differentiating the three places. The Director of the United States Coast and Geodetic Survey has kindly informed me that the time of tide would be almost simultaneous all along the coast from the Piscataqua to Cape Neddick. In support of Richer's observational accuracy, he further indicates (letter of 11 August, 1959) that the "time of 11:15 A.M. for high water on 16 July, 1670, appears to be reasonable. . . ."

[71] Des Barres' map, as map 3 indicates, names as well as locates "Sea Point" and "Godfry Cove." Brave Boat Harbor is not named or perhaps as accurately represented on the map as the other two appear to be. My photostat is from a Library of Congress copy of *The Atlantic Neptune,* copy 2, vol. 3, map no. 12. Presumably this is from the collection published in London in 1781 as pt. 2 of vol. 2 of the *Neptune*: Joseph F. W. Des Barres, *Charts of the coast and harbours of New England from surveys taken by Samuel Holland. . . .*

[72] *Observations de Caïenne,* 89, as cited in n. 66, above.



MAP 4. The fort and harbor of Pentagoûët in Acadia, after a French map of *circa* 1688. From a copy in the Map Division of the Library of Congress.

practically at water's edge, on low cliffs dominating the harbor (map 4). During the eighteenth century, both harbor and town came to be known as Castine, following nearly fifty years in which their history was intimately associated with the colorful career of Jean Vincent d'Abbadie, Baron de Saint-Castin (1650–1712). In the later eighteenth century the harbor lay under the guns of Fort George, which the British built in 1778 on the high ground in the center of Castine's jutting headland. The United States Geological Survey map of the Castine Quadrangle gives Fort George, whose ruins are still a prominent landmark, a latitude of approximately 44° 23′ 25″ N. The latitude of the site of Fort Pentagoûët, known to have been situated somewhat west of the present waterfront area of the town roughly half-a-mile from Fort George, cannot have been far from 44° 23′ N.[73]

On 31 July and 4 August, respectively, Richer observed the height of the tides at Pentagoûët. During his stay he also made observations of the latitude, reporting it to be 44° 22′ 20″ N.[74]

This figure is in error by something over 40″, thus conforming well with the apparent error in the latitude of the harbor of Belle-Île presumptively observed by Richer on the outward voyage from La Rochelle.[75] Perhaps, as seems likely to be the case with the latitude of Belle-Île, Richer's value for that of Pentagoûët is the mean of several observations. For at both these places, unlike Pescatoué, where the visit was presumably brief, Richer had the time in which to get several readings. One important reason for doing so would have been his involvement in the trials currently being made of telescopically equipped instruments devised a few years earlier by the Abbé Jean Picard, instruments which were bringing revolutionary new refinement and accuracy to French observational astronomy.

It is accordingly significant to note that Richer reports the latitude of Pentagoûët in what, even in 1679, was not yet common usage for observations of celestial altitudes. Specifically, he gives his observation(s) in degrees, minutes, and seconds of arc, rather than in degrees and minutes only. At the time the latitude was observed, this was a radically new departure, practicable in serious astronomical observation only since Picard began using a special 28-inch quadrant which was probably the first instrument for measuring large angles equipped with a complete telescope and cross-hairs.[76] We wonder, of course, whether, either in preparing his memoir for publication in 1679, or at some earlier date, Richer modified his observed value for the latitude of Pentagoûët, applying to it a correction growing out of improved knowledge of the instrument he had employed. Further, was the instrument he used one of the new telescopic type, and hence capable of observations of such refinement? Could it, in fact, have been Picard's original 28-inch quadrant which we know Richer used extensively at Cayenne in 1672–1673—an instrument he more than likely had with him at La Rochelle in 1670 in anticipation of his scheduled three-year expedition to the East Indies? These are interesting questions. The sources do not provide the evidence with which to answer them.[77]

[73] Additional geographical detail will be found on the U. S. G. S. map of the Castine Quadrangle mentioned in the text, and used in the edition of 1904. The most extensive information on the history of the settlements and forts at Castine is in G. A. Wheeler, *History of Castine, Penobscot, and Brooksville, Maine; including the ancient settlement of Pentagoët,* Bangor, 1875. Part III of the work, "Documentary," reprints a valuable selection of documents, of which roughly forty relate to the pre-Revolutionary period. Wheeler's later, more detailed studies of the old Fort of Pentagoûët are in *Collections and Proceedings of the Maine Historical Society,* second series, **4**: 113-123, 1893. For detailed discussion of the fort and its remains, see pp. 118–121.

