

**THE IMPACT OF THE EIGHTEENTH-CENTURY
NAVIGATION REVOLUTION
UPON EUROPEAN PACIFIC CARTOGRAPHY**

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Introduction

Prior to 1765, European cartographers produced charts of the Pacific based more on a visitor's perceptions than precise measurements. While such renderings captured peoples' imaginations, they were useless, even dangerous, to explorers. Such charts were equally profitless to countries colonizing widely-scattered Pacific islands. Consider the futility of claiming land one could not again find. I use the year 1765 as a demarcation point because after this navigation methodology brought certainty to ocean exploration. Moreover, after this date our knowledge of the Pacific increased immensely as the navigation revolution advanced. Spurred by genius and persistence, this revolution transformed the world. Indeed, Britain's rise to hegemony relied heavily upon its merchantmen accurately plying the waves, allowing Britain's empire to encompass much of the world. This revolution not only facilitated Britannia's rise; it also transformed how people viewed the world, ultimately setting in motion Europe's reckless nineteenth-century quest for empire.

Researchers can quantifiably observe advances the navigation revolution imparted upon Pacific exploration by comparing the journals of sixteenth-century Spanish explorer Alvero Mendana to eighteenth-century British explorer George Vancouver's. Such a comparison reveals the gulf of knowledge that separated these individuals and their centuries. In 1565, Mendana located and charted islands that were not found again for nearly two centuries; so imprecise was his navigation he could not retrace his own exploration, but by 1795, two-hundred-plus years of progress afforded British explorer Vancouver, the ability to return to any plotted location, allowing him to gather information that is useful today. Chronicled in this work are the efforts of many explorers, for as we shall see, Europeans relentlessly mapped the Pacific, preserving for the modern researcher

their data in the form of logs, journals, and travel books. It is these that facilitate this examination of the navigation methodology utilized mapping the Pacific.

Before the mid-1700s map-makers faced many problems. Discounting longitude, what troubled cartographers most was not what to draw but how to accurately project a globe onto a two-dimensional surface. Gerard Mercator's projection method resolved this problem in 1569 in part by increasing the distance between latitudes as they move away from the Equator.² With this projection he provided cartographers and sailors ability to better plot headings and determine distance. Thus equipped, navigators began filling voids that maps contained by returning volumes of information from distant shores. At the dawn of the eighteenth century, one last hurdle persistently stalled cartographers as it confounded scientist--solving longitude. Knowing place precisely while gathering a map's data is key to attaining accurate results, and it was this pillar of cartography that most frustrated early Pacific exploration. As a result, conceptualizing this vast ocean confounded map-makers and mariners alike. Accurately establishing place requires knowing longitude, and as we shall see, the absence of an accurate method of determining longitude stymied Pacific exploration throughout the sixteenth and seventeenth centuries. In resolving such navigational deficiencies, scientists provided theories, governments the financing, and sailors the means by which to test the litany of theories developed. Ultimately though, it was cartographers who paved the way for all as they graphically represented the once unknown. Seventeenth-century scientists, including Johannes Werner, Jean Cassini, Johan Kepler, and Galilei Galileo, attempted to solve longitude. Yet as they collectively unraveled this conundrum, none of their longitude methods appeared to be well suited to a mariners' needs.³

²Leo Bagrow, *History of Cartography* (Chicago, 1985), 118.

³Donald Johnson, "The Search for Longitude and the Prime Meridian," *Sea History* 66 (1993), 18-21.

Knowing where and how to place an island upon a map is important to good cartography, but it is the actuality of the information displayed that is supreme. After all, the best Mercator projection is worthless if the land-forms it represents are misplaced, or non-existent. Even a careful navigator might fail to find a destination misrepresented by as little as 2 degrees of longitude, and the odds of missing a destination were certain when navigators misjudged longitude by as much as 30 degrees--a distance equal to eighteen-hundred nautical miles at the equator. Deficiencies in early Pacific mapping, before calculation of longitude was perfected, produced lasting effects, as subsequent explorers utilized the defective charts their predecessors produced, however, Philip Carteret, Francois de Surville, and other eighteenth-century explorers did not purposefully use defective charts. These were the only charts available.

Cartographers during the Age of Exploration were not entirely blameless for the inaccuracy of their products, economics also came into play. For just as a cartographer's chart might illustrate terrain that existed only in a sailor's imagination, it might likewise contain fictional land contrived by the map-maker himself as charts with fanciful location laden with treasure sold better than those devoid of such promise. Profit notwithstanding, such additions flawed maps by skewing people's perceptions of their world. Working in an era when so much concerning the Pacific was yet unknown, cartographers had free reign to invent nearly anything in mid-ocean. By the 1760s, however, the era of freewheeling cartographers neared an end.

During the closing decades of the eighteenth century, adding definition to Pacific maps became a priority for many European countries, particularly France and Britain as each vied for dominance. Consequently, these two countries spent vast sums of money financing voyages of discovery. By necessity, much of this money went to the development of navigation theory and practice, and by the mid-eighteenth century their monumental expenditures began to pay dividends. Transoceanic voyages tested many methods of

determining longitude, and while some of these theories proved to be outlandish, two techniques, the lunar distance and chronometer methods, ultimately proved successful. The efficacy of these competing systems can be determined by comparing island coordinates recorded in ships' logs with their actual location. Such an examination reveals that both of these systems were reasonably accurate, although eventually celestial complexity doomed lunar distance, as the chronometer became dominant in calculating longitude.

European map making stems from an economic tradition, as exemplified by the popularity of map-making during the Renaissance and Reformation, a time when people broke traditional church bonds by sketching their towns and more. Usually these were picture maps that conveyed not only cartographic information, but horizons and side views as well. Such work graced the walls of many seventeenth-century households, as Vermeer's *The Art Of Painting* demonstrates.⁴

Greeks produced some of the earliest maps during the peak of their maritime power, as they placed the known earth's surface upon parchment. Extensive regional travel and economic expansion necessitated these efforts, which produced crude, but thoughtful renderings. Third-century BC maps by Eratosthenes, later built upon by Strabo, and Ptolemy, mingle both recognizable land-forms and strange nonexistent locales. Such tenuous beginnings enabled succeeding generations to make corrections. Furthermore, Greeks refined cartography by introducing a coordinate system that produced unprecedented regularity in their maps.⁵ These longitude and latitude lines became permanent fixtures on maps, although their accuracy remained questionable until the late eighteenth century.

As the Age of Exploration dawned, and the world became figuratively larger, maps became critical. During this era, ship construction techniques and efficient sail-design

⁴David Woodward, *Art And Cartography* (Chicago, 1987), 92.

⁵Oskar Hermann Kristian Spate, *The Spanish Lake* (Minneapolis, 1979), 7.

enabled mariners to reach farther into unknown waters. Fifteenth-century voyages often led sailors far from land, necessitating better navigation and reliable charts. And while such charts contained the contours of newly discovered shorelines, currents, and wind patterns, fifteenth-century European maps were still devoid of the world's greatest body of water. Moreover, due primarily to deficiencies in navigation, even as late as the mid-1700s, Europeans little understood the perimeters of the Pacific.

Britannia hastened Pacific exploration, during the eighteenth century setting standards by which every expedition was measured. Captain James Cook and his compatriots did not singularly chart the Pacific, however. Portuguese, Spanish, Russian, and French sailors, likewise, there ventured, charted, learned, lived, and died. In this pursuit, European exploration of the Pacific pushed understanding of sailing, navigation and even nutrition beyond safe limits, for once in the Pacific, away from South America's coast, prior to the 1760s, a navigator was lost. Using his best dead-reckoning, a pilot calculated his ship's position, but without precise longitude he was almost certain to be wrong. Consequently, pilots created charts of only limited use. Furthermore, the duration of a Pacific voyage induced terrible suffering among sailors who remained aboard a crowded, unhealthy vessel for months, living among filth, rats, roaches, and deadly microbes. As if these maladies were not enough, scurvy likewise relentlessly tormented and killed as it decimated a stricken crew. Amidst such horror sailors survived to recount tales of strange people and distant lands, and in so doing they inspired the next generation's adventurers.

Pacific exploration reached a crescendo during the last half of the 1700s, as the Age of Enlightenment prompted governments to make massive expenditures upon voyages of discovery. Throughout this era, individuals collectively brought the vast, unknown Pacific into the Age of Reason, in which scientists measured, charted, and laid bare its hidden recesses. These voyages supplied cartographers with volumes of detailed geographic

information, which by the second half of the eighteenth century allowed map-makers to construct precise maps and navigational charts of the entire Pacific. The key to precision mapping is knowing both latitude and longitude and the principle means by which explorers ascertained the latter will be the focus of this thesis. Dead-reckoned, chronometer, and lunar distance derived longitude all played significant roles mapping the Pacific, but it was the navigator utilizing lunar distance and chronometer longitude who recorded results most advantageously. Both lunar distance and chronometer derived longitude enabled accurate location determination, although as this thesis will demonstrate, the navigator relying upon chronometers alone produced inconsistent results, while the navigator utilizing lunar distance longitude typically recorded accurate coordinates.



Figure 2
"Celestial Navigation" from the *Regimento de Munich*, Lisbon, c. 1495.⁶

⁶R. C. Bridges, and P.E.H. Hair, eds., *Compassing the Vaste Globe of the Earth: Studies in History of the Hakluyt Society 1846-1996* (London, 1996), 80.

Chapter One

Marine Navigation Methodology 1500-1800

"We carried out various manoeuvres and steered various courses...."
Guillame Labe, 1769

The Pacific Ocean encompasses half the Earth's surface as it spans from Asia to the Americas. Unknown to Europeans until Ferdinand Magellan's circumnavigation in 1519, the ocean's immensity vexed mariners who tried to conceptualize it for generations afterward. Unknown currents, shifting wind patterns, and hidden shoals confounded the efforts of those who explored the Pacific. Nonetheless, for centuries daring sailors ventured forth despite the miserable state of ocean navigation. To cartographers, accurate navigation made the difference between a useful chart and fantasy, to sailors, however, accurate navigation divided life from death. Dozens of voyages reveal the fate of a lost crew wandering the Pacific, and perhaps none more poignantly than that which occurred in 1741.

Under the command of Commodore George Anson, the men of *Centurion* suffered terrible privation along the coast of South America. Anson's expedition ineffectively utilized the lunar distance method of determining longitude, as its practitioners were not capable of making the complex observations at sea.⁷ After rounding Cape Horn, Anson's vessels needed repair and his crew rest, prompting him to head *Centurion* towards Juan Fernandez Island located off Chile. Upon reaching the proper latitude, Anson consulted his pilots as to which direction to steer. A correct decision meant quickly reaching a safe

⁷Leo Heaps, *Log of the Centurion*, (New York, 1972), 98.

harbor, just as a wrong one meant missing the island. Longitude held the answer. After many moments of tense conversation, Anson decided to turn the ship to starboard where after four days of fruitless search, with scurvy now rampant, he ordered *Centurion* turned about. Anson daily recorded the extent to which the illness raged among his men as they afforded dead comrades the most dignified burials possible.⁸ After turning about and sailing for two days, crewmen sighted the coast of Spanish Chile, a hopeless locale for British sailors, and so the luckless crew again steered westward. During the last days of this ordeal, the few officers and sailors who remained able to work nearly perished as they struggled to control *Centurion*. Maneuvers, such as tacking, that ordinarily took the crew thirty minutes to accomplish, necessitated over two hours of arduous work for the diminished crew.⁹ Sixteen days after reaching the latitude of Juan Fernandez Island, they dropped anchor in its harbor. Lack of certain longitude cost eighty crewmen their lives and it nearly ended Anson's Pacific enterprise.¹⁰

Anson's account graphically demonstrates that before longitude's determination, the safe and accurate charting the Pacific was not possible. Finding this elusive east-west positioning perplexed sailors for generations, for without knowledge of both latitude and longitude, any mariner out of sight of land could only guess at his position often with fatal results. Part of the location problem had been resolved many years earlier, before Columbus ever reached Hispaniola, as pilots fixed their latitude with reasonable accuracy. Determining this first tenet of navigation involved calculating the angle of celestial bodies above the horizon. Pilots had been slowly going blind looking into the sun as they daily performed these calculations. Knowing one's distance north or south of the equator solved

⁸Heaps, *Centurion*, 86-100.

⁹Ibid., 98.

¹⁰Dava Sobel, *Longitude* (New York, 1995), 19.

only half of the location problem as pilots could not determine their position east and west of a fixed point by sun or stars alone, another system was need.

During the early 1600s, Galileo devised a method to accurately determined longitude on land by utilizing either the Jovian moons, whose predictable motion allowed the observer to establish time, or a pendulum clock to do the same. Galileo's terrestrial triumph did not transfer well to sea, a problem aptly illustrated by the difficulty of watching planetary objects in a telescope or maintaining a pendulum's regularity while rolling about the waves on board a ship at sea.

Before investigating longitude's resolution further, let us examine the state of navigation as Europeans first ventured onto the Pacific. In a treatise written in the 1520s, Antony Pigafetta, the chronicler of Magellan's circumnavigation, detailed what he believed to be the primary elements of navigation. Pigafetta wrote, "it is supposed that all the circumference of the earth is divided into 360 degrees; and each degree is of 17 leagues and a half."¹¹ Of finding one's longitude along these east-west lines, he wrote:

I have considered many methods for ascertaining it [longitude] and I find three methods fitting to that object. First, from the latitude of the moon the longitude is calculated of the place in which the observation is made. By knowing the latitude and longitude of the moon in Seville in degrees and minutes, and seeing also the latitude and longitude which it has in the place where you are, you will know how many hours and minutes distant from Seville you are. Second, the moon furnishes another method for ascertaining the longitude, but that is when I know the precise hour in which the moon observed at Seville ought to be in conjunction with a given star. From this for each hour difference, 15 degrees of longitude are calculated.¹²

¹¹Lord Stanley Of Alderley, trans., *The First Voyage Round The World By Magellan By Pigafetta* (London, 1876), 164.

¹²*Ibid.*, 169.

Pigafetta was essentially describing the lunar distance system, but two centuries would lapse before its perfection. During Pigafetta's era, lack of a celestial-conjunction almanac made this system of limited practical use. Pigafetta concluded his discourse with a confusing rendition of the means whereby longitude could be found using a compass. A derivative of this theory survived until the end of the 1700s when Vancouver tested it along the coast of South Africa, where, as countless times before, it proved to be utterly useless. Not realizing this method's futility, Pigafetta stated that "in order to know, by the needle, the degrees of longitude, form a large circle, in which place the compass, and divide it into 360 degrees."¹³ He continued:

...And having placed the needle at 360 deg., where it indicates the arctic pole; when the needle is in repose, draw a thread, which should pass from the arctic pole, pointed out by the needle to the antarctic pole, and let this thread be longer than the diameter. After that take the south, which you know by the greatest altitude of the sun. Turn the compass, until the thread which traverses it coincides with the direction of the meridian shade; then, from the antarctic pole of the needle, with the thread which remained over, draw another thread to the arctic pole; and you will thus find how many degrees from the meridian the compass needle is. So many will be the degrees of longitude, which you will have from the place where the compass begins to set itself in motion.¹⁴

The illogic of this method probably sparked many navigator's scorn, prompting Pigafetta to complain that, "at the present time pilots content themselves with knowing latitude; and...they will not hear speak of longitude."¹⁵ Pigafetta's account contains little navigational information about the islands Magellan's men located, except the Philippines,

¹³Stanley, *The First Voyage*, 169.

¹⁴Ibid.

¹⁵Ibid., 167.

where he gives the correct latitude for Luzon, but puts the longitude for this locale 25 degrees too far eastward.

While his earlier discourse regarding longitude was fraught with problems, Pigafetta's finding of latitude was based upon principles of science. The latitude of a place is its distance above or below the equator in degrees, the equator being zero degrees and the poles being 90 degree north and south. Of latitude Pigafetta wrote:

The latitude of any place may be ascertained by the sun's altitude. If you find yourself between the equinoctial and the arctic pole and the shadow falls towards that pole, look how many degrees and minutes meridional declination the sun has that day; and this you will subtract from the altitude of the sun which you have taken: afterwards, deducting the remaining degrees from 90 degrees, you will have in the residual, the number degrees of north latitude that is your distance from the equator.¹⁶

In this manner, Pigafetta and his contemporaries made angular calculations from which they determined latitude.

Navigators found their latitudinal angles with one of three instruments in the seventeenth century, namely, the astrolabe, the cross-staff, and the back-staff. The astrolabe was a heavy circular device about 12 inches across. Its weight enabled mariners to steady it in a stiff breeze. Sailors often attached a plumb line to the top with a weighted bob at the end so that they knew when the instrument was hanging vertically, and the circle's 90 degree mark pointed at the horizon. John Davis, one of the early seventeenth century's foremost navigators, took for granted that his readers were familiar with the use of this device, of which he wrote, "...this instrument [the astrolabe] hath beene in long use

¹⁶Stanley, *The First Voyage*, 166.

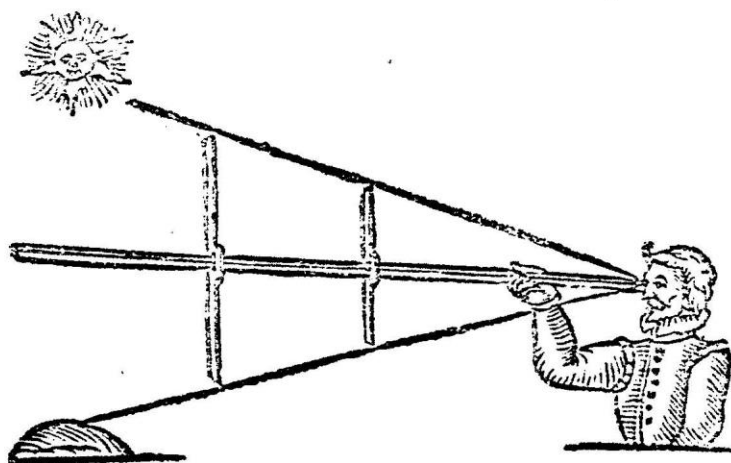


Figure 3
A mariner using the cross-staff¹⁷

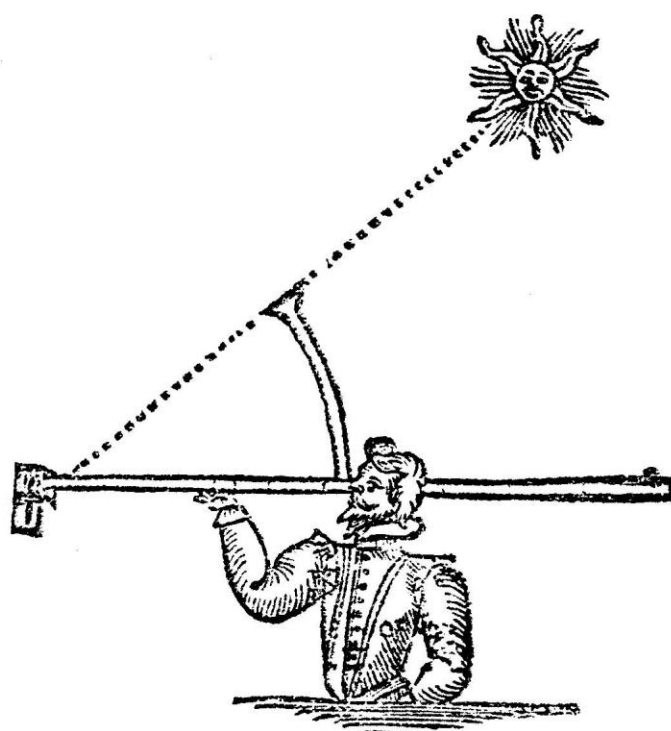


Figure 4
A mariner using the back-staff¹⁸

¹⁷Markham, *Davis*, 263.

¹⁸*Ibid.*, 332.

among seamen, and is an excellent instrument being rightly understood and ordered...."¹⁹ Indeed, Arab seafarers had for centuries utilized this marvelous instrument, and it was they who introduced it to Europeans.²⁰

Another common seventeenth-century instrument for ascertaining latitude was the cross-staff (figure 3). This device consisted of a wooden stick about 1-inch-square and 36-inches long. The transom was usually two-inches thick and 2-and-a-half-inches wide. The crosspiece was pierced with a mortise, cut so that the transom could be moved on the stick. The cross piece had two peepholes, one at either end, and there was a third hole on the near end of the long staff. To calculate the angle between the horizon and the sun, the user had to line up the three sights so the upper one was pointed directly at the sun and the lower one was pointed at the horizon. The drawback to these instruments was that the user had to look into the sun. In 1601, John Davis described the use of a cross-staff, writing:

To find the true placing of the staffe at your eye, thereby to amend the parallar of false shadow of your sight, do thus: take a staffe having two crosses, a long crosse, which endeth in 30 degrees, and a short crosse which beginneth at 30 degrees where the long crosse endeth, put the long crosse upon his 30 degrees, and there make fast; then put the short crosse likewise upon his 30 degrees, there fasten him without moving; then set the ende of the staffe to your eye, moving it from place to place about your eye, until at an instant you may see both ends of crosses, which when you finde, remember that place and the standing of your body, for so must your staffe be placed, and your body ordered in all observations.²¹

Consistency was crucial as each measurement had to be made like the next. In spite of its usefulness, however, the cross-staff possessed many flaws, with the navigator having to look into the sun being foremost.

¹⁹Albert Markham, ed., *The Voyages And Works Of John Davis* (London, 1880), 335.

²⁰Richard Fletcher, *The Quest For El Cid* (Oxford, 1989), 53.

²¹Markham, *Davis*, 264.

Circumventing the cross-staff's primary deficiency, the back-staff eliminated the danger of staring into the sun. Instead, the user pointed the back-staff at the horizon opposite the sun (figure 4). He then slid a transom until the sun cast a shadow on the end of the staff. Next, as with the cross-staff, the user observed at what number the transom intersected the scale, and from this number he calculated latitude.²² Davis describes the back-staff as being "...a yard long, having two half crosses, the one circular, the other straight, the longest not 14 inches, yet this staff do contain 90 degrees."²³ He continued, "the minutes are particularly and very sensibly laid down, by which staffe, not regarding the parrallar of your sight, nor looking upon the sunne, but only upon the horizon, the sunnes height is most precisely known."²⁴

Again, latitude is calculated by determining the angle of the sun or a star to the horizon. In the late sixteenth century, navigator Thomas Hariot performed the following mathematical example of finding latitude with either a back-staff or an astrolabe. Of the latter he specified the importance of a navigator taking several readings from which to find the median. Such multiple readings would better account for any variation induced by the ship's motion. Using the pole star to find latitude, Hariot performed the following calculation:

Apparent altitude of the starre by the lesse set	42.30'
Parallax of the staffe	0.32'
Surplus of the horizon	<u>0.05'</u>
The true altitude of the starre	41.53'
The allowance against 40 degrees	<u>1.39'</u>
Therefore the altitude of the pole starre is	43.32'

²²Lloyd Brown, *Map Making* (Boston, 1960), 121-123.