[74] *Observations de Caïenne,* 89, as cited in n. 66, above. The tidal observation on 31 July was made the day of full moon, the tide being high at "9 or 10 seconds before noon." So precise a figure suggests that solar observations in connection with the determination of both local time and latitude (from the meridian altitude of the sun) were in progress. The difference between low and high tide that day was 10 feet (pieds), although the tide on 4 August is said to have been "even higher than the other days."

[75] See above, p. 624.

[76] A summary account of Picard's introduction of what he and contemporaries knew as "telescopic sights" will be found in J. W. Olmsted, The "application" of telescopes: 1667 or 1668? *Sky and Telescope* **8**: 7 ff., 1948. A fuller discussion is in *Isis* **40**: 214-224, 1949. Earlier practice was to report altitudes, etc., to the nearest minute, or occasionally the half-minute.

[77] During 1669 and after, Picard was successfully employing telescopically-equipped quadrants and similar instruments for measuring angles in his celebrated and impressively accurate "measurement of the earth." He had been seizing every opportunity to test these new instruments. He thus had quite as much reason to wish to have a telescopically-equipped quadrant used on an expedition to Madagascar in 1670 in which Richer was involved as he did a year later when preparations were being made for the latter's expedition to Cayenne. It may be more than coincidence that Picard seems to have made no observations with his first, 28-inch telescopic quadrant *after* 3 March, 1670, and probably not for some little time before. It was during this first week in

The one fact which stands out in this discussion is that Richer's value for the latitude of Pentagoûët is correct within limits of accuracy of ± 1′, instrumental errors and those due to refraction included. And such limits, it may again be said, constitute the touchstone by which to judge the quality of contemporary astronomical work. Even though Richer did not have a special emplacement for his instruments, as he did at Cayenne, it seems unlikely that so good a result came merely from chance. Richer's skill as an observer, the presumable quality of his instruments, his involvement in the current efforts to improve standards of observational accuracy—all these, as previously indicated, have a bearing on the quality of the results of which he was capable when conditions were favorable. They appear to have been so at Pentagoûët. Thus Richer's figure of 44° 22′ 20″ N. for the latitude of the fort should probably be accepted as the most refined and accurate astronomical observation thus far made in North America, or—for that matter—in the western hemisphere; further, it may be considered the most accurate determination of latitude yet made in the New World. It seems doubtful that the latitude of any other North American point was known with comparable accuracy for at least another generation and probably longer.[78]

March, according to Colbert, *Lettres* . . . **5**: 294–295, that Richer's instruments and luggage left Paris for La Rochelle, ostensibly for the long voyage and expedition to Madagascar. P. Lemonnier, *Histoire céleste* . . ., 17, 20, and *passim*, Paris, 1741, is the source for Picard's observations at this period. The instruments Richer used at Cayenne are described by him in *Observations de Caïenne*, 5–6, 8.

[78] The principal contemporary French account of the North American coast from New England to the Gulf of Saint Lawrence offered nothing better than the statement that "the river of Pentagoûët is situated under the latitude of forty three and a half degrees. . . ." Nicolas Denys, *The description and natural history of the coasts of North America*, Paris, 1672, ed. and transl. W. F. Ganong, 247, Toronto, Champlain Society, 1908. An attempt in 1652 to establish the north boundary line of the Bay Colony, ordered by the General Court, had resulted in a determination of the latitude of the head of the Merrimac River which was in error almost 4′. S. E. Morison, *Harvard College in the seventeenth century* **1**: 211 and n. 3, 2 v., Cambridge, Mass., Harvard University, 1936. According to Samuel Williams in 1785, the earliest reported figure for the latitude of Cambridge was derived from observations of eclipses made in 1694 by Thomas Brattle. The resulting value of 42° 25′ Williams says was generally accepted until his own observations in 1784–1785, using a 2½-foot quadrant made by Sisson, showed the latitude of Harvard Hall to be 42° 23′ 29″. *Memoirs of the American Academy of Arts and Sciences* **1**: 62–69, Boston, 1785.

X

The relatively refined determination of the latitude of Pentagoûët is one specific accomplishment of Richer's first experience in scientific voyaging. The place at which it was made was situated in an area in which French interests, growing out of explorations initiated early in the century, were of long standing. Indeed, the history of French settlements at Pentagoûët dates back to 1613 in the days of Champlain, to whom, as his map of 1632 indicates, the river on which the fort was situated was known as the Pemetogoit; only in the next century, under English rule, did it difinitively become the Penobscot.[79]

After 1670, when Grandfontaine chose it for his headquarters, the strategic importance of the fort at Pentagoûët was increasingly recognized. In fact, from that time until just after the turn of the century, throughout the Saint-Castin period, either Pentagoûët or one of the forts on the Saint-John's River was regularly the post of France's principal garrison in Acadia and the seat of the provincial government as well. Only after 1700 was Pentagoûët surpassed in importance by the rising star of Port Royal.[80]

Thus the official surrender of the fort to the French on August 6, 1670, two days after Richer's second observation of the tides in the bay, was a political event of some consequence. For us its interest lies in the strong probability that Richer and Meurisse, the first persons associated

[79] For a contemporary account of the founding of the first French settlement, see *The works of Samuel de Champlain* **4**: 12–20, 6 v., Toronto, Champlain Society, 1922–1936; also *The Jesuit relations and allied documents*, ed. R. G. Thwaites, **8**: 130, 287, 73 v., Cleveland, 1896–1901. E. Lauvrière, *op. cit.* **1**, provides a good secondary account of the entire period. The map referred to is reproduced as plate 10 of the "Portfolio of Plates and Maps" which accompanies the edition of Champlain's works cited above. New Englanders were using the name Penobscot in the seventeenth century.

[80] J. B. Brebner, *New England's outpost: Acadia before the conquest of Canada*, 43, New York, Columbia University, 1927, Columbia University Studies in History, Economics, and Public Law, no. 293. Grandfontaine maintained his headquarters at Pentagoûët until he was recalled the year after a raid on the fort in 1674. On the role of the settlement and the fort during the Saint-Castin period, *cf.* L. J. Burpee, *The Oxford encyclopedia of Canadian history*, 566, New York, Oxford University, 1926; *Encyclopedia of Canada* **2**: 12, 6 v., Toronto, University Associates of Canada, 1935–1937. Additional information and bibliography is in Thwaites, ed., *Jesuit relations* **63**: 65, 299–300; **71**: 315–334, and *passim;* P. F. X. de Charlevoix, *History and general description of New France*, transl. J. G. Shea, **3**: 138–139, 186–188, 210–211, and *passim*, 6 v., New York, 1866–1872.

with the Académie Royale des Sciences to be charged with a mission overseas, and its first representatives to come to the New World, were present. That they were likewise at Port Royal on 2 September when it in turn was relinquished to the French seems less likely.[81] Had Richer visited that settlement, he would very probably have had an additional latitude and some further tidal observations to add to his scientific catch.

The probablity is strong that the *Saint-Sébastien* sailed for France directly from Pentagoûët sometime in August, well before the surrender of Port Royal. For on 18 September De Terron wrote Colbert that the vessel had entered the harbor of La Rochelle the previous evening, and that he was forwarding at once a letter and copies of memoranda sent by Grandfontaine.[82] Richer and Meurisse were presumably on board when the ship dropped anchor. At any event, Richer was able to round out his voyage across the Atlantic with some observations at La Rochelle on the occasion of the autumnal equinox, 21 September. On that day he observed the height of the tides in the harbor, just as he had exactly six months earlier when his departure for the East Indies appeared imminent. Sometime before the end of the year both he and Meurisse were again in Paris.[83]

XI

The official report to the Academy on the scientific results of the voyage can hardly have been easy or pleasant for Richer to make. To be sure, he had made some useful and commendably accurate determinations of latitude; he had obtained valuable information about the height of the tides on the eastern and western shores of the Atlantic; apparently he had done a little collecting; possibly he had accomplished other things besides.[84] But on the all-important subject of longitude, there was nothing but failure—disastrous failure, at least as regards the chronometric method—to report. The absence of Huygens, who was still convalescing in Holland, must have been a boon to Richer when he appeared before the Academy early in January, 1671, to present an account of his mission.[85]

The report at least had the merit of brevity. The storm which had been encountered soon after leaving La Rochelle, Richer indicated, had been too much for the clocks; thereafter nothing could be done with them. Of progress toward the solution of the problem of longitude by this method there was nothing to relate. Before success could be attained, he implied, further mechanical improvement of the clocks would be necessary.