²³Markham, *Davis*, 333.

²⁴*Ibid.*

In this manner a pilot calculated his latitude based upon a star's altitude above the horizon.²⁵ As we have seen, by the sixteenth century, navigators could establish latitude with fair certainty, but the problem of determining longitude continued to perplexed sailors.

Knowing one's longitude and latitude was but part a navigator's challenge. Setting a compass bearing by which to steer a ship was another. Exploring navigation further, Pigafetta included a chapter in his *Treatise On Navigation* titled, "Direction Of The Ship," observing:

If you wish to navigate to any place, you must first know its position...Then by means of a compass you will point directly to that place. If you wish to go from east to west, always proceed on the same parallel. To go from south to north, always proceed on the same meridian. Do you wish to go from one place to another as many degrees distant in longitude as it is different in latitude? Then take the course of 45 degrees...If the latitude is greater than the longitude, then add to the 45 degrees as many by which the latitude exceeds the longitude...If the longitude is greater than the latitude, the lesser number is still subtracted from the greater; and the direction will be derived after deducting.²⁶

The compass bearing was then plotted on the compass rose, which by the sixteenth century, cartographers typically included on their sea charts.

In 1607, John Davis wrote *The Seaman's Secrets* in which he aptly stated that navigation was "that excellent art which demonstrateth by infallible conclusion how a sufficient ship may be conducted the shortest good way from place to place by corse and travers."²⁷ According to Davis, "navigation consists of three partes...first the horizontall navigation...second is cosmographically navigation...third is the great circle navigation."²⁸

²⁵Markham, *Davis*, 335.

²⁶Lord Stanley, *The First Voyage*, 173.

²⁷Markham, *Davis*, 239.

²⁸*Ibid.*

Navigating in the horizontal plane referred to compass courses, tides, and currents. Cosmographic navigation referred to celestial navigation, while great circles involved directing a ship the shortest distance between points. Davis considered great circle navigation "the chiefest of all three kinds of sailing, in whom all the others are contained...by continuing a corse the shortest distance between places."²⁹ In knowing what course to steer, a navigator relied upon the Mercator projection, or a loxodrome as it is today known. This projection was new when Davis was writing, and its revolutionary design allowed a navigator to draw a straight line between points on his chart, giving him a compass course to steer by.

Davis continued his treatise by explaining how Earth is divided into 360 degrees, and that "longitude is the portion of the equator contained between the meridian of the [Azores] and the meridian of the place desired: the reason why...longitude begins here is that there the compass hath no [variation]."³⁰ John Davis placed the Prime Meridian in the Azores based upon a common, though erroneous, scientific belief that in this location, a compass had no variation. In doing this, he insinuated, as did Pigafetta, that mariners could find longitude with a compass.

The Seaman's Secrets does not clearly describe how to find longitude; however, a method that was widely practiced at this time was described by Spanish explorer, Antonio De Morga, in 1600. His method, functional for the navigator, but of little use to the cartographer, counted the number of sailing days required when traveling between two points. From this, if the helmsman held a true course, distance could be deduced, or dead-reckoned.³¹ This method is not accurate, however. The problem with dead-reckoning is

²⁹Markham, *Davis*, 314.

³⁰*Ibid.*, 284.

³¹Henry Stanley, trans., *The Philippine Islands At The Close Of The Sixteenth Century* (London, 1868), 353-358.

that it measures distance over the surface rather than distance over the bottom--a crucial distinction when determining longitude. Calculating distance over the bottom, which provides true longitude, is difficult, especially when one considers the subtle effects of wind and current upon a vessel. Moreover, consider the catastrophic effects of a tempest upon a ship's course. None of these natural elements, be they subtle or severe, could be easily measured, and thus dead-reckoned locations were more often wrong than right.

Navigational deficiencies during the seventeenth century caused cartographers to rendered imprecise maps. It is no mystery why locations are skewed. Ships' logs from this era demonstrate why cartographers made poor maps. In 1582 as Captain Edward Fento was outward bound from England, he called a council of his pilots. Fento wrote in his journal that, "divers of their charts and reckoning were showed,...by some it appeared we were 115 leagues, by some 140 leagues, and some still further short of Brazil. But all agreed to be within 20 minutes of the [latitude] line, some to the north, so to the south."³² This illustrated how the pilots' estimates of longitude differed by hundreds of miles. A similar situation occurred the following year as the sailors neared home. When they sighted land five leagues distant, some of the pilots took it for Uist, others for Fontenay. Finally, closer scrutiny proved their sighting to be the Scilly Isles, nearly two degrees of latitude and fully one hundred miles distant from their dead-reckoned longitude.³³

Utilizing only latitude, a seventeenth-century explorer's return to an island in mid-ocean involved far more guesswork and luck than science. Furthermore, many charted locations did not even exist. Most of these false locations were not deliberate deceptions, but arose from double sighting a single location unknowingly revisited as contrary currents and storms caused navigators to loose their way. During the eighteenth century, the persistent pursuit of a means by which to determine longitude finally began to pay

³²Edward. G. R. Taylor, *The Haven-Finding Art* (London, 1956), 216.

³³*Ibid.*

dividends, as two approaches to this riddle simultaneously enabled finding longitude at sea. Their premise was the same, but their executions were very different.

Throughout the seventeenth and eighteenth centuries, scientists perfected methods for determining longitude, encouraged by promises of huge prizes for success. Fierce competition produced many rival systems by the mid-1700s. In the end, only two methods produced logical products by which the mariner could ascertain longitude while under sail--the lunar distance and chronometer methods. Regardless of their idiosyncratic procedures, time was the common denominator that linked these systems. Establishing this common denominator is what radically distinguished them.

Understanding either method requires understanding how cartographers divide the world from east to west. Meridian lines accomplish this, bisecting the globe from north to south in order to determine distance east or west of a fixed point. Since the late nineteenth century, Greenwich, England has served as the western cartographer's demarcation line for the world. England achieved this lofty status in part by having a fine observatory at Greenwich during the eighteenth century. Hegemony further solidified Britain's claim to be the center of the world. Prior to its placement at Greenwich, the Prime Meridian shifted from London, to Corsica, to Paris and many other European cities.

Meridians of longitude are measured by degrees based upon the movement of Earth. Our planet revolves once--360 degrees--in twenty-four hours. Dividing three hundred and sixty by twenty-four, the hours in a day, establishes that the Earth moves at a rate of fifteen degrees an hour, or one degree every four minutes. Based upon this foundation, a degree of longitude is subdivided into sixty minutes, and a minute is further divided into sixty seconds. Longitude can also be used to determine distance traveled. At the equator, one degree of longitude equals sixty nautical miles, or sixty-eight statute miles, with one minute of longitude equaling one nautical mile. As a ship moves away from the equator, the length of one degree of longitude diminishes because the circumference of the

Earth decreases, while the measurement in degrees remains constant at any location on the globe.³⁴

Determining longitude with lunar distance is complex. A navigator must record many measurements and then process them through a series of calculations, all of which must be performed correctly for the result to be of any use. The lunar system was introduced in 1514, when German Astronomer Johan Werner struck on a way to use the movement of the moon to determine time. On that basis, location could be derived anywhere on Earth. A keen observer will notice that the moon travels a distance nearly equal to its diameter every hour. The moon's motion can thus be tracked as it apparently passes by planets and stars. Werner suggested that a map should be created to predict when the moon would pass by recognizable, fixed objects in the sky. His system could even be utilized during daylight since the moon's distance from the sun could likewise be determined. This system could work, but it required many years of celestial observation to develop a comprehensive map of the moon's motion in the sky. Eventually, enthusiastic astronomers toiled and succeeded in producing just such a map of the heavens.³⁵

In 1615, William Baffin successfully utilized this lunar distance system to determine longitude at sea. Deficiencies persisted, however, and a century later, British Astronomer Royal, Edmund Halley continued to refine it. It was not until the 1760s that this system perfected by then Astronomer Royal, Nevil Maskelyne.³⁶ In principle, Werner's method was simple. A navigator would compare the local time when he observed a particular conjunction of the moon and a star to the time when the same conjunction occurred at a known, fixed point. The difference between the two times (in hours) multiplied by fifteen equaled the east-west distance between the two places (in degrees of longitude).

³⁴Harry A. Morton, *The Wind Commands* (Vancouver, 1975), 177.

³⁵Sobel, *Longitude*, 23.

³⁶Morton, *Commands*, 177.

The lunar distance system required a navigator to measure the altitudes of various heavenly bodies and the angular distances between them. Next the objects' nearness to the horizon had to be factored in. The refraction of light caused problems, since it put apparent positions above their actual locations. The observer also faced the problem of lunar parallax, since the tables were set as if the observer were at the center of Earth, not on board a ship at sea level. Furthermore, on the quarter deck, the observer stood twenty feet or more higher still. A skilled mathematician could correct for all of these factors, but many calculations were required to arrive at the proper answer.³⁷ The instruments used to find the angles of astronomical objects to the horizon were the octant and, later, the sextant. These instruments had to be precise and easy to use. An error in measurement of but 5 minutes of arc in reading the moon's position resulted in an error of more than 2 degrees of longitude.³⁸

It is easy to understand why chronometers became the accepted means of determining longitude at sea by the early nineteenth century, their utilization being far less complicated than the lunar distance method. In theory, the most complicated part of the chronometer system was determining local time. A few simple observations could establish this, and once done, usually at noon when the sun peaks in the sky, local time was compared to the time shown on the chronometer, which represented time at a fixed point. The disagreement was transformed into longitude, measured as 15 degrees for each hour's discrepancy.³⁹ Key to this system was possessing a clock capable of maintaining nearly perfect time. A dime-store watch today is capable of this, but in the early eighteenth century, such a clock, capable of standing up to the rigorous demands of transoceanic

³⁷Sobel, *Longitude*, 98.

³⁸Taylor, *Haven-Finding*, 250.

³⁹Morton, *Commands*, 177.

voyages, seemed an impossible achievement to everyone. To everyone, that is, except John Harrison.

In 1736, the sea clock began to transform not only navigation, but also human perception of time and place. John Harrison's revolutionary method for establishing longitude at sea began when his H-1 clock accurately kept time during a journey from England to the West Indies. Upon arrival in the West Indies, astronomers checked Harrison's clock-determined longitude against their lunar distance calculation, finding them to be nearly identical. In fact, during the return voyage, as the ship neared England, Harrison asked the captain what their longitude was and where he anticipated landing. Using his best dead-reckoning, the captain replied. Utilizing H-1, Harrison calculated their location and together they waited. When land was spotted, Harrison was correct--the age of the sea clock had arrived.⁴⁰ Many contemporary scientists speculated that clocks would never keep accurate time aboard a ship, but H-1 proved them wrong.

Harrison continued advancing the technology of time-keeping until he completed his masterpiece, clock H-4, in 1759. He placed within it many innovations that made this specimen conducive to mass production.⁴¹ Owing to John Harrison's initial genius, and the subsequent modifications of his device, by the mid-nineteenth century, navigators could precisely determine longitude anywhere on earth with relative ease. As we shall examine in chapter three, chronometer technology in its infancy presented many problems. Nonetheless, with longitude found, cartographers precisely sited sea and land, until, by the close of the eighteenth century, little of the Pacific remained uncharted as Earth became defined, drawn, laid strangely naked, its shrouds of mystery vanishing before the winds.

⁴⁰Sobel, *Longitude*, 81.

⁴¹*Ibid.*, 108.



Figure 5
Maris Pacifici, by Abraham Ortelius, 1589.⁴²

⁴²Guy Vadeboncoeur, *The Discovery of the World* (Chicago, 1985), 62.

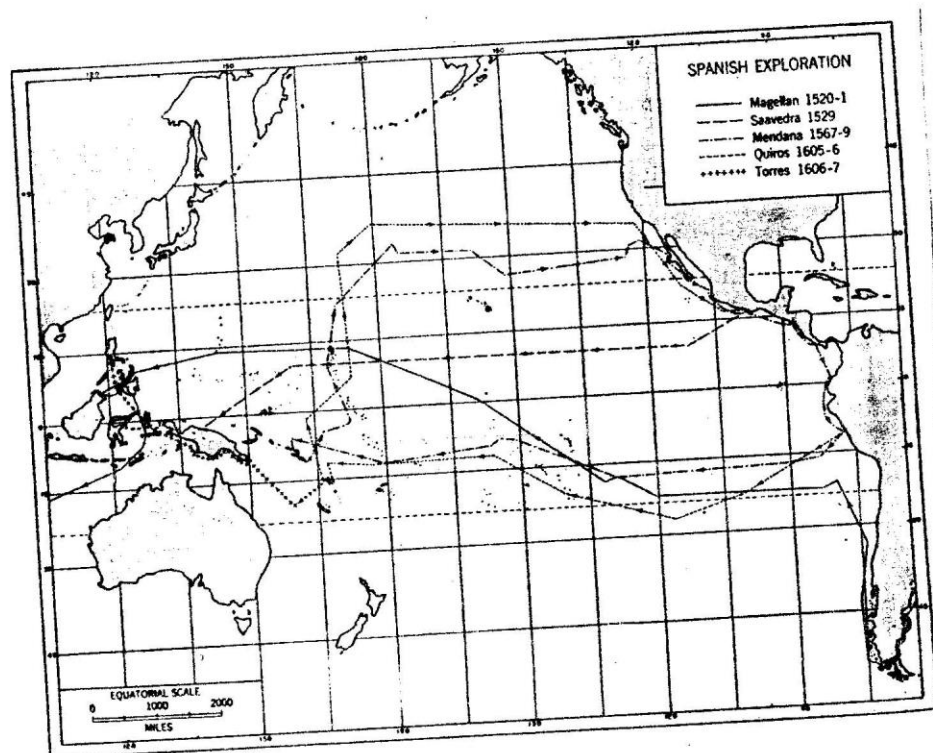


Figure 6
Voyage tracks of Magellan, Mendana, Quiros, and Torres⁴³

⁴³Freeman, *Geography of the Pacific*, 66.

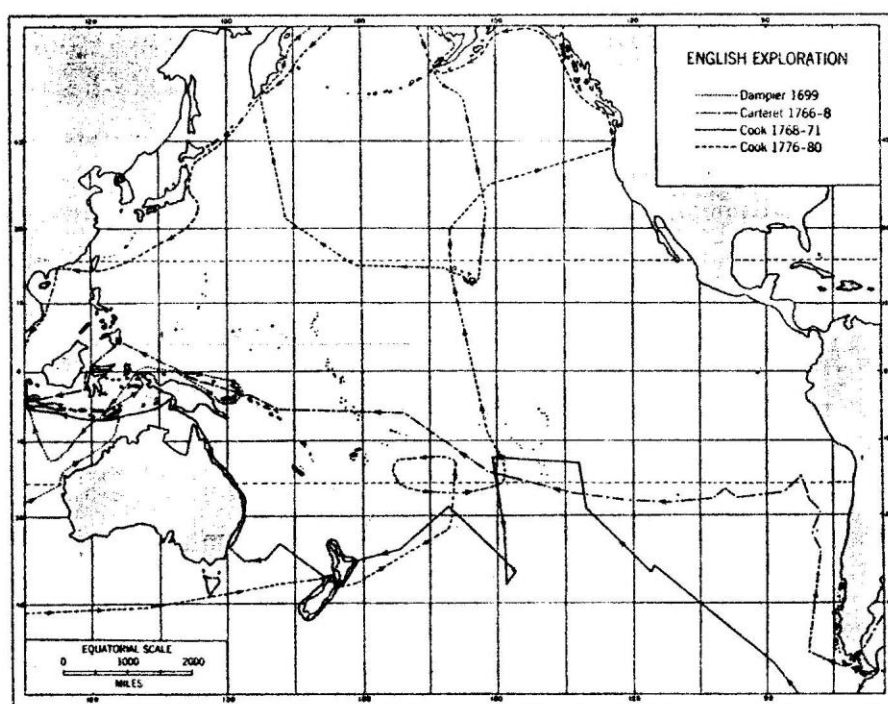


Figure 7
Voyage tracks of Carteret, and Cook.⁴⁴

⁴⁴Freeman, *Geography of the Pacific*, 73.

Chapter Two

Mapping the Pacific with Dead-Reckoned and Lunar Distance Longitude

"Our cunning South-Sea, like a God, turns nothing into all things."
Edward Ward

Following Ferdinand Magellan's lead, Alvaro De Mendana commanded the next major Pacific exploratory mission in 1568. Believing the Pacific held more *terra firma* than it does, Spain ordered Mendana to seek a large continent rumored to be 600 leagues (1800 miles) west of Peru. Once located, the twenty-five-year-old Mendana was to claim it for His Catholic Majesty, subdue its inhabitants, and baptize those who desired the Christian faith. Shipwrights in Peru constructed the two vessels that would ferry Mendana and his men into the unknown South Sea. Officials in the Spanish Court calculated that it would take little time for Mendana to traverse the leagues between Peru and their new continent, accordingly they provided their sailors with but a few weeks worth of victuals. Weeks into the voyage, with no land yet in sight, food ran short as the discouraged Spaniards continued westward, searching the skyline for mountain peaks. For many years, musing geographers speculated that the Earth needed a "Southern Continent" to counter-balance the weight of Europe and North America. Not all on board Mendana's ship were convinced, leading a disgruntled pilot to quip that "the landsman reasons, but the seaman navigates."⁴⁵

⁴⁵Lord Amherst Of Hackney, trans., *The Discovery Of The Solomon Islands By Alvaro De Mendana In 1568* (London, 1901), L.

Mendana's expedition found no continent balancing gyrating Earth, but did locate islands in the Ellice Group. Without another means of determining longitude, pilots based their estimates upon dead-reckoning, plotting these islands 1450 leagues from Peru (one league being approximately three miles), fully 600 leagues short of actuality. As the inaccuracy of Mendana's pilots demonstrates, dead-reckoning is fraught with potential error. Storms, currents, miscalculating a ship's progress, all confound estimates. For Mendana, this meant their accumulated error was 30 degrees of longitude. One week later, the expedition encountered Santa Isabel, one of the Solomon Islands. Here Mendana's pilots plotted the latitude correctly at 8 degrees south, but there is no mention of longitude in the narrative.⁴⁶ It is likely that this omission was to conceal the Solomons from other European powers until Spain fully embraced them in its empire. Further confusing matters for any brave sailor wishing to find these islands was a map printed in 1592, showing the Solomons to be 1300 leagues west of Peru. The map-maker should have situated them nearly twice that far--2400 leagues distant from Peru.

In 1595, King Philip II ordered Mendana to return to the Solomon Islands and there establish a colony. Mendana's chief pilot on this voyage was Pedro Fernandez De Quiros, who in 1605 would lead his own expedition into the Pacific. The first land that Mendana discovered in this second venture were the Marquesas chain of islands. The location where they landed Quiros noted as being, "about 10 leagues circumference, so far as we could see. It is clear and open towards the sea, lofty and wooded ravines, which is where the natives live. The port is on the south side."⁴⁷ Quiros further mentioned the presence of a large native population. Exactly which island in the Marquesas this was is impossible to ascertain from the clues provided. The following days were filled with further

⁴⁶Lord Amhurst, *The Solomon Islands*, 19.

⁴⁷Clements Markham, trans., *The Voyages Of Pedro Fernandez De Quiros, 1595 to 1606* (London, 1904), 18.

exploration and discovery of additional islands. Once again, no distance from Peru is stated for these discoveries which Quiros plotted in about latitude 10 degrees south.⁴⁸

The modern location of the next islands is likewise uncertain. Charted 1535 leagues from Peru, perhaps they were the northern Cook Islands. Next the weary sailors sighted Santa Cruz, where they established a settlement along a freshwater stream. Quiros wrote, "in this country there are large pigeons, doves, herons, ducks...ants, but no mosquitos: a new thing in such a low latitude."⁴⁹ Of the natives' transports, he observed that "they have some large and beautiful canoes, with which they navigate to a distance....They are flat bottomed, made of a single tree....The sail is large, and made of matting, wide above and narrow below."⁵⁰

The Spaniards restlessly remained here for four months, when in November, they moved on, causing Quiros to scribe, "...the flag and the rest of the people embarked, and so an end was given to this promising enterprise....It was a noteworthy thing to see the dogs running along the beach and barking....The smallest dog rushed into the sea, and came swimming to the ship...and was taken aboard; and of him it may be said that fortune favours the brave."⁵¹ Small dogs and leather-skinned sailors equally needed good fortune upon the great South Sea. The pilots reckoned Santa Cruz to be 1850 leagues from Peru in latitude 10 degrees 20 minutes south.⁵² Again, their latitude was correct, but their longitude estimate was 23 degrees short.

Highlighting the deficiencies of navigating without precise longitude is that the expedition ultimately failed to find the Solomon Islands. Bewilderment abounded as the pilots believed they had traveled far enough westward to strike the Solomons, but they did

⁴⁸Markham, *Quiros*, 19.

⁴⁹*Ibid.*, 50.

⁵⁰*Ibid.*, 52.

⁵¹*Ibid.*, 97.

⁵²*Ibid.*, 153.

not. In fact, the pilots claimed the ships were farther west than Mendana had charted the islands. Today it seems likely that the sailors were 10 degree of longitude--about 600 miles--short of the Solomons when they terminated their search. Musing as to why he had failed to locate his destination, Quiros put forth three theories: "...that they [the Solomon Islands] had less longitude than really the case...that there is some motive of private interest, leading to a concealment...or that ignorance and the want of instruments to calculate certain distances," had caused the expedition's failure.⁵³ Quiros's last supposition is most plausible, and indeed want of an instrument to calculate distances accurately would continue to haunt sailors for generations more.

In 1605, Quiros led his own expedition into the Pacific for the Spanish crown. His orders were to discover the Austrial regions. Specifically, planners wanted Quiros to claim the Antarctic, and subdue its inhabitants. Additionally, he was to explore New Guinea and Java.⁵⁴ Attempting this, Quiros steered his ships southward from Peru until they reached the 26th degree of latitude.⁵⁵ Many cartographers placed the Antarctic in this parallel, although it is actually much farther south. The expedition named the first land encountered, La Encarnacion. They plotted it as being 1000 leagues from Callao, Peru, in latitude 25 degrees south.⁵⁶ The island is likely Ducie Island near Pitcairn, and Quiros's fix is close. Next, in early February, 1606, they located an island they named San Juan Bautista. Quiros plotted it at 24 degrees 45 minutes south latitude, 1,075 leagues distant from Callao.⁵⁷ They noted the island as being low, green with thick vegetation and about 21 miles long. Their dead-reckoning was close, but they placed San Juan Bautista about 200 miles west of its true location. Not finding the Antarctic in the anticipated latitude, Quiros steered

⁵³Markham, *Quiros*, 136.

⁵⁴*Ibid.*, xxii

⁵⁵*Ibid.*, xxii.

⁵⁶*Ibid.*, 330.

⁵⁷*Ibid.*

northward. Upon reaching the latitude of the Solomon Islands, 10 degrees 20 minutes south, he turned more westerly, hoping to encounter the fabled islands from which King Solomon had acquired his gold.

While searching for the Solomon Islands, the expedition ran-short of water. Hoping to elevate this problem, Quiros wrote that they "...arranged the hearth, and the apparatus for obtaining fresh water from salt. The fire was lighted over the machine, and it began to give fresh water with much ease. This day they got three Peruvian jars full. The object was to try the machine, and the water was found to be clear, soft, and good for drinking."⁵⁸ The still produced adequate drinking water, but the machine's thirst for fuel negated anything more than its infrequent use. Continuing westward, the pilots wrote of their navigation that "all the differences of the rumb lines cause the entry of distances on the charts to be somewhat imaginary, owing to the yawing of the ship N.E. or N.W.; so that there is divergence from the route or road that the pilots think she is going."⁵⁹ Somewhat imaginary distances often resulted from dead-reckoned longitude and while Quiros and his pilots were aware of this problem, they were not able to correct it.

In April, the expedition reached the Santa Cruz Islands, which are between 166 degrees and 167 degrees east longitude. The first island encountered they named Nuestra Senora de Loreto, plotting it at 10 degrees 10 minutes south latitude, 1,750 leagues west of Peru.⁶⁰ Today it is uncertain which island this was, although most likely it was Taumaco. The island's inhabitants at first viciously attacked the Spaniards. Later, under a tenuous truce, probably attempting to rid their home of these foreigners, the islanders told the Spaniards about a large island to the south which Quiros took to be Santa Cruz.

⁵⁸Markham, *Quiros*, 333.

⁵⁹Ibid., 342.

⁶⁰Ibid., 355.

Taumaco is 2,300 leagues west of Peru, so after four months at sea, the pilots' reckoned longitude was 550 leagues too far eastward. Departing Taumaco, Quiros remarked, "until now we had been making for Santa Cruz, steering W. on its latitude, and we had gone from the port of Callao 2,250 leagues on different courses, although that island is 1,950 leagues in 10 degrees 10 minutes S.E. in a straight line from the port of Goumey."⁶¹ Months into the voyage, as they neared Santa Cruz, one of the pilots penned, "at this time we must have gone, by imagination and reckoning, 2120 leagues."⁶² Believing they had traveled too far, it seemed obvious to all that they had missed Santa Cruz. Undaunted, Quiros continued, naming the next island he encountered Virgin Maria. Quiros located the island in late March. "...We discovered a great land with high mountains, which promise to be no less than continental" he wrote.⁶³ Later exploration revealed that rather than sailing a continuous coastline north or south, Quiros circumnavigated an island, dashing his hopes that he had discovered the continent cartographers had here charted.

Next the expedition steered south to Espiritu Santo. This island excited Quiros, who admired its large, deep, and protected harbor, which he named Saint Philip and Saint James Bay. Of the bay he noted, "...all the fleets of the world might enter it."⁶⁴ One of the pilots, Don Diego de Prado, noted the harbor was 16 leagues in circumference.⁶⁵ The expedition here spent many weeks gathering food, and water, while alternately trading and fighting with the islanders. The pilot charted Espiritu Santo at 15 degrees 10 minutes south latitude, a reasonably accurate placing. Unfortunately, Quiros's journal does not give the island's distance from Peru. The reader may deduce its location by adding the leagues noted

⁶¹Markham, *Quiros*, 363.

⁶²Ibid., 353.

⁶³Ibid., 366.

⁶⁴Ibid., 370.

⁶⁵Henry Stevens, *New Light On The Discovery Of Australia As Revealed By Don Diego De Prado* (London, 1930), 121.

in previous entries. Such calculations show that their log placed them about 2250 leagues distant from Callao, Peru. Espiritu Santo is 2300 leagues from Peru, making their dead-reckoning here exceptionally accurate.

The Spaniards' official claiming of Espiritu Santo occurred on the 14 May 1606. In dispensing this act, Quiros proclaimed:

I take possession of all these parts of the south as far as the pole in the name of Jesus, Savior of all people...I take possession of these parts as far south as the pole...and of all the rights His majesty may determine lawfully to pertain in regard to the divisions of the lands and the services of the natives...Finally, I take possession of this bay named St. Philip and St. James, and its port Santa Cruz, and of the site where is to be founded a city which is to be named New Jerusalem, which is in latitude 15 degrees 20 minutes S., and all the lands in sight from here, and all this part of the south as far as the pole, which from this time is to be called the Austral part of the Espritu Santo.⁶⁶

The expedition's vessels here parted company, with Pilot, Luis de Torres commanding one westward, where he eventually skirted the southern coast of New Guinea, perilously close to the continent for which they searched, Australia. Meanwhile, Quiros sailed eastward, safely returning to New Spain.

In spite of their claiming the Austrial territory, Spain never fully embraced the Austral region of the South Sea. Instead, other Europeans raked this territory into their expanding commercial networks. Likewise, Spanish claims to the frigid South Pole remained fantasy. During the seventeenth century, Europeans revealed many more secrets hidden in the South Sea, as pilots entered its land masses, currents, and winds into their rutters. Throughout this crucial century though, Spain's jealous hold on the Sea became increasingly tenuous as English and Dutch vessels plied its waves. In his *The Worldes Hydrographical Discription*, John Davis wrote, "...the Spaniard trading in Canton ...doth

⁶⁶Stevens, *New Light*, 380-382.

by his ordinarie assages...knowe that the East continent of Asia lieth due North and South....but with what care they labour to conceale that matter of Hydrographie for the better preservation of their fortunate estate."⁶⁷ Sixteenth-century Spanish bureaucrats kept much of the Pacific secret, sharing little navigational information of recent discoveries, however, persistent exploration by other Europeans opened much of the ocean in spite of Spain's collusion.

In 1722, Dutch explorer Jacob Roggeveen located one of the Pacific's more exotic locales, Easter Island. The Dutch named it the Island of Davis, thinking it was part of the mythical Davis Land continent. Roggeveen plotted the island on his charts at 27 degrees 4 minutes south latitude and 265 degree 42 minutes east longitude, with Tenerife in the Canary Islands serving as Meridian. Twentieth-century cartographers locate Easter Island at 27 degrees 6 minutes south latitude and 109 degrees 22 minutes of longitude west of Tenerife. Typical of the eighteenth century, Roggeveen calculated his longitude only eastward giving him a number greater than 180 degrees. Calculating Easter Island's location in this manner places it at 267 degrees 10 minutes of longitude, meaning Roggeveen's calculations were 1 degree 52 minutes eastward. The Dutchman's dead-reckoned longitude was close, certainly comparable to results achieved later in the century.

Sadly, this first encounter proved to be deadly for the inhabitants of this lonely island as the Dutch sailors shot and killed more than a dozen of them.⁶⁸ Later voyages revealed that the island's inhabitants were great thieves, and it was likely this activity that sparked the hostile Dutch response. As explorer Francois de la Perouse and his men discovered some 60 years later, the islanders made great sport of relieving others of anything they desired to possess.

⁶⁷Markham, *Davis*, 201.

⁶⁸Bolton Corney, ed., trans., *The Voyage Of Captain Don Felipe Gonzalez* (Cambridge, 1908), 11.

In 1770, Captain Don Felipe Gonzalez and his expedition were the next Europeans to visit Easter Island. The Spaniards departed Chile sailing westward in search of Davis Land, and the Island of Davis--Easter Island--assuming it was part of the continent. Three weeks into the voyage, they neared the longitude where Davis Island appeared on their charts, causing a pilot to remark, "the Island of Davis bore W., distant 22 leagues, but no indication of land has been seen."⁶⁹ The following day the journal reports that they had traveled westward of the longitude of Davis Island and so they decided to sail only during the day, laying bare poled at night in order to avoid a disastrous nighttime careening.

The next day the pilot noted, "latitude observation 27 degrees 13 minutes, long. 274 degrees 54 minutes: wind E., fine. As I considered I was much out in my longitude I began, from to-day, to work out the equation by the sun, and to correct the tables of its declination...."⁷⁰ From this it would seem that the pilot dead-reckoned his longitude to this point, and he was wrong. The pilot's lunar distance calculated longitude met with greater success. Realizing that they had further to travel, they continued to steer their ship westward. Three days later, the crew spotted birds flying and all took this as a sign land was near. The following day the pilot noted, "...we sighted land ahead, 8 leagues distant...and we were able to make out it was mountainous."⁷¹ The pilot charted Easter Island at 27 degrees 2 minutes latitude, 267 degrees 2 minutes longitude from Tenerife. Calculating the islands' longitude in this manner today places it at 267 degrees 10 minutes--their determination was nearly perfect.

The Spaniards thoroughly explored the island, and like everyone else who has seen them, they were fascinated by the Morays scattered about the land. "We have ascertained that what we took for pyramid shaped shrubs are in reality statues or images of the idols

⁶⁹Corney, *Gonzalez*, 88.

⁷⁰*Ibid.*

⁷¹*Ibid.*, 90.

which the natives worship."⁷² The pilot continued, "I afterwards ascertained in examining them and taking measurments the entire body is a single block: there is a small concavity on the upper surface in which they place the bones of their dead, from which it may be inferred that they serve at once for idols and funeral pyres."⁷³ Further pondering these statues, he wrote "that a people lacking machinary and materials for constructing any should be able to raise...a statue of such height causes wonder...on an island in which iron, hemp, and stout timber are absolutely unknown."⁷⁴ Anthropologists and archaeologists have only recently determined how these statues were raised and transported.

The chief pilot lamented that mapping the island was done in an incomplete manner, noting, "...on account of certain impediments, it was not possible to fix a base-line on shore for trigonometric operations."⁷⁵ A base-line is vital to make exact measurements via triangulation. The pilot noted Easter Island to be 50 miles in circumference, with no harbor capable of affording shelter to a single vessel of moderate size. "The whole of the shoreline is beset with reefs, cliffs, and rough ground," the pilot noted.⁷⁶

The persistent belief that a continent existed in the mid-Pacific was based upon discoveries by Quiros and Mendana. This belief was perpetuated in 1595 when cartographer Michael Mercator presented the Southern Continent spanning from the tip of South America to the tropic of Capricorn below New Guinea. Cartographers continued to place Austrial del Espiritu Santo on their charts, although no one other than Quiros claimed to have located it. Perpetuating this confusion, eighteenth-century cartographers made Austrial del Espiritu Santo a free-floating continent, its location and dimensions varying

⁷²Corney, *Gonzalez*, 93.

⁷³Ibid.

⁷⁴Ibid., 94.

⁷⁵Ibid., 100.

⁷⁶Ibid., 101.

from the vague coastline presented by John Green in 1753 to its complete omission by French cartographer Pierre Mortier.

In 1766, the British Admiralty prepared to send its own expedition to the South Sea in search of the elusive Davis Land and other locales suitable for exploitation. The Admiralty, ever the epitome of good-old-boy politics, chose the well connected, though inexperienced, Samuel Wallis as expedition leader. The government chose the more experienced Philip Carteret to command the escort vessel *Swallow*. Aptly named according to Carteret, the vessel was "...above 30 years old, and one of the worst, if not the very worst of her kind in His Majesty's Navy."⁷⁷ *Swallow* did not point well during windward tacks, a design flaw, that along with its slowness of speed, caused the expedition to be incapable of achieving the goals laid out for it. Wallis's vessel, *Dolphin*, on the contrary was a very fine sailing craft, swift and agile, though unfortunately, its commander possessed neither the skill nor the drive to push *Dolphin* to its reasonable limits.

The Wallis expedition was the second of three expeditions dispatched to the South Sea by Britain during the 1760s. The first, begun in 1764 was under John Byron, who sailed with orders to seek the southern continent in the South Atlantic as well as to discover and exploring the North-West Passage's exit into the Pacific. Toward fulfilling these duties, after a brief stay in the Falkland Islands, Byron steered his vessels toward Africa, from where they would enter the Pacific via the Indian Ocean. He traveled this slower course considering his ships to be "too much disabled for the California voyage."⁷⁸ Upon entering the Pacific, Byron set a speed record returning to England. Consequently, the voyage left many questions unanswered which infuriated the Admiralty. Byron returned having found neither a new continent nor the Northwest Passage, nor did he diligently

⁷⁷Helen Wallis, ed., *Carteret's Voyage Round The World 1766-1769*, Volume 1 (Cambridge, 1965), 20.

⁷⁸*Ibid.*, 5.

search for either, he did, however, return certain that a continent lay not far south of the Tuamotu Archipelago.⁷⁹

Left with many unanswered questions, Britain initiated another more comprehensive exploration of the South Sea. On this second governmentally sponsored voyage of the decade, Samuel Wallis led two ships in search of land thought to lie between Cape Horn and New Zealand, where, in spite of more than two centuries of exploration, uncertainty remained. Sea charts exemplified this, one chart carried aboard Wallis's vessel, *Dolphin*, that crafted by John Green in 1753, incorrectly placed New Zealand 100 degrees west of the Straits of Magellan. If the expedition found no continent while sailing to New Zealand, it was to set a northwesterly course to 20 degrees south latitude "in search of land or islands not hitherto discovered."⁸⁰ Finally, the crown wanted Wallis to find the Solomon Islands, unseen by Europeans since Mendana's departure in 1567.⁸¹

Serious problems beset Wallis's expedition from the outset, underscoring Carteret's apprehension regarding *Swallow*. Before its inclusion in a circumnavigation mission it served as an impress ship in the Medway River. To make it suitable for a round-the-world voyage, carpenters made many modifications. Bulkheads were added fore and aft as a precaution against heavy seas notorious in the Straits of Magellan. What most concerned Wallis and Carteret was how poorly matched the vessels were. *Swallow* sailed awkwardly, "dully," to quote its captain, while *Dolphin* lithely parted the waves. As a result, from the outset it seems likely Wallis intended to divorce himself from *Swallow* following *Dolphin*'s Pacific entry.

Following tradition, the Royal Navy sheathed *Swallow*'s bottom with a layer of sacrificial planking, offering no protection from barnacle growth, as it only forestalled

⁷⁹Wallis, *Carteret*, 7.

⁸⁰*Ibid.*, 6.

⁸¹*Ibid.*, 311.

torado worm damage. Impeding progress, a barnacle fouled bottom slows a ship's headway by several knots. Meanwhile, *Dolphin's* experimental copper clad underside greatly enhanced its sailing characteristics as its bottom collected far less marine growth than *Swallow's*. A smooth bottom likely accounted for much of the speed Wallis's craft exhibited. Furthermore, the copper formed an impenetrable barrier against wood-devouring torado worms.⁸²

Prior to departure, the vessels' holds brimmed with the crew's rations. The ever frugal Admiralty wrote that if these provisions were miserly distributed, they would sustain a hungry crew for two years. Salted, dried and pickled, the rations provided abysmally few nutrients as the Royal Navy did not yet recognizing the health benefits of vegetables and fruit. As a direct result of such a poor diet, scurvy agonizingly killed many sailors. Throughout the embarkation phase, Carteret bitterly complained to the Admiralty that they needed to pay more attention to the fitting out of his vessel. Lamentably, most of his requests went unheeded. What particularly concerned Philip Carteret was the omission of a forge. Its absence meant the crew could not repair broken iron fittings, meaning that if one broke when they were in mid-ocean, such misfortune could doom them. Summing up his despair prior to departure, Carteret retorted that compared to *Dolphin*, his conveyance was "a miserable tool." ⁸³

On 21 August 1766, the expedition set sail. Steering southward toward Cape Horn, the crewmen made a brief landfall in Madeira, where they took on board sweet wine. Here Carteret vehemently beseeched Wallis to provide his ship with more junk--old rope to be worked into new rope or used as caulking. Carteret asserted that the Admiralty had not supplied him with enough of this material for a voyage across the Pacific should the vessels

⁸²In 1757 copper sheathing was first used on HMS *Alarm* as it sailed to Australia and back to England.

⁸³Wallis, *Carteret*, 8-23.

be parted in a storm. The answer infuriated Carteret. Wallis merely replied that he carried enough for both ships. This disagreement was only the first of many between the captains, and being ever mindful of his subordinate rank, Carteret relented. *Dolphin's* hold brimmed with supplies that Carteret needed to bargain with Islanders. "Before we left England the Admiralty had ordered aboard the *Dolphin* some cloth, linnen, beeds...[items] useful in conciliating the friendship of Indians. Captain Walis told me that part of this consingment was for me...." Months into the expedition, Wallis continued to hoard supplies, and there was little Carteret could do about it beyond writing letters of protest.⁸⁴

By April 1767, the vessels lay waiting for an opportunity to enter the Straits of Magellan. In this notoriously dangerous locale, *Swallow* uncharacteristically took the lead. Wallis here relied on Carteret's previous experience in the Strait, and in all likelihood, Carteret's knowledge of this place was what kept Wallis from parting company sooner. Throughout the journey to Patagonia, sailors regularly climbed *Dolphin's* rigging to reef its sails, slowing its progress so that *Swallow* could catch up. For Wallis, *Swallow* and her crew were a liability. And while neither *Dolphin's* log nor Wallis's journal makes any allusions to this, it seems obvious their separation was deliberately planned, for within two days after entering the Pacific, *Swallow* and her crew were abandoned. Carteret now summoned all his knowledge and ability as he steered his vessel as far south as possible. For navigation purposes the pilots chose Cape Pillar as Prime Meridian. Situated at 52 degrees 74 minutes south latitude and 74 degrees 42 minutes west longitude, Cape Pillar soon fell into *Swallow's* solitary wake.⁸⁵ Wallis's departure left his former companions devoid of many vital supplies and without assistance should disaster strike. Realizing he was alone with an exhausted crew, Carteret instructed his pilots to head for Juan Fernandez Island off the Chilean Coast.

⁸⁴Wallis, *Carteret*, 121.

⁸⁵*Ibid.*, 117.

Before their separation, *Dolphin's* pilots established Cape Pillar's longitude at 75 degrees 10 minutes west of London. They derived this nearly perfect calculation via lunar-distance. After the ship's parted company, however, it becomes obvious that Carteret and his pilots could not utilize this system. Instead, they navigated by dead-reckoning, with Cape Pillar serving as their point of departure. When they reached Juan Fernandez Island the men of *Swallow* found little comfort, for unbenounced to them, Spain had established a fort on this lonely island. Designers intended that this bastion guard South America's coast against attack. Furthermore, they intended to deny respite to those venturing upon the South Sea. Spain's outpost consisted of "...25 or 30 houses round the fort...[and] much cattle feeding on the brow of the hills...."⁸⁶ Carteret here made no attempt to refresh his disappointed, and ill men, instead choosing to sail to the island of Mas Afuera.⁸⁷

Carteret undertook this sidestep, misguided by Commodore George Anson who greatly exaggerated the blessings Mas Afuera offered, where harsh reality crushed the weary sailors hopes when they found Mas Afuera to be "merely a heap of rocks." *Swallow's* crew struggled to obtained refreshment from the barren island, the fatigued sailors finding little respite. Squalls on several occasions broke rigging, including the vessel's main yard which the carpenters attempted to bolt together, but for want of a forge and iron, the task was difficult to properly complete. After wrestling little freshwater and a few seals--from which they derived meat and lamp oil--from the island, the sailors departed.⁸⁸

Carteret's dead-reckoned location of these islands was remarkably accurate. He placed Juan Fernandez Island at 33 degrees 40 minutes south latitude and 78 degrees 52 minutes west longitude. Its actual position is only slightly different at 33 degrees 37 minutes latitude and 78 degrees 50 minutes longitude. Carteret also ascertained Mas

⁸⁶Wallis, *Carteret*, 128.

⁸⁷*Ibid.*, 130.

⁸⁸*Ibid.*, 143.

Afuera's location perfectly at 33 degrees 45 minutes south and 80 degrees 46 minutes west. Remarkably, Carteret and his pilots maintained a high degree of accuracy throughout their voyage.

Swallow and her crew departed Mas Afuera on 23 May 1767, heading northward toward the islands of Saint Felix and Saint Paul. "I thought it would be a very fitting piece of service to examine them and see if they were fitt for shiping to refresh at in case of need...they might prove to be servicable to Great Britain in time of a Spanish War."⁸⁹ Green's chart located these islands at 26 degrees 20 minutes latitude and between 1 and 3 minutes of longitude west of Mas Afuera, while John Robertson's, *Elements of Navigation*, plotted them at 25 degrees 30 minutes latitude and a bit farther west at 82 degrees 20 minutes of longitude west of London. "I supposed he [Robertson] might be more exact than the charts in laying down so small islands, and as a live and an English author I imagined he had some good authority which I was not aquatinted with for laying them in that latitude."⁹⁰ Carteret's faith in Robertson proved false as the author placed them 2 degrees 30 minutes too far west and 15 minutes of latitude too far north, accordingly Carteret could not locate them.

These islands caused Carteret to make an insightful and correct assertion about mythical Davis Land. He wrote of them:

I think it is pretty evident...that these two islands are the land that Captain Davis fell in with in his way from the Gallapegoe Islands to the southward and that there is no such thing as what is laid in all our charts under the name Davis Land, notwithstanding what has been said in Roggeweins Voyage in 1722 about an Island they called Eastern [Easter]....After examining the account as it is given us by Mr. Wafer, Surgeon of the said Davis ship, from their ignorance

⁸⁹Wallis, *Carteret*, 144.

⁹⁰*Ibid.*, 145.

not knowing how to allow for the variation of compass, and their haveing allowed it to the westward when it was to the eastward.⁹¹

Carteret remained in latitude 28 degrees for the next 40 degrees of longitude, after which he wrote, "this being the highest latitude the winds...would permitt me to keep, and by all it is evident I went to the southward of this pretended Continent of Davis Land, as it is laid down in all Sea Charts."⁹² He continued, "and if any truth be in the account of Roggeweins voyage...in 27 degrees south latitude...700 leagues from America, we would likely be south of them, but then it proves it to be no Continent."⁹³ To Carteret, Davis Land now seemed a figment of either imagination or wishful thinking. Cartographers expunged the location from their renderings soon after Carteret's return.