This conclusion Huygens was not yet prepared to accept.[86] He had first learned of the failure

[81] Documents on the surrender of Pentagoûët and the other posts in Acadia are in *Collection de manuscrits . . . relatifs à la Nouvelle France* 1: 199-202. The act of surrender of Pentagoûët and other documents relating to this post are reproduced by Wheeler, *op. cit.*, 254 ff., chiefly from the transcripts made in France by B. Perley Poore in the Archives of the Commonwealth of Massachusetts, esp. vols. 2, 3. The surrender of Gemesié or Jemseck on the St. John's River was received on 27 August by Grandfontaine's lieutenant, Soulanges, who likewise accepted that of Port Royal on 2 September—both from the same English representative, Capt. Richard Walker. E. Lauvrière, *op. cit.* 1: 123; Charlevoix, *op. cit.* 3: 138, n. 3.

[82] Colbert de Terron to Colbert, 18 September, 1670, B. N., Mélanges de Colbert 176: fol. 319. Grandfontaine was evidently expected to inform his government promptly of the success or failure of his mission. To guard against the possible nondelivery of his reports and maps of Pentagoûët sent via the *Saint-Sébastien*, messengers carrying the relevant information were sent overland to the returning intendant of Canada, Talon, at Quebec, arriving about 10 November. *Cf. Collection de manuscrits . . . relatifs à la Nouvelle France* 1: 194, 200–201, 202; Courcelles to Colbert de Terron, Quebec, 19 September, 1670, B. N., Mélanges de Colbert 176: fol. 416 *verso*, 417, reporting on messengers *previously* sent to Acadia to get news of M. de Grandfontaine. One of the two known sketch maps of the fort of Pentagoûët in 1670 or thereabouts appears to have accompanied the memoir of 10 November, 1670, from Talon to De Terron, announcing the arrival in Quebec of the messengers from Acadia and reporting on the affairs of the province. A somewhat different map, probably of 1670, may be that sent directly to France by the *Saint-Sébastien*. The two originals are catalogued in H. Harisse, *Notes . . . à l'histoire, à la bibliographie, et à la cartographie de la Nouvelle France . . . 1545–1700*, 193, Paris, 1872; also G. Marcel, *Cartographie de la Nouvelle France . . .*, 26, Paris, 1885.

[83] *Observations de Caïenne*, 89; *Comptes des bâtiments . . .* 1: col. 476. Meurisse was paid for the expenses of his trip from La Rochelle to Paris on 27 December, 1670, presumably some little time after reaching the latter city.

[84] In Acad. Sci., Registres 7: 124, 1675–1679, it is recorded that a member of the group, the botanist Marchand, showed the assembled company a plant called *Solanum acadiense*, which had been collected by Jean Richer. At Cayenne, Richer also did a little zoological collecting.

[85] The text of the report, like some of the correspondence relating to it, is apparently lost—probably with the Academy's *procès-verbaux* for the years 1670–1674. Its nature can be pretty well established from Huygens' letter of 4 February, 1671, *Œuvres complètes* 7: 54–55.

[86] Later the validity of Richer's contention was indirectly acknowledged by Huygens when he attempted to change and improve the suspension of the pendulum

of the clocks by letter directly from Richer. Later a summary of Richer's report to the Academy—in all probability from the pen of the secretary, Duhamel—sent him into a rage. The fault, he vehemently insisted, was with the observers, not with the clocks, just as it had been on Delavoye's first voyage.

In a letter written on 4 February, Huygens was more specific. Richer's handling of the clocks, he declared, had been bad throughout the voyage. For want of a little oil, properly applied, the clocks had been needlessly damaged and afterward more or less ruined; for want of attention to the written instructions provided, they had not been started again after the storm so that they might be observed during the balance of the voyage. In short, he concluded, "the want of success on this occasion, as far as I can judge, stems more from the carelessness of the observers than from the failure of the clocks."[87] How Richer's report could have satisfied the members of the Academy, he could not comprehend. Basically, what Huygens would not yet acknowledge, as about a decade later he did, was that the adaptation of pendulum clocks to marine conditions was impracticable.[88]

XII

At the end of 1670 prospects for the success of Huygens' marine version of his pendulum clocks were dim indeed, particularly in comparison with those designed for use on land. The latter, subsequently labeled "astronomical clocks," had now attained a high degree of accuracy and were assured a brilliant future. In fact, when used in combination with two recent "inventions" by members of the Académie des Sciences, namely filar micrometers for measuring small celestial angles (1665–1666), and the quadrants equipped with "telescopic" sights for the more accurate measurement of large angles, as first brought into use by Picard from 1667 to 1669, the clocks were soon to revolutionize both the methods and the standards of observational astronomy.[89] It is at this point that modern, precise astronomy of position begins.