From 22 June, until 2 July 1767, Carteret held *Swallow* on a gradual northward track. It was at this time that Carteret located Pitcairn Island. Encountered on the evening of 2 July at 25 degrees 4 minutes latitude and 130 degrees 6 minutes west longitude, Pitcairn was a desolate, rocky outcrop fringing the tropical archipelagoes of the Pacific. A few years later, the infamous Fletcher Christian and his mutinous compatriots here scuttled *Bounty*. Of Christian's future home, Carteret wrote that the location, "...proved to be a small high uninhabited island not above 4 or 5 miles round, scarce much better than a rock out in the ocean, but not withstanding, it is covered with trees and seems to have fresh water...."⁹⁴ Pitcairn held little promise to the men of *Swallow*, where "...the surf broke so violently on all sides against rocks that there was no landing...."⁹⁵ Sharp-eyed sailors spotted Pitcairn while it was still 15 leagues away. Carteret plotted the island at 25 degrees

⁹¹Wallis, *Carteret*, 145.

⁹²Ibid., 147.

⁹³Ibid., 148.

⁹⁴Ibid., 150.

⁹⁵Ibid.

2 minutes south latitude and its longitude he reckoned as being 52 degrees 30 minutes west of Cape Pillar, or 133 degrees 30 minutes west of London. Carteret's fix placed the island nearly perfectly north and south, but his longitude erred a little more than 3 degrees westward. Nonetheless, Carteret's dead-reckoning was significantly more accurate than that achieved by earlier Pacific explorers.

Upon leaving Pitcairn, Carteret wrote, "...I never saw so long rolling high swell before, in any of my former voyages, the winds [were] variable keeping mostly from the S. to WNW, seldom to the eastward, which hindered me from keeping in anything of high south latitude, but drove me more northward, for we had no manner of trade wind in these latt."⁹⁶ Better understanding the wind and current patterns of the Pacific was key to accurate dead-reckoning and by the latter half of the eighteenth century, accumulated knowledge of such forces greatly improved a navigator's ability to negotiated the distance between islands.

The months at sea took a toll on *Swallow* and her crew, and in late July, Carteret detailed the difficulties facing his ship and men. His litany included rotting wood, sail cloth, sail twine, "the quantity of...which had been allowed us was inadequate to what we wanted...", and of utmost concern, "the running rigging now was much worn and often breaking."⁹⁷ If these worries were not enough, scurvy soon wracked many sailors. Not only was his ship physically endangered; so was his crew.

Carteret little understood scurvy. Like la Perouse twenty years later, he blamed an outbreak on weather conditions, writing that, "as in all this traverse, we had much hard rain, & wet weather."⁹⁸ Eighteenth-century science held damp weather as the prime inducement of scurvy. Wrongfully cursed, the squally weather did replenish the crew's

⁹⁶Wallis, *Carteret*, 151.

⁹⁷Ibid.

⁹⁸Ibid.

water supply as they captured rain with an awning placed over the stern of the vessel. The surgeon ensured the water's potability by adding to it spirits of vitriol.⁹⁹

On 11 July, the crew encountered Osnaburgs Island. Today this location is called Mururoa and it is one of the southeastern islands in the Tuamotu Archipelago, at 22 degrees south latitude and 139 degrees west longitude. Carteret's reckoning placed it at 22 degrees latitude and 60 degrees 48 minutes west of Mount Pillar and as in the case of Pitcairn, this erred about 3 degrees westward. He noted the island as being low, flat, and covered with trees.¹⁰⁰ The following day they located two more small islands at 20 degrees 30 minutes latitude and 65 degrees 30 minutes longitude west of Cape Pillar. Here crew members found no sweet water or vegetable matter, although they did acquire fresh meat as "the island's birds were so tame that they suffered themselves to be approached so as to be caught by hand without offering to mouve."¹⁰¹ The latitude determined for these desolate islands was nearly perfect, but its longitude fix remained a chronic 3 degrees westward of actuality. Green's chart placed several islands in this vicinity, leading the captain to surmise that Quiros visited these islands in 1605.

The first days of July produced favorable winds, which allowed Carteret to steer *Swallow* southward. When the wind veered out of the South again, the captain resumed a more northerly course toward the Equator. Carteret consistently tried to fulfill his orders to remain in latitudes as far south as possible. Unfortunately his conveyance would not allow it. "Although our track here is high, if not higher south than any men before which have gone across this ocean (excepting it be ye *Dolphin* who in all probability is a great ways to the southard of us) notwithstanding we have not seen any land...of consequence...nor...any

⁹⁹Wallis, *Carteret*, 152.

¹⁰⁰*Ibid.*, 153.

¹⁰¹*Ibid.*

Continent."¹⁰² Carteret was right to believe that *Dolphin* could be in a more southerly locale. *Dolphin* was a nimble ship, far more seaworthy than *Swallow*. Comparing the logs of the vessels, however, reveals that Wallis consistently held *Dolphin* at least 3 degrees north of *Swallow*. Wallis's lack of drive and his unwillingness to maximize the sailing capabilities of his vessel are to blame for this.

In August, Carteret noted that scurvy sickened an increasing number of his crew, causing him to prudently decide to steer a more northerly course in hopes of picking up the trade winds, which according to Green's chart would bring *Swallow* to the Solomon Islands. Carteret steered this course in vain, as Green incorrectly placed these elusive islands 170 degrees west of London. In reality the Solomon Islands are located about 200 degrees of longitude west of London. Therefore, in the 170th degree, Carteret saw only swells gently rolling across open-ocean. Traversing this region, Carteret wrote, "we kept between the latt. of 10 and 11 degrees hoping to fall in with the Solomons. We were by my account now 177 degrees 30 minutes east of London...not seeing any land I hauled southward."¹⁰³ He did so hoping that, unlike Byron and Quiros, he would locate Mendana's mysterious islands. "As Comodore Byron two years ago went over the north part where the [Solomon] islands are said to be with out seeing any thing of them, no more than me now of the southern part."¹⁰⁴ Carteret rightfully doubted Green's placement of these islands. His journal even asserts that no such islands existed.

Continuing westward, the expedition skirted along the north coast of the Santa Cruz Islands. Lord Howe Island is one of the locations they charted here, where Carteret calculated *Swallow* had traversed 114 degrees 50 minutes of longitude since departing Mas Afuera. This determination placed Lord Howe Island at 164 degrees 6 minutes East of

¹⁰²Wallis, *Carteret*, 153.

¹⁰³*Ibid.*, 166.

¹⁰⁴*Ibid.*

London, less than 2 degrees in error, a remarkably accurate placement considering Mas Afuera lay more than six thousand miles behind *Swallow's* wake.¹⁰⁵

Although Carteret discovered few islands during his Pacific crossing, he did chart those discovered with remarkable accuracy, as longitude error of 2 or 3 degrees is not insurmountable. The problem with Carteret's navigational methodology was that it required an almost uncanny ability to judge distance. The key word here is judge, as Carteret, or any other mariner relying upon dead-reckoning, did not calculate longitude with the certainty other methods allowed. Accurate or not, a dead-reckoned location was merely a guess, for if storms swept a vessel any distance, a pilot could only speculate how far, and then resume his longitude calculations based upon this uncertain reference point.

Carteret's expedition was the last major voyage of exploration in the Pacific that did not rely upon more sophisticated techniques for determining location, and the accuracy with which he mapped the Pacific was remarkable. His success was due to several factors: good weather (or at least predictable winds), accumulated knowledge of currents and how they affected *Swallow's* motion, and finally, skill. As we shall see in the next chapter, Carteret's mapping was nearly as accurate as that of George Vancouver. This result is phenomenal considering Vancouver used both lunar distance and chronometers to calculate his east-west position.

While Carteret ventured upon the *Mar del Sur*, France initiated a well-funded exploratory mission of its own. Louis Antoine de Bougainville's Pacific expedition began in late 1767. Unlike Carteret, Bougainville sailed with knowledge of how to utilize lunar distance to ascertain longitude. This method is vastly more complicated than either chronometer longitude or dead-reckoning, though it produced the most accurate results.

¹⁰⁵Wallis, *Carteret*, 173.

To facilitate its use, the expedition sailed with an astronomer, Jean Verron, who unfortunately persistently erred his longitude calculation.¹⁰⁶

The expedition's two vessels, *Boudeuse* and *Etoile*, set sail from Brest, France on 15 November 1767. Plans called for Bougainville's ships to sail to China, where he was to claim a small, offshore island for France. Such a location would then be utilized to trade with reclusive China. Furthermore, French scientists insisted that the vessels sail into the mid-Pacific, believing this region contained islands endowed with precious metals and spices, both of which could enrich recently vanquished, and nearly bankrupt France.¹⁰⁷

During the first phase of their voyage, Bougainville halted his vessels at Tierra del Fuego on 18 December 1767, and here waited several weeks as nature whipped the seas into a hopeless froth. Finally, on 26 January 1768, the expedition entered the Pacific and headed to 20 degrees south latitude, where they turned westward. Bougainville's log reveals the problems inherent in cartography without accurate navigation. The first series of islands encountered were in the Tuamotu Archipelago, when on 22 March 1768, Harp Island--Cook's Bow Island, and today, Hao Island--was encountered. Verron established the longitude of Hao at 139 degrees 51 minutes west, and its latitude at 18 degrees 27 minutes south. His latitude is only 1 minute off, but Verron's longitude is another matter. The longitude of this atoll is 140 degrees 43 minutes west of Paris.¹⁰⁸ The error of 52 minutes east possibly arises from inaccuracy in the almanac Verron used, early editions of which contained many errors that were slowly eliminated, although fifteen years later, George Vancouver likewise charted locations too far east. Bougainville here wrote in the ship's log that his reckoning of their longitude placed the islands 39 minutes east of

¹⁰⁶John Dunmore, *French Explorers in the Pacific* (Oxford, 1965), 66.

¹⁰⁷*Ibid.*, 68.

¹⁰⁸T.F. Kennedy, *A Descriptive Atlas of the Pacific Islands* (Auckland, 1966), 33.

Verron's calculations, further compounding the error of their mapping if they chose to use this calculation.¹⁰⁹

As we have seen, improperly estimating current direction, speed, and windage induces error when calculating distance traveled over the bottom, and like Carteret, Bougainville's dead-reckoning efforts suffered from such miscalculation. The last island charted in the Tuamotu Archipelago was Reitoru. Verron placed the island at 17 degrees 39 minutes South and 142 degrees 18 minutes west of Paris. Its actual location is at 17 degrees 50 minutes south and 143 degrees 05 minutes west. Again, Verron's placement was off by 57 minutes east.¹¹⁰ The expedition next anchored at Tahiti on 2 April 1768. Verron determined its longitudes as being 150 degrees 55 minutes west, whereas modern calculations place Tahiti's longitude at 149 degrees 30 minutes west.¹¹¹ Verron again erred, this time by 1 degree 25 minutes westward (more than sixty nautical miles), underscoring the complexity of the lunar distance method of finding longitude.

Jean Francois de Surville commanded another French expedition to the Pacific in 1767, however, poor navigation severely hampered his undertaking. In part due to their reliance upon century-old charts, they professed to be lost much of the time, consequently, their longitudes were often inadequate for proper mapping. The vessel's second in command, Guillaume Labe, and its captain both kept a log of the ships position. While in the Batans, Labe wrote, that according to the charts, they should be in the middle of the Carolines. "These maps are worth nothing at all," he commented, making a very telling observation of the poor state of Pacific cartography. A few weeks earlier, the expedition's navigator used lunar distance calculations to estimate their position as being near the island of Matelotte, but they could not find it. De Surville, at this time wrote that he was certain

¹⁰⁹Dunmore, *French Explorers*, 73.

¹¹⁰*Ibid.*, 75.

¹¹¹Kennedy, *Atlas*, 33.

of his latitude, but that his longitude was hopeless as strong currents caused mounting dead-reckoning error in his navigation. Furthermore, he was not confident enough in his ability to make lunar distance calculations to rely upon them.¹¹² The expedition landed in but a few places and explored them only superficially. While plotting locations among the Solomon Islands, their longitudes were wrong by over 4 degrees.¹¹³

In the Solomons, de Surville located an island he dubbed *Premiere Vue*. Today this location is known as Wagina Island. De Surville plotted its location at 7 degrees 21 minutes latitude, which is acceptably close, but his longitude calculations placed Wagina at 151 degrees 15 minutes east of Monmouth, when the island is actually located at longitude 155 degrees 45 minutes east of Monmouth.¹¹⁴ The journal provides few clues as to why their longitude calculations were erred so severely. Adding further confusion, de Surville plotted New Zealand nearly perfectly.¹¹⁵ Such inconsistency serves to underscore the necessity of having a well trained navigator who could consistently perform the lunar distance calculations.

James Cook's first Pacific voyage was the last major scientific expedition to enter the Pacific without a chronometer to aid navigation. Unlike de Surville, Cook and his pilots were highly proficient at establishing longitude via lunar distance. In August 1768, *Endeavour* sailed from Plymouth. On this first of three voyages of discovery that Cook commanded, he traversed the Pacific in latitudes south of the Equator, eventually traveling to the Society Islands, New Zealand, Australia, and New Guinea. Before its conclusion, the expedition covered thousands of poorly charted mid-ocean miles. *Endeavor's* log provides

¹¹²Dunmore, *French Explorers*, 132-133.

¹¹³John Dunmore, ed., *The Expedition of the St Jean-Baptiste to the Pacific* (London, 1981), 34.

¹¹⁴*Ibid.*, 84.

¹¹⁵*Ibid.*, 133.

many clues as to the painstaking care with which the scientists and Cook charted their progress.

Their first land-fall after entering the Pacific occurred on 6 April 1769 at Bow Island. Cook fixed the east side of the island at 18 degrees 23 minutes south and 141 degrees 12 minutes west of Greenwich. Again, 140 degrees 43 minutes is the correct longitude of Cook's Bow Island, and so, where Bougainville was here off by 52 minutes, Cook's longitude was wrong by only 30 minutes, not perfect, but closer. One week later, *Endeavor* anchored in Matavai Bay, Tahiti, or King George Island as Cook named it. The expedition's astronomer, Charles Green established the bay's position at latitude 17 degrees 30 minutes south and longitude 149 degrees 30 minutes west. Even by modern standards, his calculations were nearly perfect. For three months, the men of *Endeavour* plied the waters around the island, investigating its many bays and harbors, all the while scientists produced remarkably accurate charts.¹¹⁶

After departing Tahiti, *Endeavour* reached New Zealand on 7 October 1769. Cook named their landfall, Poverty Bay, as it offered the expedition so few resources. Charles Green plotted Poverty Bay at 38 degrees 42 minutes south latitude and 181 degrees 36 minutes west longitude. Cook noted that after the voyage from Tahiti, *Endeavour's* dead-reckoned log erred by 3 degrees 16 minutes east.¹¹⁷ Modern navigation sets Green's position at 178 degrees 24 minutes east longitude, rather than a number greater than 180 west, so Poverty Bay's actual longitude of 178 degrees east demonstrates that the lunar distance calculations Green produced were only slightly in error, while the ship's dead-reckoned log erred significantly.¹¹⁸ During their investigation of the two islands, the

¹¹⁶John C. Beaglehole, *The Voyage of Endeavour 1768-1771* (Cambridge, 1955), 72-140.

¹¹⁷*Ibid.*, 167.

¹¹⁸Kennedy, *Atlas*, 38.

expedition's botanists noted the wide variety of flora growing on New Zealand. The Maori's customs and language most captured Cook's interest.

After departing New Zealand, the expedition reached Bateman's Bay, Australia in April of 1770. Lying along the rocky southeastern coast of Australia, between the present cities of Melbourne and Sydney, Cook plotted his first land-fall at 209 degrees, 30 minutes west, or 150 degrees and 30 minutes east longitude.¹¹⁹ And again, their navigational calculations were nearly perfect. Skirting along the east coast of the Australian Continent, the explorers compiled lengthy lists of bays and inlets, both safe and hazardous. Of particular interest to the botanists were Australia's pine trees, which Cook described as being like live oaks. From these reports, England hoped that naval stores could be obtained in Australia, but the indigenous pines proved to be too brittle for most ship building applications. After departing Australia, the expedition entered the Indian Ocean, then rounded Africa, heading northward for London where they anchored on 13 July 1771.

While along the coast of New South Wales, Australia, Cook made the following journal entry about the mapping his expedition produced as well as its utilization of the lunar distance method, writing:

However, take the chart in general and I believe it will be found to contain as few errors as most sea charts which have not under gone a thorough correction, the latitudes and longitudes of all or most of the principal head lands, and bays may be relied on for we seldom failed of getting an observation everyday to correct our latitude by, and the observation for settling the longitude were no less numerous and made as often as the sun and moon came into play, so that it was impossible for any material error to creep into our reckoning. In justice to Mr. Green I must say that he was indefatigable in making and calculating these observations which must have taken up a great deal of my time, which I could not at all times spare. Not only this, but by his instructions several of the petty officers can make and calculate these observations: it is only by such means that this method of

¹¹⁹Beaglehole, *Endeavour*, 300.

finding longitude at sea can be put into universal practice--a method that we have generally found to be accurate to within a half degree; which is a degree of accuracy more than sufficient for all nautical purposes.¹²⁰

Lunar distance measurements proved to be a great leap forward in navigation at sea. Moreover, Cook's faith in this system was validated by the accuracy of the charts his expedition produced. The primary pitfall of the lunar distance method was the complexity of its calculations. And while Cook states that it could be learned, its application would be limited as most mariners--including de Surville and Carteret--had great difficulty mastering its intricacy.

¹²⁰Beaglehole, *Endeavour*, 392.

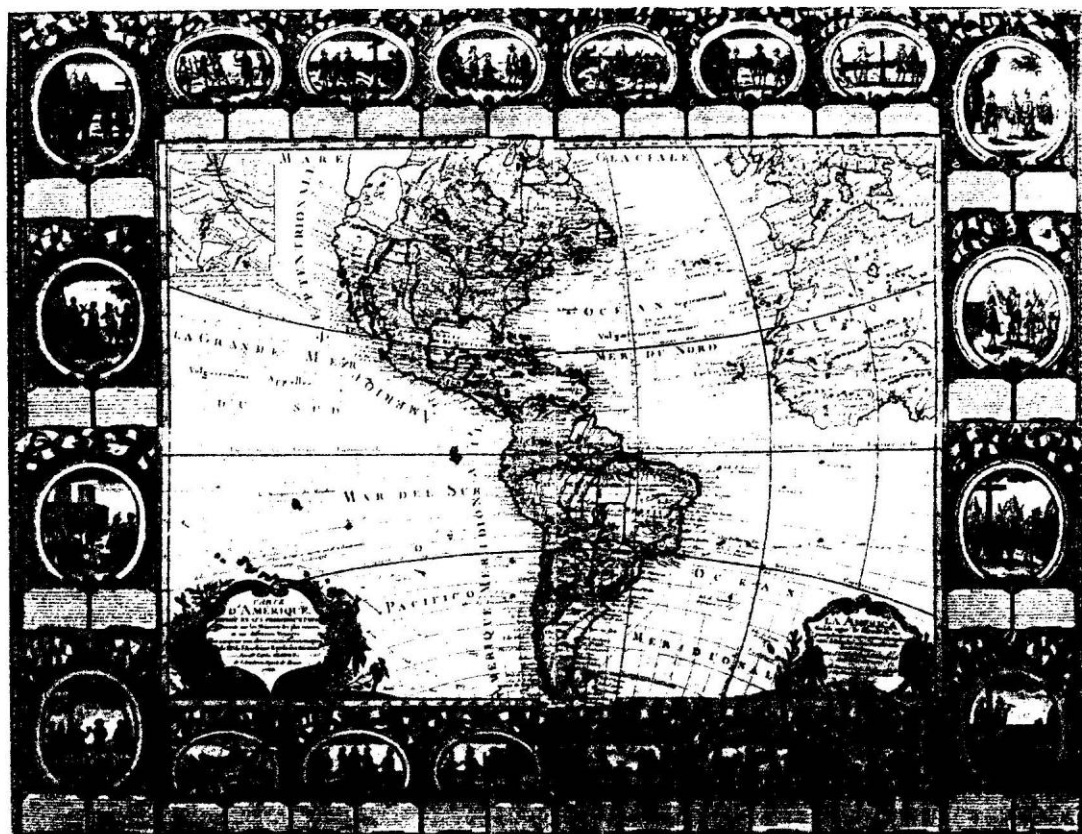


Figure 8

Carte de L'Amerique, Dressee Sur Les Memoires Les Plus Recentes, Et Assujettie Aux Observations Astronomiques, by L'Abbe Jean-Baptiste-Louis Clouet, 1788.¹²¹

¹²¹Vadeboncoeur, *Discovery*, 60.

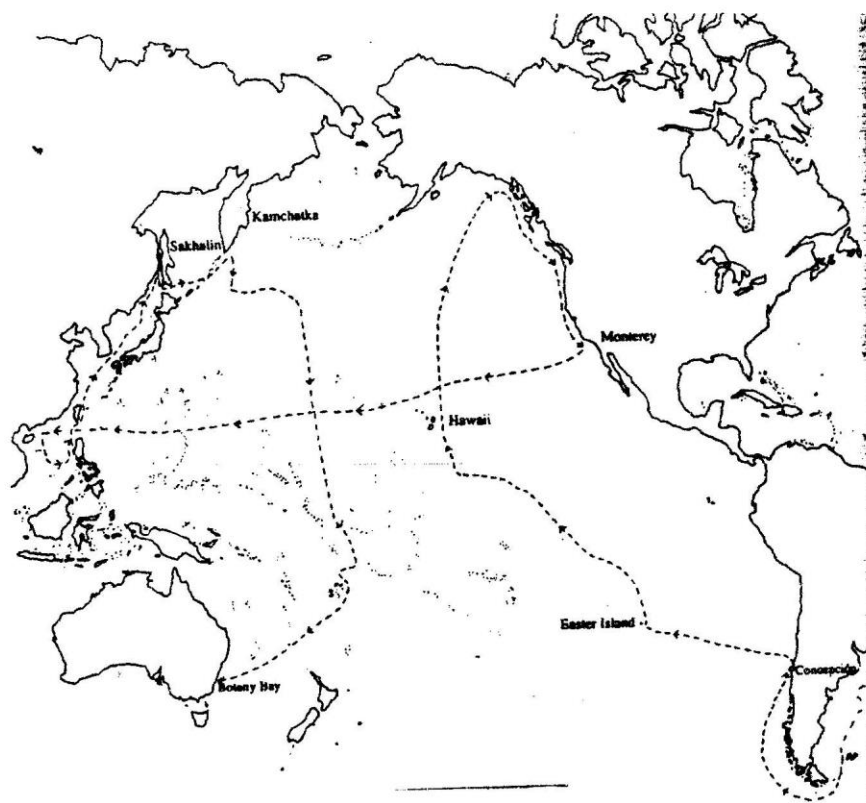


Figure 9
Voyage track of the la Perouse expedition.¹²²

¹²²Dunmore, *The Journal of Jean-Francois de Galaup de la Perouse*, vol. 2 (London, 1996), 261.



Figure 11
Voyage track of the Vancouver expedition along the coast of North America¹²⁴

¹²⁴Anderson, *Surveyor*, 6.

Chapter Three

Mapping the Pacific with Chronometer and Lunar Distance Longitude

"In the accumulation and practical application of knowledge there is no end."
Fontenelle

After 1765, Pacific exploration benefited greatly from advancements in navigational technology. Of the assortment of new tools available to the ocean navigator, unarguably none had greater impact than did the chronometer. Consequently the application of chronometers to Pacific mapping will be this chapter's primary focus. The marine chronometer enabled pilots to calculate longitude with greater ease than ever before. These devices were not the end-all in the quest for longitude, as we shall see. Early chronometers, including those taken to the Pacific by Francois de la Perouse, George Vancouver and others did not provide results sufficiently accurate for a captain to rely upon them. As a direct consequence of this, late eighteenth century navigators utilized chronometers in tandem with lunar distance longitude.

Imprecise navigation plagued sailors from Magellan until Carteret. As demonstrated in chapter two, however, in the second half of the eighteenth century, determining longitude at sea solved one of the greatest riddles that had vexed sailors and cartographers since antiquity. Solving longitude at sea revolutionized exploration of the Pacific, where at last a sailor could plot the east-west location of an island, and with certainty return to it. Once this was accomplished European economic exploitation of the Pacific's wealth of resources began in earnest as whalers, seal hunters, slavers, and guano gatherers waded in.

British explorer George Vancouver noted in 1790 that "sea officers of the most common-rate abilities...with the principles of this science...[will be able] to acquire their situation in any Ocean...provided [a spot] be sufficiently conspicuous to be visible at any distance from five to ten leagues."¹²⁵ A league is three miles, thus an island visible from a ship's masthead at a distance of 30 mile or less could be reached with certainty by any navigator competent in the use of a sextant and possessing either an *ephimeridian almanac* or a good chronometer.

During the eighteenth century, Britain hastened Pacific exploration, setting standards by which every expedition was measured. While England set the pace, it was not alone on the Pacific. Also plying the rolling swells of this ocean were Portuguese, Spanish, Russian, and French sailors. By the mid-1700s, it was primarily France that challenged Britain's Pacific enterprise, albeit perpetually awash in Britain's wake. Many reasons account for Britain taking the lead in Pacific exploration, foremost being the fact that Great Britain was an island nation steeped in maritime traditions, whereas Continental ambitions typically occupied the French more than did maritime exploits. In spite of their second-rate status in the Pacific, the French continued exploring, culminating their efforts in the 1780s with a Pacific voyage they hoped would surpass any other. Regrettably, King Louis XVI's well financed expedition commanded by Jean-Francois de Galaup de la Perouse tragically shorted its imagined triumph.

Regardless of its ultimate demise, the la Perouse expedition's application of chronometers to navigation and charting exemplifies what skilled navigators could accomplish with this device. Misfiled in the French National Archives during the early nineteenth-century, la Perouse's journal was there rediscovered by a graduate student in 1978. The journal we have today survived the expedition's destruction because la Perouse

¹²⁵Kaye Lamb, ed., *George Vancouver: A voyage of Discovery to the North Pacific Ocean and Round the World 1791-1795*, vol. 1 (London, 1984), 273.

sent installments to France whenever possible during the three-year voyage. The journal describes a well organized voyage, poised to rival those led by Britain's James Cook; but sadly in 1788, the la Perouse expedition foundered upon a reef in the New Hebrides, marooning the unfortunate survivors.¹²⁶ Sailors searched desperately for many years attempting to locate the la Perouse expedition, but rescue from an unknown island in the vast Pacific proved impossible. It was not until 1827 that the French discovered the actual resting place of many of their adventurers.¹²⁷

Early in 1785 the la Perouse expedition's planners chose two ships, *Astrolabe*, and *Boussole*. They next ordered the dockyard to quickly fit them out for a voyage of several years' duration. These small vessels would be home for more than two hundred brave sailors and scientists. To ensure the health and safety of the men, the government ordered shipwrights to make modifications such as adding copper sheathing to protect the hulls from fouling, and cutting additional portholes to ventilate and light the below-decks. La Perouse insisted upon the latter, on the basis of Cook's experience. Furthermore, workers expanded the ships' hold space, allowing storage for tons of scientific equipment, clothing for every climate, and ample sustenance.¹²⁸

While planning their grand voyage, members of the la Perouse expedition studied any material pertaining to Cook's voyages. Such information circulated widely among the scientific community as it deliberately cast off political differences. Accordingly, la Perouse dispatched Paul Monneron to London to procure further advice, and while the British government did not offer assistance, the scientists connected with Cook's voyages did. In London, Monneron purchased the latest navigational equipment available from George

¹²⁶John Dunmore, ed., *The Journal of Francois de la Perouse*, vol. I (London, 1994), viii.

¹²⁷John Dunmore, *Pacific Explorer* (Palmerston North, New Zealand, 1985), 295.

¹²⁸Dunmore, *Perouse*, vol. I, xciv-xcvii.

Adams, Britain's leading instrument maker, including an azimuth compass, four steering compasses, two night telescopes, thermometers, barometers, and two sextants.¹²⁹

Timekeepers procured in London for the voyage included a pendulum device, and chronometers made by British makers, John Arnold, and Larcum Kendall, the latter having reproduced Harrison's H-4. Moreover, the expedition carried two devices by the Swiss clock-maker Ferdinand Berthoud.¹³⁰

Well equipped and financed, the 1785-1788 la Perouse expedition rivaled any Pacific voyage previously undertaken. The French Naval Board's orders for la Perouse contained the following lofty objectives:

...we still lack a full knowledge of the earth and particularly of the Northwest coast of America, of the coast of Asia which faces it, and of the islands that must lie scattered in the sea separating these two continents. Consequently a great deal remains to be done by a nation that is prepared to undertake the completion of the description of the globe. The Portuguese, the Spanish, and the Dutch in earlier times and the English in the present century, have opened up new routes to navigation; and everything seems to invite the French who share in the empire of the seas with them, to perfect a work of which, until now, they have only done a small part.¹³¹

The plan further included the possibility of establishing a lucrative fur-trade agreement with China based in the Pacific Northwest of America. La Perouse nonetheless consistently subordinated the commercial aspects of this venture to the campaign of discovery.

An interesting aside to the official voyage stems from a British rumor that the French government sent sixty criminals to Brest to embark on board one of la Perouse's ships. The criminals reportedly were to be transported to New Zealand where they would

¹²⁹Dunmore, *Perouse*, vol. I, cxi.

¹³⁰Derek Howse, *Greenwich Time and the Discovery of Longitude* (Oxford, 1980), 77.

¹³¹Dunmore, *Perouse*, vol. I, cviii.

harvest timber, then believed to be excellent for repairing ships, particularly masts.¹³² The British were keenly interested in such a prison colony as they themselves were already planning one for Botany Bay, Australia. Rumors of French convict transportation proved to be false as did reports of fine timber. The South Pacific's short-grained, thinly rosined pines split under moderate stress, making them useless to shipwrights.¹³³ Ironically, when the British established a prison colony in 1788, it was the French government that desired a thorough investigation. La Perouse's expedition visited Botany Bay, and after several weeks of scrutiny, the Frenchmen sailed away, never to contact Europeans again.

On 1 August 1785, twenty-five officers, twelve scientists, and 188 seamen boarded their respective ships and bid France *adieu*.¹³⁴ The first experiment conducted involved checking the accuracy of their chronometers' longitude against that derived via lunar distance measurements. Results showed that as expected, the pendulum clocks maintained abysmally poor accuracy, while the spring-driven devices remained predictable in their movement enabling the navigators to correctly calculate time in Paris and therefore their present position.¹³⁵ The spring-driven chronometers were much used to correct any deficient longitudes on the charts. La Perouse's zeal for recording accurate locations continued throughout his journal, where in many instances, he proudly corrected locations determined by Cook, even if by only a half mile.

After four months of exploring the South Atlantic, the expedition's rounding of Cape Horn was much easier than la Perouse believed possible, as for centuries, sailors had feared these waters, and rightly so, but during summer, the joining of the Atlantic and the Pacific experiences a calm period, and it was during this pause that la Perouse sailed. After

¹³²Dunmore, *Perouse*, vol. I, cli.

¹³³Robert Hughes, *The Fatal Shore* (New York, 1986), 101.

¹³⁴Dunmore, *Perouse*, vol. I, cliii.

¹³⁵*Ibid.*, 16.

entering the Pacific, the expedition turned northward and sailed to Concepcion Bay, Chile. While there, scientists determined that Berthoud's chronometer 19 was maintaining its same rate of gain established in Brest, France, gaining a predictable 3 and-a-half seconds per day. "Timekeepers nos 25 and 29 varied sufficiently for us to lose confidence in them," la Perouse remarked, asserting that their error was caused by incorrectly estimating their rate of change.¹³⁶

After resting at Concepcion Bay, Chile for a few days, the expedition began its mission of charting unfamiliar regions. First, the sailors searched in vain for Juan Fernandez Island off the South American coast. Their old charts plotted it in the wrong location, so the ships' navigators could not find it. The vessels continued heading westward until they arrived at Easter Island on 4 April 1786. Easter Island was a place of mystery and entertainment for the explorers, where the intrigued scientist studied its huge stone figures, while the crewmen found great sport observing the islanders' uncanny ability to steal things, particularly hats. To prevent any harm coming to the otherwise peaceful islanders, la Perouse told his men their hats--even his own was stolen--would be replaced without charge.

Of the monuments, la Perouse observed, "all which remain today seem very old. We found no sign of any religious practices, because I do not believe anyone should take the statues for idols, although they seem to show them some veneration."¹³⁷ La Perouse's journal is filled with such anthropological observations. While at Easter Island, mapping the ocean continued uninterrupted, as navigators determined the island's longitude at 111 degrees 55 minutes west. Modern instruments place the island at 111 degrees 46 minutes west--of Paris, not Greenwich, since Paris was the standard la Perouse used.¹³⁸ The

¹³⁶Dunmore, *Perouse*, vol. 1, 52.

¹³⁷*Ibid.*, 62.

¹³⁸*Ibid.*, 57.

difference between the two was only 9 minutes of longitude, or about five nautical miles, was a distance within sight of a ship's lookout.

On 10 April 1786, crewmen watched the morays fade into the distance. While crossing to Hawaii, la Perouse praised the precision with which Berthoud's chronometer 19 kept time. "...As on all occasions, Mr. Dagelet [a navigator] never missed an opportunity to make observations. They agreed so well with the chronometers that the difference never exceeded 10 to 15 minutes of longitude--they backed each other up."¹³⁹ La Perouse placed the results obtained by chronometer on par with those achieved via lunar distance. Accurate longitude enabled the expedition to determine the set and drift of some Pacific currents, an advantage dead-reckoning did not permit. "Daily we could tell the direction of the currents from the difference between our dead-reckoning and our observed longitude."¹⁴⁰ Here la Perouse calculated that ocean currents caused the log's reckoned location to error 3 leagues per-day, so that when they reached Hawaii, dead-reckoning falsely situated the vessels 10 degrees of longitude too far east. Traveling northward from Easter Island, la Perouse correctly elaborated upon the effects of the South Equatorial Current, the Equatorial Counter Current and the North Equatorial Current, surmising that "...it is the direction of these currents which was not carefully estimated in early times that caused the errors found on Spanish charts,...[placing islands] too close to the coast of America...."¹⁴¹ The generally westward flow of these currents caused the distance traversed over the bottom to be more than the distance determined by the knot-log which provided pilots the ship's speed over the surface with currents not considered (figure 12).

La Perouse's epiphany regarding Spanish charts caused him to doubt the existence of a group of islands Spain plotted west of Hawaii, a belief vindicated after days of futile

¹³⁹Dunmore, *Perouse*, vol. 1, 76.

¹⁴⁰*Ibid.*

¹⁴¹*Ibid.*

search found not a trace of land.¹⁴² Next the vessels made a stop on the Hawaiian Island of Kauai, where lunar distance determined longitude of 161 degrees 5 minutes agreed



Figure 12
Currents in the Pacific.¹⁴³

¹⁴²Dunmore, *Perouse*, vol. 1, 79.

¹⁴³Freeman, *Geography of the Pacific*, 20.

with that established by Cook a dozen years earlier, and it was very close to correct by modern calculations.¹⁴⁴ The month of May was more than half gone when the expedition steered toward North America. Each day now became critical as summer neared, considering that mapping the northwestern coast of America was impossible during winter when fog presents a serious impediment to ships sailing along Alaska's coast.

Northwest America had not yet been well examined, so the sailors did not know what to expect. Disappointed reigned, however, when on the horizon they spotted only a snow-covered, treeless landscape. Their first landfall la Perouse named Monti Bay, which he plotted at 59 degrees 41 minutes north latitude, and 143 degrees 3 minutes west longitude. Today this location is known as Yakutat Bay, and the fix to which la Perouse assigned it was nearly correct.¹⁴⁵ When given the opportunity, the expedition relied upon lunar-distance-calculated longitude while charting, with the chronometers serving as a backup means of ascertaining location. In spite of the chilly weather conditions, the navigators carefully mapped the Alaskan coast while proceeding southward toward Lituya Bay--near Juneau, Alaska.

Lituya Bay presented great hopes for the expedition, where regardless of its harsh climate, the expedition found abundant wildlife to hunt, and Indians ready to trade. La Perouse notes that gold was present and that the Native Americans willingly traded it for iron. The expedition charted Lituya at latitude 58 degree 37 minutes latitude and at a lunar-distance-determined longitude of 139 degrees 50 minutes west of Paris, which is nearly perfect as modern calculations place Lituya Bay only 13 minutes north and 5 minutes west of la Perouse's calculations.¹⁴⁶ The explorers spent many days rowing along the shoreline in small launches trying to locate a passage across America. When they found a large river,

¹⁴⁴Dunmore, *Perouse*, vol. 1, 80-90.

¹⁴⁵*Ibid.*, 98.

¹⁴⁶*Ibid.*, 127.

la Perouse confidently scribed, "this is the channel by which we planned to enter into the heart of America; we thought that it might lead to a great river running between the mountains, which had its source in one of the great lakes in northern Canada."¹⁴⁷ La Perouse was neither the first nor the last explorer disappointed by a failed search for the fabled passage through North America. Before departing Alaska's chilly waters, at Cape Bingham, they determined that Bertoud's chronometers were maintaining accurate time. Again, their rate of gain altered little.

In August, as Alaska's winter approached, the *Astrolabe* and the *Boussole* departed Lituya Bay and continued south towards Monterey, California. The coasts of Oregon and California had not been visited by Europeans recently and consequently, contemporary maps contained irregularities and incorrect longitudes, both of which la Perouse dutifully righted. A year after its departure from France, the expedition's chronometers were functioning predictably. At this point in the voyage, the instruments lost an average of four and a half seconds per day, less than one second altered from that determined in Brest, France. Navigators easily corrected such predictable loss, giving them great certainty.¹⁴⁸ Confidently, the expedition relied upon chronometer determined longitude while at sea rather than attempting the more cumbersome lunar distance method. For two weeks the expedition sailed south along the coast of North America without utilizing the lunar distance system, when on August 17, la Perouse wrote, "the whole of the day was calm...we made some excellent astronomical observations; this was the first since our departure from [Lituya Bay]; our latitude was 58 degrees 12 minutes and according to our chronometers our longitude was 136 degrees 52 minutes, and the average of our distances was 137 degrees 27 minutes or a difference of 37 minutes west. Those of the *Astrolabe*

¹⁴⁷Dunmore, *Perouse*, vol.1, 110.

¹⁴⁸*Ibid.*, 150.

were 15 minutes east."¹⁴⁹ The chronometers here achieved a remarkable record of accuracy.

While confident of his placement of the coastline's features, la Perouse cautioned those in his wake. Of the charts produced while venturing toward Monterey, he wrote, "one should not however overlook the fact that this chart leaves much to be desired in respect of details; we sailed too fast along the coast to have seen everything and we are answerable only for the features we determined...and the trend of the coast..."¹⁵⁰ Precise, complete charting required more time than the expedition's expansive goals allowed. Nonetheless, the coordinates determined during this stage were highly accurate.

Monterey was a relatively new Spanish colony, established only fifteen years before the *Astrolabe* and *Boussole* arrived.¹⁵¹ While there, la Perouse praised his chronometers' accuracy, particularly that of Berthoud's number 18 and 19. To this point in the voyage, their accuracy was remarkable, especially considering the extreme temperature fluctuations traveling in such latitudes can induce. Temperature fluctuation plagued early chronometers, causing their metal springs to expand and contract, thus producing variations in the speed with which they measured the passage of time.¹⁵²

The expedition's mapping objectives in southern California included verifying or refuting the writings of Admiral de Fuentes, whose 1640 expedition to the Pacific many scholars doubted. The admiral's alleged journal included references to a series of inland lakes which began in California and traversed the entire North American Continent. After a thorough investigation, however, his sailors found no passage and la Perouse accordingly

¹⁴⁹Dunmore, *Perouse*, vol. 1, 154.

¹⁵⁰*Ibid.*, 197.

¹⁵¹Dunmore, *Pacific Explorer*, 238.

¹⁵²Dunmore, *Perouse*, vol. 1, 195-197.

removed it from his maps.¹⁵³ "Travel liars" published volumes of material during the eighteenth century describing glorious voyages to exotic lands. Most of these books were based entirely on fantasy, though a knowledge-hungry Europe devoured them, mingling their contents with real geography. La Perouse succinctly expressed his contempt for these fiction writers and their gullible readers, stating that "...readers will be kind hearted enough to combine the pleasure they may gain from reading about this campaign with some thought for those who underwent these hardships may perhaps see with interest navigators, after a year at sea, struggling at the ends of the earth against fog, bad weather and scurvy along an unknown coast, which once upon a time was the setting for geographical tales that are too readily accepted by modern geographers."¹⁵⁴ La Perouse mapped the globe with great precision, and his frustration at having to remove dangerously situated fictitious locations was obvious.

In September 1786, the ships weighed anchor and resumed exploring the Pacific as they headed for Macao. During their westward crossing, the expedition discovered and plotted Necker Island, and French Frigate Shoals. A nighttime encounter with the latter nearly destroyed the ships, but fortunately, a lookout heard surf breaking and warned the helmsmen to veer off.¹⁵⁵ The remainder of the crossing was uneventful as the ships neared the Asian coast on 2 January 1787.

Macao was a metropolis compared to Monterey, but the enigmatic Chinese Empire caused la Perouse to remain cautious throughout his stay. China was officially closed to foreigners, and la Perouse knew that if any of his men ventured away from the Portuguese fort they would be arrested and executed. With this in mind, he ordered his men to remain on board their ships or within the confines of the harbor's fort. The expedition plotted

¹⁵³Dunmore, *Perouse*, vol.1, 165.

¹⁵⁴*Ibid.*, 95.

¹⁵⁵*Ibid.*, 207.

Macao's position at latitude 22 degrees 12 minutes north and via lunar distance, longitude at 111 degrees 19 minutes east of Paris, where again la Perouse was nearly perfect.¹⁵⁶ Chronometer number 19 placed their longitude at 113 degrees 33 minutes, more than 2 degrees too far east. The clock's rate of change increased considerably during the past months, so the navigators established a new correction table for the device. An explanation offered by la Perouse for the inconsistency in this device was that during the passage the chronometer had stopped. Here his Journal reveals a problem with chronometers--they had to be wound daily. La Perouse wrote of this mishap, "...we found the daily loss of number 19 to be 12 minutes 36 seconds, far more than we had previously observed: it should be said however that we forgot to wind up this chronometer for twenty-four hours, and, that it had stopped...."¹⁵⁷ Such a mistake was inexcusable, and la Perouse placed the blame upon himself.

After departing China, the vessels headed west, where they stopped briefly in the Philippines. While in Manila, they conducted many lunar distance observations, correctly establishing the city's longitude at 118 degrees 50 minutes, demonstrating its accuracy nearly two years after their departure from France, chronometer number 19 placed them only 4 minutes west of this.¹⁵⁸ A complete study of all of the time keepers is unfortunately not possible as la Perouse makes no mention of the accuracy of any other chronometer. The one mentioned frequently, Berthoud's number 19, performed remarkably well to this point in the voyage.

The expedition next headed north into the East China Sea where the Frenchmen charted the southern coast of Korea and the west coast of Japan, both regions being unclear on European charts. The waters around Japan and Korea presented many hazards.

¹⁵⁶Dunmore, *Perouse*, vol. 1, 221.

¹⁵⁷*Ibid.*, 227.

¹⁵⁸*Ibid.*, 248.

Before he departed France, planners had warned la Perouse that he might encounter storms and pirates here and that any charting accomplished in this location would be done at extreme risk to the ships and men.¹⁵⁹ While off the coast of Taiwan, la Perouse charted Huaping Hsu Island at 25 degree 43 minutes north and 121 degrees 14 minutes east. Modern calculations today situate Huaping Hsu Island at 25 degrees 24 minutes north and 119 degrees 38 minutes east.¹⁶⁰ The uncharacteristic longitude error of 1 degree 36 minutes is perhaps attributable to chronometer error since sailing along this dangerous coast likely did not allow cross-checking these calculations against lunar distances.

After passing Japan, the expedition vainly searched for an entrance into the Sea of Okhotsk. During this juncture, the expedition used chronometer number 19 to determine the position of Castries Bay, Siberia, as being 139 degrees 41 minutes east longitude and 51 degrees 29 minutes north latitude, and again this reading is 1 degree 14 minutes east of actuality. Unfortunately, while at Castries Bay, a careless carpenter felled a tree upon the astronomers' tent resulting in the destruction of chronometer number 18.¹⁶¹ Next, the expedition turned south toward the Russian town of Petropavlosk on the Kamchetka Peninsula, where to the surprise of all, dispatches la Perouse received from France included instructions for the *Astrolabe* and *Boussole* to proceed to Botany Bay, Australia in order to investigate the British colony reportedly under construction there.¹⁶² The original plans for the voyage did not include visiting Australia, instead, they called for mapping the Santa Cruz and Solomon Islands, after which they were to return home. Regardless, the French government wanted more information about Britain's new colony and the *Astrolabe* and *Boussole* were the only French ships able to expediently reach Australia. As ordered, the

¹⁵⁹Dunmore, *Perouse*, vol. 1, cxxxii.