Moreover, in direct aid of navigation, astronomical clocks contributed vitally during the years before and after 1700 to the general renovation of cartography which has already been briefly described.[90] The practical success of G. D. Cassini's method for the determination of terrestrial differences of longitude, like the verification of his tables of the motions of Jupiter's satellites, hinged on their use. Thus in 1671–1672, employing accurate pendulum clocks of Huygens' design, Picard, who was on a scientific expedition in Denmark, and Cassini, who remained in Paris, were able to determine the difference in longitude between the Observatoire de Paris and the site of Tycho Brahe's famous, but long since destroyed observatory on the island of Hven. Shortly thereafter, as part of the Academy's next scientific expedition, Richer at Cayenne and Cassini at Paris were able by similar observations to fix fairly accurately the difference in longitude between these two widely separated stations. For cartography, at least, these were epoch-making accomplishments. Without Huygens' clocks neither would have been possible.[91]

used in his marine clocks. *Horologium oscillatorium* (1673), in *Œuvres complètes* **18**: 120–122.

[87] *Œuvres complètes* **7**: 54–55.

[88] *Ibid.* **8**: 197. For this change in Huygens' attitude, see below, p. 634. Huygens' correspondence attests a certain ambivalence about the prospects for the success of the marine pendulum clocks from as early as 1663, e.g., *Œuvres complètes* **4**: 432. While he was wavering, opinion in London in the Royal Society gradually crystallized against the pendulum clocks, following the lead given by Robert Hooke, an outspoken critic of the prospects for such clocks and a proponent of the use of a spring balance in place of a pendulum. *Cf. ibid.* **6**: 495; **7**: 6, the latter a letter from Oldenburg to Huygens in February, 1670. Hooke had made his position explicit in 1665, possibly with the intent of embarrassing Huygens, whose rivalry in the search for a solution of the problem of longitude he did not welcome. Before the Royal Society, on 15 March, 1664/65, Hooke remarked that, "in his opinion, no certainty could be had from pendulum watches for the longitudes, because, 1. They never hung perpendicular, and consequently the cheeks were false. 2. All kinds of motions upward and downward, (though it should be granted that the watches hung in an exact perpendicular posture) would alter the vibrations of them. 3. Any lateral motion would produce yet a greater alteration. . . ." Quoted in R. T. Gunther, ed., *Early science in Oxford* **6**: 238–239, 14 v., Oxford, Oxford University Press, 1923–1945.

[89] On this "revolution," *cf. Isis* **34**: 123, 1942; **40**: 214–215, 1949.

[90] See above, pp. 613–615 and n. 8, 9, 11, 12. To the references there listed, add the admirable article of L. Gallois, based on critical use of the principal manuscript sources, L'Académie des Sciences et les origines de la carte de Cassini, *Annales de géographie* **18**: 193–204, 289–310, 1909, the first installment being the pertinent one.

[91] The results of the Picard-Cassini observations are discussed in Picard, *Voyage d'Uraniborg, ou observations astronomiques faites en Dannemarck*, printed in vol. 7 of *Mémoires de l'Académie des Sciences de 1666 à 1699*. No critical study of this expedition has appeared. For the Cayenne-Paris longitude, see *Isis* **34**: 125 and n. 79, 1942. The use of the clocks in establish-

No such future was in store for the marine pendulum clocks. By 1671 it was becoming apparent that they were unlikely to offer an immediate solution of the problem of longitude at sea. Huygens must have felt this in his bones even while he was berating Richer for his handling of the clocks during the voyage to Acadia. To be sure, he might for many years make sporadic efforts to improve the design of the clocks in the interest of greater seaworthiness and increased accuracy. Yet earlier doubts and misgivings appear to have remained. As if to give them the lie, the great *Horologium oscillatorium*, which appeared in 1673, contained an optimistic account of the trial of the clocks during the voyage of 1669 to Candia.[92] However, in 1675, the Royal Society's *Philosophical Transactions*, following the Parisian *Journal des Savants*, reported Huygens as currently advocating a spiral spring as the most promising motive force for accurate portable clocks.[93]