¹⁶⁰Dunmore, *Perouse*, vol. 2, 261.

¹⁶¹*Ibid.*, 305.

¹⁶²Dunmore, *Pacific Explorer*, 263.

expedition departed Kamchatka on 30 September 1787, and headed east until it reached the longitude of Samoa where they turned and hastily proceeded due south.¹⁶³

On 6 December 1787, a lookout spotted Tutuila, where the expedition made a brief stop. La Perouse fixed this location uncharacteristically wrong by 9 degrees of longitude.¹⁶⁴ The final chapter of his journal is fraught with such error, as other plotted locations contain blank spots followed by the word "longitude." Perhaps la Perouse hurriedly completed this chapter so as to send it off with the next ship departing Botany Bay for Europe. After all, the journal was only to be a narrative expanding on the ship's log. The problem is that the expedition perished in 1788 along with its logbooks, so regrettably, the incomplete journal is now all that we have.¹⁶⁵

When the expedition arrived at Botany Bay, la Perouse found several British ships there at anchor, most of which had arrived only four days earlier.¹⁶⁶ La Perouse found the British officials making final plans for their prison colony, of which, the observant la Perouse undoubtedly wrote a great deal. These writings were lost. While in Botany Bay, British sailors visited the French ships where crewmen exchanged many stories. Less welcomed were escaped British convicts, who climbed on board the French ships where they tried to stowaway, however, the French refused them passage.¹⁶⁷ Prior to his going, la Perouse sent a mailbag to one of the British ships returning to England. The bag contained two of the last surviving letters he sent to France, and they provide valuable insight into his plans for their last year of exploration. He wrote:

¹⁶³Dunmore, *Perouse*, vol. 2, 450.

¹⁶⁴*Ibid.*, 416.

¹⁶⁵*Ibid.*, 415-448.

¹⁶⁶Dunmore, *Perouse*, vol. 1, 276.

¹⁶⁷Hughes, *The Fatal Shore*, 88.

I shall go up to the Friendly Islands...New Caledonia, the Santa Cruz of Mendana, the southern coast of Surville's Arsacides [the Solomons] and Bougainville's Louisiades. I shall pass, towards the end of July 1788, between New Guinea and New Holland [Australia]. In September and part of October I shall visit the Gulf of Carpentaria and the whole of the west coast of New Holland as far as Dieman's Land;...[I shall] reach the Ile de France in December 1788.¹⁶⁸

No further word from la Perouse ever reached France, and the official books of the expedition were closed on the last day of December, 1788. For many anxious months in 1789, people hoped the expedition would be found, but as another year passed without word, it seemed unlikely that anyone from the expedition would return.

Several rescue missions were dispatched after 1788, but none gathered enough evidence to piece together the expedition's last disastrous moments. The mystery of the la Perouse expedition's loss was not definitively solved until 1827, when Peter Dillon found a silver sword guard and other European items on an island in the Santa Cruz group. From its inhabitants he heard a story about the destruction of two ships in a violent storm. The wrecks were on a nearby island named Vanikoro, which Dillon soon sailed to. On Vanikoro, an old man told him details of the disaster:

From him I gleaned the following particulars relative to the ships which were wrecked there when he was a boy of about ten. From the natives he learned that the two ships alluded to in his narrative ran on shore in the night on reefs some considerable distance from the land. The one which got on shore near Whannow was totally lost, and such of the crew as escaped to land were murdered by the islanders. The ship which had been wrecked at Paiow was broken up to build a two-masted ship. The people, while employed building the ship, had a fence built around her of wooden palisading, within which they lived. There were several of the islanders friendly disposed towards them: others were hostile, and kept up a continual

¹⁶⁸Dunmore, *Pacific Explorer*, 280-281.

war. When the new vessel was built, all but two of the men embarked in her, and sailed away for their native country, after which they never returned.¹⁶⁹

Archaeological research conducted in the 1960s confirmed the 1827 report. Recovered artifacts strongly suggest that the two vessels wrecked at Vanikoro are the *Astrolabe* and the *Boussole*.¹⁷⁰ Of the two-masted vessel the islanders saw sail away, not a trace has ever been found.

The voyage of la Perouse captured the imagination of many individuals who anxiously awaited news from the expedition. Information la Perouse returned enabled scientists to chart the Pacific with more precision than ever before, and although he did not yield the volume of material that Cook accumulated, la Perouse nonetheless added definition to many parts of the Pacific, particularly along the coasts of northern Asia and California. Likewise, he removed many false locations, bringing certainty to new maps. Visited locations included, Chile, Easter Island, Hawaii, the Pacific Northwest, the California coastline, Macao, Manila, Petropavlosk, Samoa, Fiji, Botany Bay, and others unknown before his death.

Two years after the demise of the la Perouse expedition, the British Admiralty mounted its last major eighteenth-century Pacific voyage of exploration. The Admiralty chose George Vancouver to command this four-year expedition, basing the decision upon his experience mapping and sailing the Pacific with James Cook. Vancouver went to sea at age 13 as a midshipman with Cook's 1772 voyage on board *Resolution*. Of Vancouver, historian John Beaglehole wrote that, "it would be difficult to image a better education for a young seaman than three years in the *Resolution* [with Cook]."¹⁷¹ One of Vancouver's fellow midshipmen wrote of the experience that "in the early part of the voyage, Captain

¹⁶⁹Dunmore, *Pacific Explorer*, 291-292.

¹⁷⁰*Ibid.*, 297.

¹⁷¹John C. Beaglehole, *The Life of James Cook* (London, 1960), 299.

Cook made all us young gentlemen do the duty aloft the same as the sailors, learning to hand, and reef the sails, and steer the ship, exercise small arms, there by making us good sailors as well as good officers."¹⁷² Vancouver again sailed to the Pacific with Cook's 1776 voyage, this time on board the consort vessel, *Discovery*, under the command of Captain Charles Clerke.

The Admiralty Board broke with tradition as it organized Vancouver's voyage, when to save money it provided but one ship. The Admiralty chose a single 330-ton merchant ship, *Discovery*, to convey its sailors to the Pacific. To facilitate in-shore exploration, planners provided the crew with a small shallop stowed in *Discovery's* hold from which they could safely venture close to land. Vancouver was not in favor of this plan and it was soon abandoned when the hold of *Discovery* proved too small to contain two years worth of provisions and a small sailboat. The Admiralty discarded its one-ship scheme and chose the 135 ton armed tender, *Chatham*, as consort.¹⁷³ Of his ships, Vancouver wrote, "the *Discovery* was copper-fastened, sheathed with plank, and coppered over; the *Chatham* only sheathed with copper. Both vessels were armed with cannon. *Discovery* was manned by a crew of 100, while *Chatham* sailed with 45."¹⁷⁴ Provisions for the crew included sauerkraut, wheat, oatmeal, malt, hops, flour and other foods, including portable soup, a concoction of vegetables, ox liver and heart, dried and cut into slabs.¹⁷⁵

The Admiralty sent this expedition primarily for two reasons. First, to explore the coastline of North America from the 30th degree of latitude northward to the 60th. Along the way Vancouver was to search for the Pacific outlet of the Northwest Passage. Zealots

¹⁷²Beaglehole, *Cook*, 299.

¹⁷³Kaye W. Lamb, ed., *George Vancouver: A Voyage of Discovery to the North Pacific Ocean and Round the World 1791-1795*, vol. 1 (London, 1984), 278.

¹⁷⁴*Ibid.*, 278-280.

¹⁷⁵*Ibid.*, 282.

still believed that such a passage existed. Of this search, Vancouver wrote, "the charts...representing the North West coast of America [being] so much broken by the waters of the Pacific, gave rise...to hypotheses...of a north-eastern communication between the waters of the Atlantic and the Pacific...and [it] was brought forth with much vigor."¹⁷⁶ Vancouver doubted that such a strait existed although he diligently searched in vain for it.

The second impetus for the Vancouver expedition was "a desire to ascertain, with as much precision as possible, the number, extent and situation of any settlements which have been made [between the 30th and 60th degree of latitude] by any European nation, and the time when such settlement was made."¹⁷⁷ If Britain could assert its claim more vigorously than its competitors, Britain might obtain uncontested exploitation rights to the wealth of furs coming from America's Northwest. Furthermore, they could claim navigation rights through any channel found bisecting the continent.

The time table established for the voyage was ambitious, but not impossible to maintain. The British government ordered Vancouver to survey the northwest coast of America during the summers of 1792, 1793, and 1794 and to winter in the Sandwich Islands (Hawaii), where he could make any repairs necessary as well as survey the islands when weather and circumstances permitted. After the summer of 1794, the expedition was to steer southward and return to England via Cape Horn.

In keeping with this ambitious schedule, Vancouver's ships departed England on 1 April 1791, bound for the Cape of Good Hope. "At midnight we took a long farewell of our native shores," wrote Vancouver of the solemn occasion. He had many times before ventured from home for years at a time, and as before, he undoubtedly wondered how his home might change during this absence. On his last journey to the Pacific, the American Colonies had declared independence and won their freedom. Likewise, the 1790s were

¹⁷⁶Lamb, *Vancouver*, vol. 1, 275.

¹⁷⁷*Ibid.*, 284.

difficult years in Europe, causing Vancouver and his compatriots to pondered how events such as the revolution in France might unfold. Of this somber occasion he wrote, "...to us destined, as it were, to a long and remote exile;...it was the source of inexpressible solicitude."¹⁷⁸

To help their expedition find its way, the Admiralty equipped Vancouver's pilots with many instruments, including 12 sextants with which they would establish latitude and make the measurements necessary to calculate longitude.¹⁷⁹ These devices were of peerless quality and they produced identical results. Likewise, the vessels departed England with Larcum Kendall's chronometer K-3, on board *Discovery*, and John Arnold's number 82, aboard *Chatham*. These devices were the finest available in Britain. Later, in 1792 when their supply ship *Daedalus* joined them, they received three additional clocks, Arnold's numbers 14 and 176, and a pocket watch by Thomas Earnshaw.¹⁸⁰

The sailors first stopped in the Madeiras, where they checked their sea-clocks, and like sailors had done for centuries, they took on board many gallons of the island's renowned wine. In the early days of the voyage, as Vancouver tested the accuracy of his chronometers against lunar observations, he judged that his chronometers produced the better results, their lunar distance longitude being about 20 minutes eastward of their chronometers. Even at this early juncture, their dead-reckoned longitude was already more than 1 degree off. As earlier stated, dead-reckoning is an estimation of the distance traveled over the bottom, calculated by determining the ship's speed and course, which are then plotted on the chart. Errors in this system are induced by currents, storms, and compass variation. In this situation Vancouver blamed the pilot's not allowing proper compass variation as the reason his reckoning was a degree wrong. By this he meant that the ship

¹⁷⁸Lamb, *Vancouver*, vol.1, 310.

¹⁷⁹*Ibid.*, 313.

¹⁸⁰*Ibid.*, 51.

was sailing in a slightly different direction than what the pilot plotted on his charts, resulting in the ship being in a place different than what the knot-log and compass indicated.¹⁸¹

As they neared the Cape of Good Hope, Vancouver tested an erroneous theory for determining longitude. The method was developed in 1784 by William Nicholson. It involved grids containing compass-variation readings along lines of latitude. Knowing what the variation was at any point along a specified parallel could provide the point's longitude. Vancouver tested this hopelessly confusing theory as he approached the Cape of Good Hope, where he found Nicholson's calculations 25 degrees off the mark. The compasses themselves caused the system's fatal error. As Vancouver wrote, "[the compasses] differed from one to...four degrees, not only when made by different compasses placed in different situations on board, but by the same compass in the same situation."¹⁸² Of the more promising chronometer method for determining longitude, Vancouver expressed reservations that price and rarity would make chronometers impractical for the foreseeable future. On the issue of lunar distance longitude, Vancouver remarked, "...I yet hope to see the period arrive when every sea-faring person capable of using a quadrant will...be enabled by lunar observations to determine his longitude."¹⁸³ Like Cook, Vancouver placed much confidence in this system, but its unavoidable complexity harbored its doom.

The *Chatham* and *Discovery* continued southward through the Atlantic until they reached Cape Town, where, in Simons Bay, the crews busied themselves preparing the ships for their long voyage into the Pacific. Here carpenters replaced the bowsprit of *Discovery*, while the officers insured the ship's stores were dry and of good quality. "The vessels wanted caulking fore and aft; the rigging, overhauling; casks to receive water; sails

¹⁸¹Lamb, *Vancouver*, vol.1, 311.

¹⁸²*Ibid.*, 320.

¹⁸³*Ibid.*

repairing; the powder airing...." These activities took many days to accomplish, all the while dysentery was striking an alarming number of crewmen.¹⁸⁴ Before departing on 17 August, Vancouver set up an observatory on shore to check the accuracy of his chronometers. The key to using a chronometer was to know at what rate the device gained or lost time. A consistent variation could be corrected by adding or subtracting an appropriate amount of time. During these early months of their voyage, the pilots corrected these devices according to instructions provided by scientists at the Greenwich Observatory, though to their disappointment, in Cape Town they determined Kendall's K-3 to be 17 minutes 45 seconds too fast. The device had gained time more slowly than they allowed, though observations made during the last days on the Cape revealed that the clock was again gaining at a rate of 6 seconds per day, just as predicted in England. Apparently it had gained at a slower rate during their junket south. Arnold's clock proved to be dangerously unreliable, as its corrected time was 1 hour 18 minutes 28 seconds too fast, thus gaining an average of more than 16 seconds per day, a rate slower than that estimated in England.¹⁸⁵

Sailing southward toward Australia, the crew lost its first member to illness. "The flux," as dysentery was then known, claimed this life, as many others struggled to survive. Arriving on the Southwest coast of Australia on 27 September 1791, Vancouver named their first landfall Cape Chatham. The captain here observed that "immediately along the sea side, [it] consists of a range of dreary hills, and little herbage...with a soil composed of white sand...."¹⁸⁶ Trees were seen at some distance, but the crew observed no signs of habitation. Cape Howe was next encountered. Here the pilots plotted their location at 35 degrees 17 minutes latitude, and 117 degrees 52 minutes east longitude according to lunar

¹⁸⁴Lamb, *Vancouver*, vol. 1, 321.

¹⁸⁵*Ibid.*, 324.

¹⁸⁶*Ibid.*

distance observations. Today this location is fixed at 35 degrees 8 minutes latitude and 117 degrees 36 minutes longitude.¹⁸⁷ As whales frolicked around the ships, Vancouver claimed all the lands he observed for His Majesty King George III.

The voyage along the South coast of Australia was uneventful as the crew observed severe devastation wrought by fire. While ashore in King George III Sound, the crew set up an observatory and again checked the accuracy of their chronometers. An astounding 110 sets of lunar observations produced an average longitude of 118 degrees 14 minutes. These calculations were close, but they erred about 14 minutes eastward. Kendall's chronometer, allowing the Portsmouth rate of correction showed 117 degrees 46 minutes, and allowing the Cape correction rate, 118 degrees 23 minutes. The average of these two rates, 118 degrees 5 minutes, is close to being accurate, in fact, closer than the average obtained by lunar observations. Arnold's chronometer, corrected by the Cape calculations showed their longitude less accurately at 117 degrees 38 minutes.¹⁸⁸

The expedition departed Australia bound for New Zealand on 27 October 1791. Off Tasmania, a check of their chronometers against lunar observations made by James Cook showed the chronometers to be in error by 20 minutes. Soon after leaving Australia, the ships parted company in a storm, causing Vancouver much concern for the safety and success of the mission. A contingency plan existed for just such an occasion, however, as prior to departing Australia, the captains had decided that in the event of a separation, they would sail on to Dusky Bay, New Zealand, which they both did.

In New Zealand, Kendall's chronometer was found to have gained time at an average rate very near that predicted in England, as its correction by 6 seconds per day now gave a longitude only 11 minutes eastward of correct. Using the Cape rate of

¹⁸⁷Lamb, *Vancouver*, vol.1, 335.

¹⁸⁸*Ibid.*, 356.

correction, Arnold's clock erred by 42 minutes.¹⁸⁹ The pilots here allowed three different correction rates for each clock, a system that undoubtedly became unwieldy and hopelessly confusing. Sailing eastward, the pilots of *Discovery* plotted Rapa Island at 27 degrees 36 minutes south latitude--only 1 minute of latitude northward of the island's location--its longitude at 215 degrees 35 minutes east, a fix erred but 20 minutes eastward.¹⁹⁰ The longitudes calculated throughout this expedition were typically erred by this margin. While not perfect, they were within the 10 league parameters set forth by Vancouver prior to departure.

In November the expedition departed New Zealand, bound for Tahiti. When the sailors arrived in early December 1791, Vancouver noted that the log's dead-reckoned latitude was only 5 minutes wrong. Unfortunately he made no journal reference to reckoned longitude. He did note longitude derived by one of the clocks, probably K-3. Kendall's device provided a time 1 degree and 10 minutes westward of their location as fixed by both Cook and themselves.¹⁹¹ Such error was extreme, exemplifying the danger of relying solely upon chronometers for navigation. Vancouver set the latitude of Point Venus, Tahiti perfectly. At this location he noted the reverence with which he held Cook's longitude determination. Of Point Venus, he states, "its true longitude, as determined by Captain Cook is 210 degrees 24 minutes." In actuality, Vancouver's results were more accurate, in fact they were only 1 minute of longitude erred, while Cook's erred 6 minutes. The longitude calculated from Kendall's chronometer, corrected at the rate determined at Dusky Bay, New Zealand erred by a mere 4 minutes, meanwhile, Arnold's device was again

¹⁸⁹Lamb, *Vancouver*, vol. 1, 366-367.

¹⁹⁰*Ibid.*, 374.

¹⁹¹*Ibid.*, 389.

proving to be unreliable as it now gained at a rate of nearly 20 seconds per day, up from the 16 seconds calculated at the Cape of Good Hope.¹⁹²

The expedition departed Tahiti in late February 1792, destined for Hawaii. During the trip, Vancouver noted that his dead-reckoned longitude remained accurate until they neared the Equator, where it had "...hitherto varied about half a degree to the westward of the chronometer; but as we advanced, we found a very strong westwardly set current."¹⁹³ One of the pilots estimated their rate of drift at 2 knots, which is in fact correct for a vessel traversing the South Equatorial Current. In spite of the pilots' efforts, however, as the vessels crossed this current, their reckoned longitude began to error greatly. Traveling northward, the chronometer longitude agreed nearly perfectly with that derived by lunar distance, from which Vancouver surmised adding 4 seconds daily to K-3 must be correct. On the evening before reaching Hawaii, Vancouver noted that, "our...longitude per dead reckoning 209 degrees 33 minutes; by chronometer 204 degrees 19 minutes, which latter is to be received as the true longitude, notwithstanding the difference of 5 degrees 14 minutes; for so much had we been effected by the western current, in this long passage."¹⁹⁴

At Woahoo Harbor (Honolulu), Vancouver penned, "we found the ship's latitude...to be 21 degrees 16 minutes; its longitude by chronometer 202 degrees 9 minutes. Mr. Arnold's chronometer on board the *Chatham* gave a longitude of 201 degrees 45 minutes, adjusted according to the rate as set at Otaheite [Tahiti]. Our chronometer [k-3] by the Portsmouth rate, shewed the longitude to be 203 degrees 29 minutes."¹⁹⁵ Honolulu is situated at 21 degrees 17 minutes latitude and 202 degrees 7 minutes east longitude. Thus Arnold's clock now provided more consistent time-keeping once corrected than did

¹⁹²Lamb, *Vancouver*, vol.1, 441.

¹⁹³Lamb, *Vancouver*, vol. 2, 444.

¹⁹⁴*Ibid.*, 445.

¹⁹⁵*Ibid.*, 458.

Kendall's. The pilots would have to reestablish K-3's rate of change before they could again rely upon it.

In Hawaii, Vancouver was surprised to encounter several Europeans and an Americans. Entrepreneurs employed these individuals to gather sandal wood for trade in India. During this era, investors were busy developing a triangular trade route in the Pacific, their fur-laden vessels departing the Northwest coast of America at the end of the fall hunting season, crossing to Hawaii where they could prepare their ships for the second half of the voyage. Next they proceeded to China with furs and to India with sandal wood.¹⁹⁶ It is not clear what, if anything beyond ballast stone, traders brought back to Hawaii or western North America from Asia.

As their intended departure date neared, crewmen busied themselves repairing the ships and collecting fresh food for their voyage back to North America. Hawaii's bounty suited them well. Meanwhile, the pilots plotted their location as 21 degrees 57 minutes north latitude and 200 degrees 18 minutes east longitude according to K-3. This fix is nearly correct as Waimea's longitude is today set at 200 degrees 20 minutes east. Arnold's chronometer gave a longitude of 199 degrees 58 minutes, not as accurate as K-3, though reasonably close.¹⁹⁷

In mid-March 1792, the expedition weighed anchor and steered northeast toward America. A few weeks out to sea, Vancouver wrote:

On Thursday the 29th, in latitude 27 degrees, I got five sets of distances of the moon and sun; the mean result gave the longitude 214 degrees 21 minutes; by the chronometer it was 213 degrees 46 minutes; and by dead reckoning, 211 degrees 44 minutes. This error in dead reckoning seemed gradually to have taken place....I was led to believe that our climate change

¹⁹⁶Lamb, *Vancouver*, vol. 2, Ibid., 470-473.

¹⁹⁷Ibid., 479.

(the thermometer having fallen from 80 to about 66 since leaving the Sandwich Islands [Hawaii]), had caused some acceleration in its [K-3] rate of going.¹⁹⁸

Vancouver well understood the problems temperature fluctuation introduced into the chronometers, and although he could not prevent it, he could compensate for it by adding or subtracting time from the devices.