The proposal was not entirely new. Huygens, and—more particularly—Robert Hooke, had been interested in spring balances at least a decade earlier.[94] At that period, Huygens, as has already been mentioned, was acutely conscious of the inequalities in the daily rates of his marine clocks even on land, and doubted they would ever be able to determine longitude with sufficient precision. Now these early doubts returned. "Because the . . . [pendulum] clocks necessarily suffer from the motion of a ship," he wrote in 1679, "there is more likelihood of success through the use of a balance wheel with a spiral spring."[95] This was at base his final decision—the decision of the man whose invention and perfection of the pendulum clock was already a landmark in the history of chronometry.

Because of the prestige his achievements conferred, Huygens, rather than Hooke, who had a tendency to promise more than he produced, appears to have been in the stronger position to influence the great horologists of the eighteenth century and to mark out the most promising path for them to follow. Yet, implicit in the conclusion he had reached was the postponement for nearly seventy years of the solution of the problem of longitude at sea. Not until two generations had passed would mechanical skill and scientific knowledge reach the point at which a marine chronometer of sufficient accuracy could be constructed; only then would knowledge of the movements of the moon have become both precise and extensive enough for the method of lunar distances to be successfully utilized.[96]

The return of the *Saint-Sébastien* from North America in the fall of 1670 could accordingly offer French scientists and government officials little hope that a solution to the riddle of longitude at sea was at hand. Yet, the significance of the voyage to Acadia was not on this account merely negative. Neither were its results, limited though these may have been. Useful observations had been accomplished and valuable experience gained by men who were shortly to undertake an epoch-making expedition to equatorial America.[97] Such beginnings as the voyage to Acadia were admittedly humble and unspectacular. Yet, because these beginnings grew out of, and in a sense epitomized, a widespread scientific concern with problems of oceanic navigation, they were not inauspicious, whether for navigation, cartography or astronomy. For French scientific voyaging the implications were even clearer and more immediate.

ing differences in terrestrial longitude was an essential element in Ole Roemer's determination at Paris in 1676 of the finite velocity of light. Roemer was brought to this discovery largely as a result of efforts to account for differences in the calculated and the observed times of the eclipses of Jupiter's satellites. The best account is I. B. Cohen, *Roemer and the first determination of the velocity of light*, New York, Burndy Library, 1942, a study originally published in the wartime issue of *Isis* **31** (84): 1940, the distribution of which was impossible outside of Belgium and Germany until after 1945.

[92] *Œuvres complètes* **18**: 116–119, as cited in n. 34, above. References to the continuation of efforts to improve the marine pendulum clocks are scattered throughout the volumes of this work, e.g., **18**: 120–122, 539–545. Yet materials in the latter volume suggest that after 1675 Huygens' energies were directed more to the development of a different type of marine clock.

[93] No. 112: 272–273, 25 March, 1675, from the *Journal des Savants* of 25 February, 1675.

[94] Contemporary information regarding Hooke's proposals concerning spring-balance watches and their use in the determination of longitude is most easily accessible in R. T. Gunther, ed., *Early science in Oxford*, e.g., **6**: 10–20, 235, 238–239; **7**: 429; **8**: 146-150. The proposals made by Hooke in the Cutlerian Lectures for 1664 are discussed by R. T. Gould, *Marine chronometer* . . ., 24–26. On Huygens' early interest and later proposals, a rather involved subject, see *Œuvres complètes*, esp. **5**: 427, 486, 501, 503–506; **18**: 501–507, 522–525.

[95] *Œuvres complètes* **8**: 197; and *cf.* **4**: 432.

[96] These developments are well presented by Marguet, *op. cit.*, 134–260. For the chronometer this may be supplemented by Gould. For an instance of contemporary discounting of Hooke's assertions of what he could do about producing accurate portable watches employing a spring balance, see Oldenburg's comments of 25 January, 1666, to Huygens, *Œuvres complètes* **6**: 7–8.

[97] The conditions and accomplishments of the expedition of 1672–1673 to Cayenne by Richer and Meurisse are discussed in my article in *Isis* **34**: 117–128, 1942.