The crew sighted New Albion, as the northwest of North America was then known, on 18 April, making landfall along the coast of California about 115 miles north of San Francisco. Examining the time pieces led Vancouver to conclude erroneously that they situated his position too far westward. He arrived at this conclusion as five crew members besides himself took a combined total of 85 sets of distances, establishing their longitude at 235 degrees 41 minutes. Their chronometer placed them at 235 degrees, which in all likelihood is more correct. Later along the coast, Vancouver determined their location as 236 degrees 25 minutes, an impossibility considering that longitude is a dozen miles inland.¹⁹⁹

While traveling northward, the number of finback whales accompanying the vessels amazed the crew. Nearing the present boundary between California and Oregon, they plotted Point St. George's at 41 degrees 46 minutes latitude, while lunar distance longitude placed it at 235 degrees 57 minutes west of Greenwich. Today this location is fixed at 41 degrees 48 minutes north and 235 degrees 45 minutes east. And again Vancouver plotted a position too far eastward.²⁰⁰

In latitude 48 degrees 37 minutes, the expedition encountered what many, including Alexander Dalrymple and other proponents of Pacific exploration, touted as the Strait of

¹⁹⁸Lamb, *Vancouver*, vol. 2, 481.

¹⁹⁹*Ibid.*, 485.

²⁰⁰*Ibid.*, 490.

Juan de Fuca. Today it is known as Cape Flattery. Many cartographers alleged that this location was the Pacific end of the Northwest Passage from the Atlantic. Following the Admiralty's orders, Vancouver explored this location where, like Cook's expedition in 1778, he found no evidence of a strait into the heart of America. At this juncture, the expedition relied on lunar distance derived longitude, making no reference to their chronometers for weeks, until Vancouver wrote that the chronometers' rates were increasing as his ships progressed northward. He noted that K-3 was gaining speed at a rate of more than 11 seconds per day, while Arnold's clock gained 27 seconds per day.²⁰¹ The most serious drawback of chronometers was here obvious, making it clear why seamen did not solely rely on them for many years to come. To navigate with certainty, pilots had to be able to conduct lunar distance calculations, as without these calculations it was impossible to establish at what rate a chronometer varied. Cold weather seems to have accelerated the clocks, but a pilot had to know at what rate, and this could not be determined without an alternate means of establishing longitude. Eighteen months into the voyage, Vancouver noted that uncorrected, Arnold's clock differed from Greenwich time by 2 hours 56 minutes, a time equal to nearly 45 degrees of longitude.

In many locations along the coast, crewmen reported seeing human skeletal remains littering the beaches, often numbering dozens at each location. Vancouver concluded that some epidemic disease had struck. He later inadvertently alluded to the Indians' cause of deaths, writing, "...several of their stoutest men had been seen perfectly naked [in the cold] and their skins were unblemished... by ...scars, excepting such as the small pox seemed to have occasioned."²⁰² Small pox killed so many Native Americans that Vancouver noted a conspicuous depopulation from the time of his previous visit twelve years before. The presence of so many unburied remains indicates that the disease, once imbedded in the

²⁰¹Lamb, *Vancouver*, vol. 2, 530.

²⁰²Lamb, *Vancouver*, vol. 3, 540.

population, reaped a swift, cataclysmic toll. Vancouver wrote nothing further on the subject. Instead, he left the determination of the Indians' cause of death to "...others with more leisure...to direct such an inquiry."²⁰³

The expedition continued charting the coast along Puget Sound and Birch Bay in the 49th degree of latitude, and as usual, the navigators' longitude was too far eastward. At Birch Bay, the expedition checked the chronometers and discovered that, uncorrected since the last check, Kendall's clock was 54 minutes 11 seconds fast, while Arnold's was 3 hours 14 minutes ahead of Greenwich time. As the ships traveled northward, they carried the expedition to a region ill-defined on existing charts. Here Vancouver wrote, "destitute of any other authority, our estimated latitude in this situation is 51 degrees 4 minutes and longitude 232 degrees 8 minutes."²⁰⁴ Uncharted regions along the coast remained a problem for not only geographers, but also merchants and politicians alike, as each needed information in order to formulate plans of exploitation. Even Spain, who had for centuries claimed this territory, did not know beyond vague notions what was here.

The la Perouse expedition and the voyages of James Cook probably inspired Spain to further investigate this most northerly region of its American Empire, but Spain no longer possessed the financial reserves to underwrite grand exploratory missions. In many respects, Vancouver's expedition sealed the fate of Britain's territorial rivals, particularly Spain, as Britain alone seemed poised to control the region. Vancouver here confidently charted and claimed territory, knowing that unlike Spain's ensign, the Union Jack unfurled would not soon depart.

The men of *Discovery* and *Chatham* continued northward toward Nootka where they would meet a Spanish delegation sent to negotiate ownership of the bay and its wealth of fur-bearing animals. Upon arrival at Nootka, Vancouver went on board the brig *Activa*

²⁰³Lamb, *Vancouver*, vol. 3, 540.

²⁰⁴*Ibid.*, 647.

to meet Spain's regional representative, Don Juan Francisco de Quadra, commandant of the marine establishment of Saint Blas and California. Here Vancouver learned that the Spanish had dispatched three ships to explore and chart the territory around Nootka. Throughout their negotiations, Portuguese, American and British vessels all entered the bay, traded and peacefully departed.

During the weeks spent at Nootka Bay, the expedition set up a shore-based astronomical observatory to ensure accurate charting. The limits of exactitude that the lunar distance system could achieve are explicitly detailed in the observatory records. During the month of September 1792, Vancouver made four sets of observations to establish longitude. His results reveal that the stationary observatory moved by as many as a dozen miles. On September 7 he recorded its longitude as 233 degrees 22 minutes; On the 8th, 233 degrees 44 minutes; On the 12th, 233 degrees 27 minutes; On the 23rd, 233 degrees 12 minutes. The observatory, in all likelihood, was situated at 233 degrees 23 minutes east longitude. If the charting work of George Vancouver, James Cook, and the Spanish explorer, Alejandro Malispina, are here compared, Malispina was closest, being but 3 minutes westward of correct.²⁰⁵

Of the chronometers at Nootka, uncorrected Kendall's was 1 hour 13 minutes ahead of Greenwich time, while Arnold's number 82 was 4 hours 3 minutes too fast. Other devices brought to Nootka by the supply ship *Daedalus* were scrutinized as well including Arnold's number 14 which uncorrected was 42 minutes fast, Arnold's number 176 was 2 hours 16 minutes fast, and finally Earnshaw's pocket watch displayed a time that was 1 hour 7 minutes ahead of Greenwich.²⁰⁶ All of these devices could aid a navigator

²⁰⁵ Andres Galera Gomez, ed., *Alejandro Malaspina: Err Busca del Paso del Pacifico*. (Madrid, 1990), 162.

²⁰⁶ Lamb, *Vancouver*, vol. 3, 684-686.

negotiating the Pacific if they were corrected, but it should be remembered that an error of 1 hour in time is equal to 900 nautical miles at the equator.

Departing to the southward along the coast, Vancouver charted many locations including the Columbia River. He warned those who ventured there of the dangers this river entrance harbored. He declared that while there he saw only "broken water...everywhere from the outer reefs to the shore."²⁰⁷ During this southern passage, Vancouver augmented his exploration with maps copied from the Spanish, just as Quadra sailed away from Nootka with copies of British charts. This reciprocity continued an informal agreement between European powers to share knowledge gained during such expeditions.

Exemplifying the dangers of long voyages, scurvy afflicted a growing number of sailors at this time. The captain wrote, "the very unpleasant state of the ship...undoubtedly...produced this calamity, by the crew being almost continually wet...the sour kroust, though served with the portable soup every day...and in the wheat for breakfast had not averted the evil." Later, he noted that the juice of lemons and oranges "checked the scurvy's progress."²⁰⁸ Exploration was still a life-threatening proposition for those involved, although medical science had progressed such that informed captains knew how to stave-off this scourge. Only 50 years before Vancouver's expedition, George Anson lost half of his crewmen to scurvy.

The expedition spent part of December and January 1793, in Monterey, California. Upon arrival in this scenic bay, Vancouver calculated the logged miles traversed since leaving Portsmouth, England, totaling an astounding 30,703 miles. While in Monterey, the expedition set up an observatory to check the accuracy of their chronometers. Kendall's device now proved to be the most inaccurate, erring by 13 minutes; Arnold's clocks erred

²⁰⁷Lamb, *Vancouver*, vol. 3, 692.

²⁰⁸*Ibid.*, 698.

between 2 minutes and 5 minutes, while Earnshaw's clock was as close to correct as could be determine. Vancouver was disappointed in the accuracy of his heretofore reliable Kendall clock. He surmised that it was the extreme, daily temperature fluctuation that caused this error as his thermometer varied by as many as 40 degrees during any 24 hour period.²⁰⁹

Tests of the devices conducted during January and February, when compared to modern calculations, reveal that Earnshaw's pocket watch maintained time accurately enough to produce more exact results than the lunar distance method. In early March, at Cape Kumukahi, Hawaii, Earnshaw's watch again provided the most accurate result, even more accurate than the lunar distance calculations rendered by the navigators and Vancouver. Kendall's clock now provided hopelessly inaccurate results nearly 2 degrees off, while Arnold's devices varied from 5 to 35 minutes of longitude in error. A second check of the devices in March revealed that K-3, corrected as per its rate at Monterey, provided a longitude for Hilo Bay of 206 degrees 17 minutes, Arnold's devices number 82, 14, and 176, based on Monterey correction rates respectively provided results of, 203 degrees 39 minutes, 204 degrees 43 minutes, and 204 degrees 10 minutes. Earnshaw's watch, based on Monterey corrections, gave a result of 203 degrees 27 minutes. Collectively 68 lunar distance observations were made providing an average of 203 degrees 57 minutes. Furthermore, at this location, one of the navigators determined longitude via Galileo's Jovian moons technique. This method revealed their longitude to be 203 degrees 52 minutes east. Modern instruments fix their location at 204 degrees 4 minutes. The results of their work show that at this point, Arnold's Number 176 maintained the most precise time. Averaging all of Arnold's devices provides a result of 6 minutes error. And while this is closer than the 7 minutes produced by the lunar distance observers, eighteenth-

²⁰⁹Lamb, *Vancouver*, vol. 3, 790.

century navigators were still left with the problem of knowing the correction rate of a chronometer's going. For this era's ocean navigator the lunar distance method remained most practical.

While at Hilo, Kendall's clock gained at a rate of 8 seconds per day, Arnold's number 82 gained 35 seconds, while number 14 gained 15 seconds and number 176 gained 43 seconds. Earnshaw's watch here gained 17 seconds per day. Compared to rates of change noted ten months prior at Flattery Bay, Kendall's clock now daily gained 3 seconds less, and Arnold's number 82 daily gained 8 seconds more than in Flattery Bay.²¹⁰

Variations in metal tension likely account for these fluctuations.

During March 1793 the pilots correctly charted Maui, their lunar distance longitudes being highly accurate. Following this endeavor, they spent April traveling back to North America, during which passage, Vancouver only noted longitude derived with chronometer, exemplifying his faith in the predictability of his geared devices. During this crossing, the devices varied on average 40 minutes when compared one to the other, slightly more than would be expected from longitude derived by lunar distance.

Vancouver's enthusiasm for his chronometers, however, was premature. On the trip back to America, Earnshaw's watch stopped while an officer was winding it.²¹¹ Vancouver noted that prior to this occurrence, Earnshaw's device had proved to be his most reliable.

In May 1793 the expedition arrived at Friendly Cove, in Queen Charlotte Sound, located at 126 degrees 27 minutes north latitude and 233 degrees 33 minutes east longitude. Upon arrival, the chronometers produced a wide array of results. Kendall's device showed the longitude to be 231 degrees 42 minutes, Arnold's number 14 gave it as 231 degrees 52 minutes, while his number 176 showed 234 degrees 10 minutes. None of these results is particularly accurate. Since departing the Hawaiian Islands, Kendall's

²¹⁰Lamb, *Vancouver*, vol. 3, 849.

²¹¹*Ibid.*, 901.

chronometer gained, on average, 17 second per day. Arnold's number 14 gained 20 seconds, and his number 176 gained 41 seconds per day.

When checked against lunar distances, Arnold's devices differed by 2 seconds or less from the rate of change predicted while the expedition was in Hilo. Kendall's device on the contrary compounded its error daily by 12 seconds, or more than 1 minute per week.²¹² To place this in perspective, it should be remembered that at the equator, 1 minute of longitude equals 4 nautical miles, not an insurmountable error. After several weeks at sea, such lack of precision could easily cause a pilot to miss an intended landfall.

The expedition now busied itself plotting the headlands and rivers adjoining Queen Charlotte Sound. The navigators' work here was quite accurate, typically placing locations within a couple of minutes latitude and longitude of their actual locations. As Vancouver revisited some locales charted during the previous season, he sometimes made slight alterations, but again, these were typically less than 4 minutes. In May, Vancouver set up an observatory in Restoration Cove on a point today charted at 52 degrees north latitude and at 232 degrees 22 minutes east longitude. Navigators compiled Twenty-eight sets of calculations showing their latitude determination to be perfect, and their longitudes via lunar distance varied only slightly, from 232 degrees 8 minutes to 232 degrees 12 minutes. Chronometer longitude varied from Kendall's result of 230 degrees 11 minutes to Arnold's number 82 on board the *Chatham* which gave a longitude of 234 degrees 5 minutes. Collectively, the chronometers produced an average longitude of 231 degrees 57 minutes, or a result 25 minutes westward of correct. Lunar distance calculations produced an average 12 minutes westward of actuality. Here, chronometers produced an error twice that of the lunar distance system.

²¹²Lamb, *Vancouver*, vol. 3, 918.

Inconsistency remained the most significant impediment to chronometers' proliferation. During the month of June, Kendall's clock gained on average 23 seconds per day, up from 17 seconds in Hawaii, Arnold's number 14 gained 20 seconds per day, up from its 15 second rate in Hawaii. Only Arnold's number 176 remained accurate enough to rely upon as it gained a consistent 42 seconds per day, only 1 second less than in Hawaii. Aboard *Chatham*, Arnold's number 82 gained 29 seconds per day, down from its 35 second rate at Hilo.²¹³

While in Queen Charlotte Sound, the expedition had much association with Indians who provided the British with many animal skins in trade for iron and lesser trinkets. The Indians likewise supplemented the sailors food supply with fresh muscles. During June and July, the expedition carefully charted the coast as it ventured northward to latitude 54 degrees and beyond, where navigators mapped locations including Prince of Wales Island. While in this locale, the expedition encountered three British sloops, their crews engaged in fur trading. The commander of the vessels warmly greeted Vancouver, telling him at length about the coastline along which they worked. From this information, Vancouver surmised that the area's rivers were too shallow for his ships to enter. Furthermore, from these conversations, Vancouver dismissed any possibility that these rivers led very far into the continent.²¹⁴ Trading with the Native Americans diminished as the vessels progressed northward, owing to the hostile reception the Indians frequently provided them. Armed with sixteen-foot, iron tipped lances, the inhabitants of this cold land were formidable, and Vancouver wisely remained wary of them. During the months of August and September the expedition cautiously charted locations as far northward as 56 degrees 47 minutes latitude.

²¹³Lamb, *Vancouver*, vol. 3, 939.

²¹⁴*Ibid.*, 982-987.

From an observatory, whose site is today fixed at 54 degrees 51 minutes latitude and 230 degrees 9 minutes east longitude, five men trained in lunar distance calculations took a series of sights from mid-July to mid-August. Their work collectively set the observatory's longitude at 230 degrees 16 minutes. The chronometers, corrected according to their predicted rate established at Restoration Bay the month prior, provided a wide array of results. Kendall's chronometer produced a longitude of 230 degrees 53 minutes, Arnold's number 14 showed 230 degrees 9 minutes, Arnold's number 176 showed 230 degrees 27 minutes, and number 82 gave a longitude of 230 degrees 10 minutes. It is noteworthy that two of Arnold's devices provided nearly perfect results. Collectively, however, the chronometers established a longitude average of 230 degrees 25 minutes, and as in June, it was less accurate than what lunar observation's produced.²¹⁵ Arnold's 176 remained the most constant, gaining at a rate of 42 seconds per day since the previous March in Hilo, Hawaii.

The expedition turned southward in September, attempting to escape the approaching winter. Upon returning to Nootka, this time Vancouver steered the vessels to the west side of Queen Charlotte Sound where he charted areas heretofore not well defined on his maps. As frigid winds encircled them, *Chatham* and *Discovery* transported their crew's rapidly southward. By late October, they were in balmy Monterey. Unlike their last visit, the reception Spain's emissaries offered the British sailors was as cool as winter in Nootka. Monterey officials informed Vancouver that his men would be allowed to gather water and wood during daylight hours, but that they must remain on board ship at night.

Regardless of their less than warm reception, Vancouver continued charting the region, where he again fixed locations eastward of correct. When the expedition reached San Diego, navigators erected an observatory, fixing its position at 243 degrees 6 minutes

²¹⁵Lamb, *Vancouver*, vol. 3, 1027.

east longitude. The modern position is accepted as being 242 degrees 45 minutes east. Kendall's clock showed a longitude of 243 degrees 22 minutes, while Arnold's number 14 showed 243 degrees 7 minutes, and his number 176 gave a position of 244 degrees 5 minutes east longitude. The change in the clocks' rate of speed is difficult to explain, as temperatures should have remained relatively constant. Kendall's device now gained 20 seconds per day, Arnold's number 14 gained 21 seconds, and his number 176 gained 36 seconds per day.²¹⁶

In December 1793, the expedition sailed southward along California. Vancouver here remarked in his journal that the Spanish charts they used contained many significant errors. Most locations were 40 and more minutes of latitude wrong. He wrote, "Senior Quadra warned me against the incorrectness of the manuscript chart, as he did not know on what authority the coast southward of Monterrey had been laid down."²¹⁷ Quadra further asserted that this was the best chart of the region Spain possessed. After centuries of travel along this coast, it at first seems inexcusable for Spanish sailors to have had no better charts in their possession, but closer scrutiny reveals a possible explanation for Spain's inaccurate charts. Vancouver notes that the Spanish maintained, "a profound secrecy...with regard to their territories and settlements in this [western] hemisphere."²¹⁸ An examination of Spanish claims in the Pacific and their desire, dating back to the sixteenth century, to maintain the ocean's inaccessibility explains the secrecy Vancouver encountered. Moreover, Spanish coastal pilots would not need detailed charts of the region, only foreign travelers would need such charts, accordingly, Spain had no real interest in producing accurate charts of their territory. Only in the far north around Nootka,

²¹⁶Lamb, *Vancouver*, vol. 3, 1112.

²¹⁷*Ibid.*, 1120.

²¹⁸*Ibid.*, 1122.

as its possession became contested, did the Spanish investigate and carefully chart their claims.

The crew next returned to Hawaii, where they would spend their third winter away from Britain, reaching the islands in late January 1794. At the time of their landfall, all of the chronometers erred, but not nearly as much as dead-reckoning. The pilot's reckoning placed them 3 degrees 40 minutes eastward of Hawaii. Kendall's K-3 situated them 52 minutes too far eastward, Arnold's number 14 gave a reading of 27 minutes longitude eastward, and his number 176 placed them 21 minutes longitude east of Hawaii. The error of the chronometers was sufficient to miss a landfall if an expedition did not approach their destination along a known parallel. During this visit, the Island's chief, Tamaahmaah, submitted his dominion to the protection and sovereignty of Great Britain. Vancouver quickly accepted his generous offer, noting that the island would be of extreme importance should Britain extend its commerce network more fully into the Pacific.²¹⁹

The *Discovery* and *Chatham* next returned to North America where Vancouver charted the icy North Pacific coast around latitude 60 degrees. During May, the expedition produced some of its least accurate charting, with longitudes being regularly 30 minutes or more eastward. During this month, at Cape Douglass in Cook's Bay, the longitude readings produced by the chronometers was again considered. The location is today fixed at longitude 210 degrees 10 minutes west. According to Kendall's chronometer its longitude was 208 degrees 9 minutes, while Arnold's devices gave results of 209 degrees 31 minutes for number 14, and 209 degrees 50 minutes for number 176. Their lunar distance observations produced an average result of 210 degrees 53 minutes. Again, Arnold's number 176 produced the most accurate result. For the remainder of June, the men busied themselves charting Prince William Sound.²²⁰

²¹⁹Lamb, *Vancouver*, vol. 3, 1162.

²²⁰*Ibid.*, 1170-71.

The sailors spent July making their way southward along the coast. During this month, a check of the chronometers established that they all still gained time. Kendall's gained at the rate of 25 second per day, Arnold's number 14 gained 23 seconds per day and his number 176 gained 51 seconds per day. Both Arnold's number 14 and Kendall's K-3 gained at a rate close to that calculated at Monterey some eight months prior, while Arnold's number 176 gained 41 seconds per day as it had at Monterey. Another check of the chronometers in August revealed the same results.²²¹

In October 1794, the ships hastened southward for the final time. While in Nootka they traded with the Spanish, acquiring rope and other supplies for their return to England. A check of the chronometers on 6 October revealed that they all erred drastically. Arnold's number 14 and Kendall's clock derived longitude each erred by more than 1 degree, while Arnold's number 176, erred by 45 minutes of longitude.²²² Their rates of change were reestablished and the exhibited time corrected. Excepting Arnold's number 176, at Monterey in November, the other two chronometers' rate of change remained predictable as they provided nearly perfect longitudes. By January, as the expedition neared the equator, the rate of change in the chronometers had returned to their standards of the previous year in Hawaii, with Kendall's K-3 daily gaining 21 seconds, Arnold's number 14 gaining 20 seconds, and his number 176 gaining 45 seconds daily.

The expedition continued along the Central and South American coasts, passing by Juan Fernandez Island, where Vancouver noted that both Kendall's clock and Arnold's number 14, maintained regular time and their results, even by modern standards, were accurate. Vancouver's dead-reckoning here, as did Anson's in 1741, erred a full 6 degrees of longitude. The ships reached Valparaiso, Chile in late March 1795, with their crews much in need of a landfall, many of them being sick with scurvy. Here Vancouver set his

²²¹Lamb, *Vancouver*, vol. 3, 1229.

²²²Lamb, *Vancouver*, vol. 4, 1409.

crews about preparing the ships for a long voyage around the Horn and back to England.

The chronometers were here analyzed for the last time during the voyage. All were found to be gaining time at an increasing rate. Kendall's clock now gained 29 seconds per day, while Arnold's 14 and 176 daily gained 25 and 58 seconds, respectively. In Chile, all of the chronometers' longitudes were at least 40 minutes in error, with Arnold's number 176 being the worst at nearly 2 degrees off.²²³ Following an uneventful voyage northward after rounding the Horn, Vancouver and his ships arrived in England on 20 October 1795.

George Vancouver's expedition to the Pacific was the most ambitious attempted by Britain during the eighteenth century. He explored thousands of miles of ocean and coastlines, all the while losing only six of his crewmen, four of these to accidental death, and not one to scurvy. The charts they produced crystallized the prior vagueness of the Pacific Northwest, and while James Cook had explored some of the same regions, it was Vancouver and his men who perfected the maps. In fact, charts produced from the data Vancouver obtained show a coastline contour not much different from what appears on modern maps, except his eastward placement of the shoreline. Unfortunately, after he returned, his monumental efforts were not adequately appreciated until many years after his death in 1798.

The results returned by both la Perouse and Vancouver make clear that utilizing a chronometer alone to determine longitude was not reliable. While the devices did provide longitude more accurately than that derived via dead-reckoning, seaclocks could at best only provide the navigator an approximate location. For some captains this was probably sufficient, but for a navigator attempting to chart the Pacific, chronometers could not be relied on without another means by which to determine east-west location. In the

²²³Lamb, *Vancouver*, vol. 4, 1522.

eighteenth century, this second method was the lunar distance system of determining longitude.

Conclusion

James Cook, George Vancouver, and Francois de la Perouse greatly expanded our knowledge of the Pacific as they capitalized on the era's revolutionary advances in navigation. The information they returned corresponded directly to advancements in cartography. Furthermore, the published accounts of their expeditions became best-sellers, affording wide distribution of the knowledge they returned. By the close of the eighteenth century, accurate mid-ocean navigation and improved charts enabled sailors to travel with certainty, opening the commercial exploitation of the Pacific's resources.

When the explorers' work discussed in this thesis are compared one-to-the-other, the charts that Vancouver produced are most accurate, although chronic problems plagued them, most notably their eastward placement of the American Northwest coastline. Vancouver brilliantly employed both of the late eighteenth century's scientific means of establishing longitude. At times the chronometer method proved to be the most precise, but more typically lunar distance calculations were more accurate (see Appendix A). While it is obvious neither system produced correct results consistently, on average lunar distance erred by 9 minutes longitude, while chronometer longitude average 20 minutes of error, more than twice as much. When examined as a whole, the lunar distance determinations by la Perouse, Bougainville and Cook provide results comparable to Vancouver's; by contrast, la Perouse attained slightly better results with chronometers than did Vancouver. La Perouse did this equipped with Bertoud's chronometer number 19. A predictable rate of change was the key to an accurate chronometer, and of all the chronometers examined in this thesis, Berthoud's number 19 proved to be the most consistent as it afforded la Perouse the ability to most accurately determine longitude with a clock. In spite of the success realized with Berthoud's device, the common application of chronometers by a navigator would not be practical for many more years.

Dead-reckoned results graphically show why Pacific charts produced before the 1760s were abysmally inaccurate. Such results are exemplified by many explorers, including Philip Carteret who returned results that averaged 2 degrees of longitude error. In comparison, Carteret's work was better than that compiled by many earlier explorers primarily for one reason, where he sailed. The Pacific's waters are stirred by many currents, and it was these currents that most confounded the efforts of a navigator utilizing dead-reckoning. Demonstrating this is Philip Carteret who plotted Pitcairn Island westward of its correct location because in that island's vicinity, the South Equatorial Current mixes with the Peru Current, producing an eastward flow. Carteret's placement of Pitcairn island demonstrates he did not account for this current. Locations he encountered later, including the Tuamotu Archipelago and Santa Cruz are more accurately plotted due to his vessel traversing the north-to-south flowing Pacific Current. This eddy of water affected the vessel's latitude, a fix Carteret easily determined with an octant, his dead-reckoned longitude remaining unaffected in this region of the Pacific.

Information returned in the sixteenth and seventeenth centuries was hopelessly flawed. Mendana's placement of islands was typically 30 degrees of longitude eastward of actuality. Quiros returned results slightly better, but still very much incorrect. The reason Mendana's charting contained such inaccurate longitude was that in the latitude he sailed, closer to the equator than did Carteret, the west flowing South Equatorial Current pushed Quiros's vessel further into the Pacific than the navigator's dead-reckoning accounted for. Specifically, as they added the distance traveled each day, the pilots did not consider the unknown additional miles that the current displaced them (figure 12, page 64).

As previously stated, in 1605 Quiros's charting was more accurate than Mendana, but this was not necessarily a result of Quiros being a more proficient navigator. He amassed more accurate location information because he sailed in a slightly more southerly latitude, where the affects of the South Equatorial Current are less severe. Quiros's ship

was driven more southerly than it was westwardly, and like Carteret, Quiros could correctly monitor his vessel's north-south location, the difference being Quiros utilized a cross-staff rather than an octant to make these determinations.

Nothing had greater impact upon marine navigation than did finding longitude. Of the methods for deriving longitude during the late 1700s, Vancouver most effectively proved the viability and necessity of the lunar distance system. If an eighteenth-century navigator could utilize but one method of finding longitude, it had to be lunar distance. Although it was cumbersome, it was most reliable. The ease with which chronometers gave longitude was deceptive. On short duration voyages they were reliable, but on lengthy ventures a chronometer's trustworthiness was dubious, for as the temperature fluctuated, so did the rate with which they measured the passage of time. If this rate varied tremendously, as Vancouver established it did, then knowing what time it was in Greenwich became impossible without a means to double-check the clocks. For example, K-3 gained a reliable 6 seconds per-day in the Greenwich observatory. Along the coast of North America three years later it gained more than 20 seconds per day. If not properly corrected, this difference of 14 seconds per day equals an hour after eight-and-a-half months. One hour of erred time corresponds to a longitude off by 15 degrees. Lunar distance calculations were the only viable means by which to establish the rate of change a chronometer exhibited. All of the chronometers carried on board the vessels revealed similar results (figures 13-16). The data compiled by Vancouver in the 1790s proves that the age of the sea clock had not yet arrived. Chronometers needed much more research and development before they alone could guide a navigator around the world. Vancouver's expedition could have easily sailed without chronometers, charted the Pacific, and returned to England. The reverse is not true, for with chronometers alone, a navigator would have as well relied upon dead-reckoning.

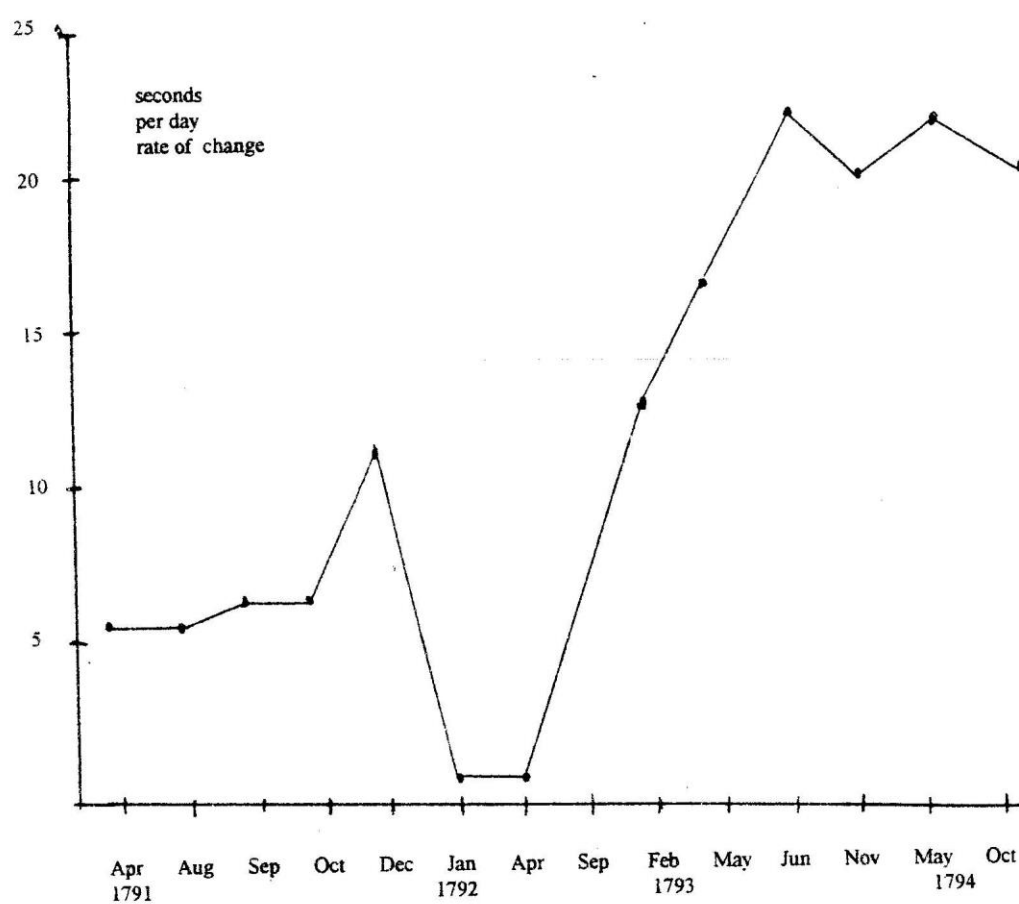


Figure 13
The rate of change demonstrated by Kendall's chronometer K-3.

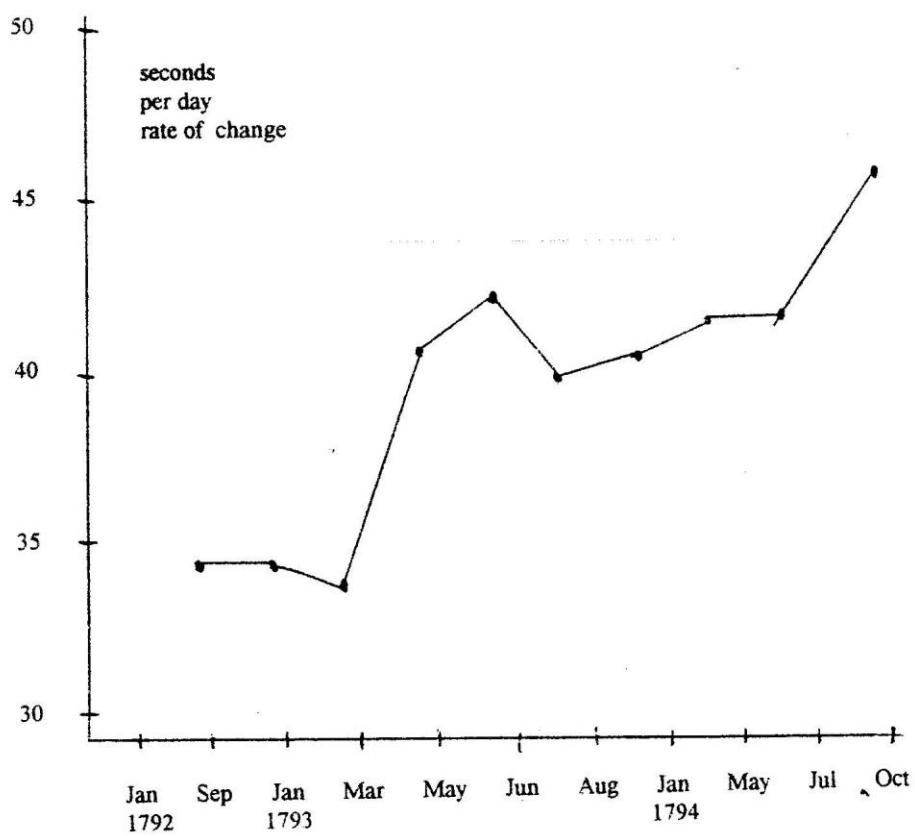


Figure 14
The rate of change demonstrated by Arnold's chronometer A-176.

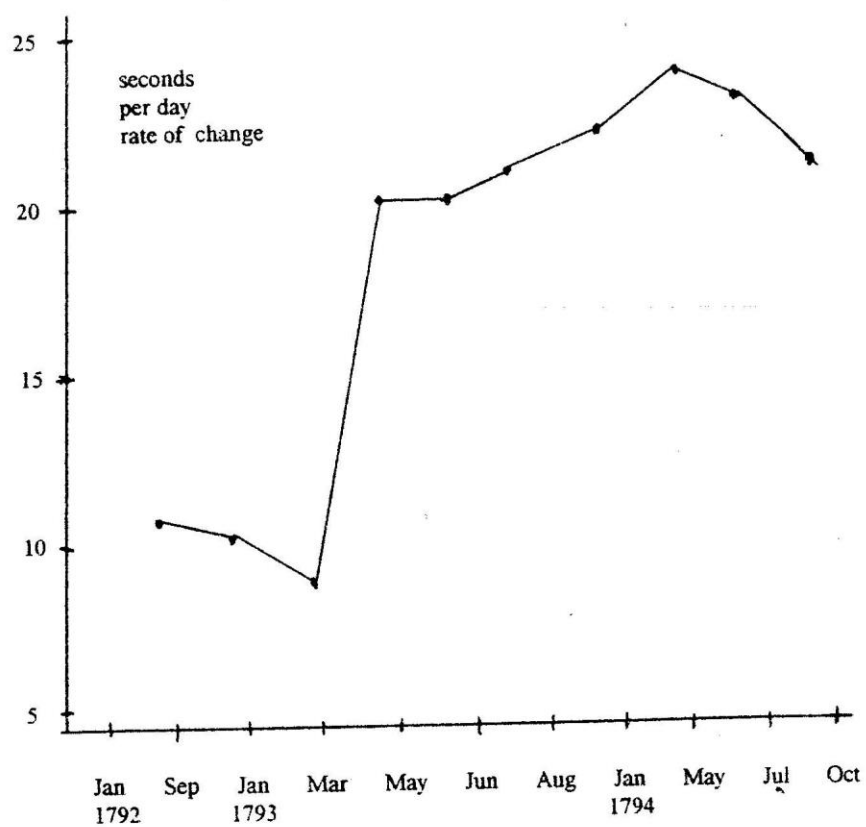


Figure 15
The rate of change demonstrated by Arnold's chronometer A-14.

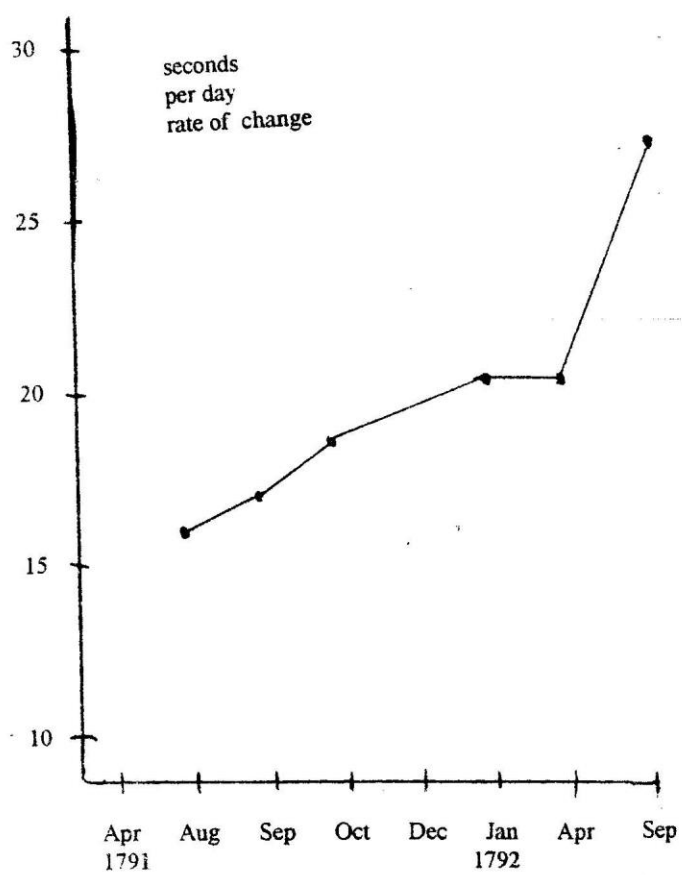


Figure 16
The rate of change demonstrated by Arnold's chronometer A-82.

As this thesis has shown, both systems of longitude derivation could produce either accurate or inaccurate charting, the difference being the skill with which a navigator could utilize lunar distance, and the quality a craftsman built into his chronometer. Used in tandem, by the late eighteenth century, these systems enabled cartographers to produce charts far superior to those constructed prior to the 1760s. As for lunar distance longitude, the most obvious problem hindering its advancement was its complexity. Sailors possessing the skills of James Cook and George Vancouver were rare. More typical were navigators of the skill that de Surville or Carteret possessed, for while they efficiently piloted a vessel with dead-reckoning, they were incapable of mastering the intricacies of lunar measurements. Captains with this level of proficiency were the norm. Consequently, the lunar distance method was never widely practiced outside of the scientific community. To be everywhere accepted, and practiced, longitude determination had to be done more easily. And while chronometers permitted this ease of calculation, late eighteenth-century clocks were incapable of maintaining the accuracy necessary for the chronometer method to be safely relied upon.

The debate over which longitude method to utilize ended by the middle of the nineteenth century when chronometers won. Owing to their improved accuracy, ease of application, and lower cost, sea clocks began to make regular appearances on lengthy voyages. The accuracy with which they measured time allowed them to be solely relied upon for both navigation or exploration and charting, and by 1840, the Royal Navy issued chronometers to all of its vessels sailing outside of Britain's territorial waters.²²⁴ As with all commercial aspects involving ships, it was cost that mattered most. If an addition was not cost effective, a vessel's owner was unlikely to finance it. What made the chronometer so widely used by the mid-1800s was that they went from functioning erratically and

²²⁴Howse, *Greenwich*, 72.

prohibitively expensive in 1775 to being both affordable and accurate by 1825.²²⁵ By this date, a sea clock sold for 60 guineas, when in the 1770s, such a device sold for 500 pounds.²²⁶ Chronometer proliferation enabled even navigators of limited skill to reach distant locations. Ultimately, chronometers did little to improve the accuracy of maps created during the eighteenth century, rather their impact was most notably felt in the next century's commercial realm.

²²⁵Sobel, *Longitude*, 163.

²²⁶Howse, *Greenwich*, 72.

Appendix A

A comparative examination of the accuracy attained determining longitude via the lunar distance and chronometer methods at six locations during the 1791-1795 voyage of George Vancouver.

King George III Sound, Australia;
14 minutes eastward by lunar distance
15 minutes eastward by chronometer

Venus Point, Tahiti;
Perfect results by lunar distance
over 1 degree westward by chronometer

Hilo Bay, Hawaii;
7 minutes eastward by lunar distance
13 minutes eastward by chronometer

At 54 degree 51 minutes along the coast of North America;
7 minutes eastward by lunar distance
16 minutes eastward by chronometer

Cape Douglass, British Columbia;
23 minutes eastward by lunar distance
40 minutes westward by chronometer

Friendly Cove, British Columbia;
nearly perfect by lunar distance
35 minutes eastward by chronometer

Nootka Bay, British Columbia
nearly perfect by lunar distance
more than 1 degree erred by chronometer

Appendix B

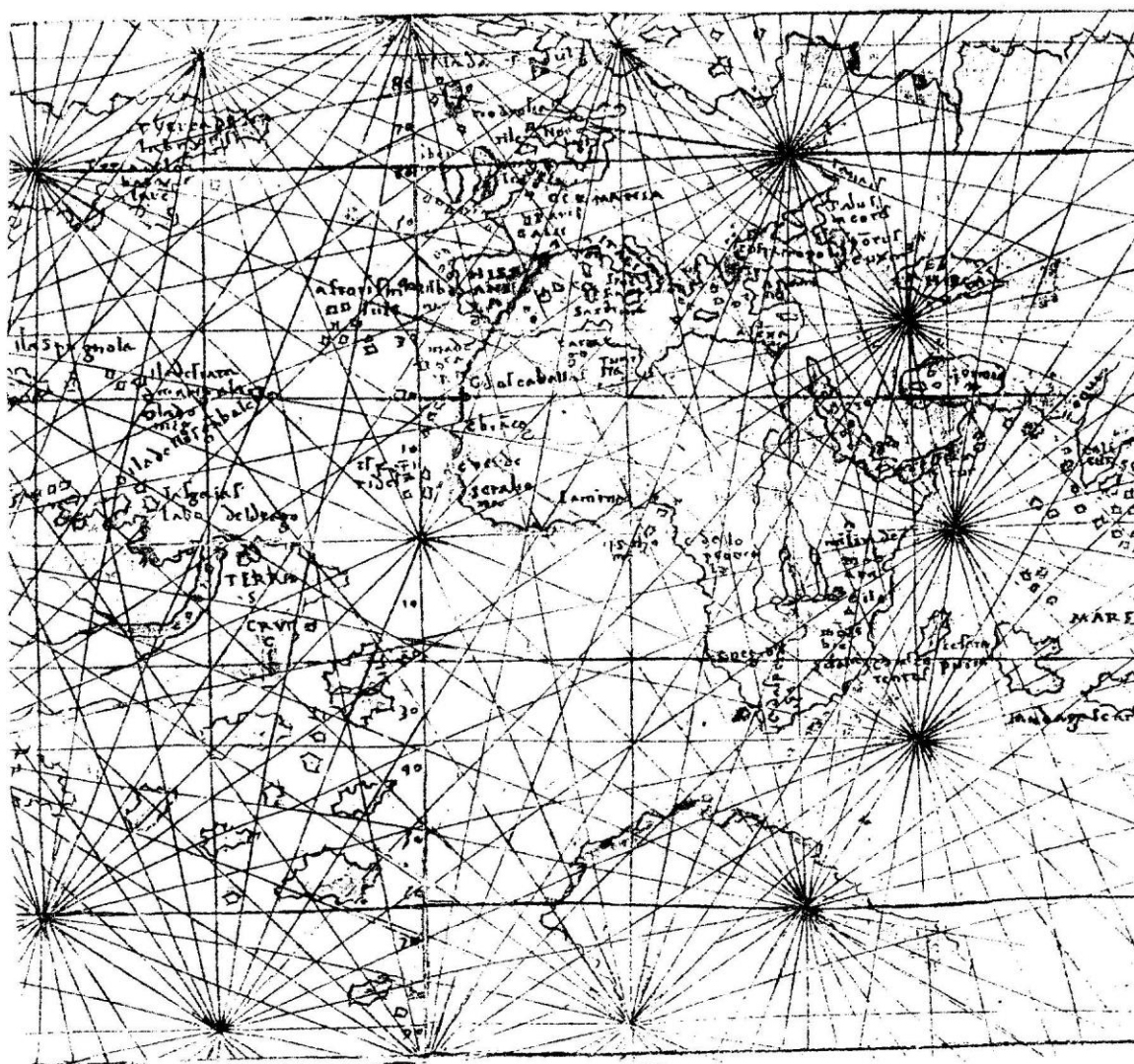


Figure 17
The World, by Francesco Rosselli, 1508.¹

¹Derek Howse, ed., *The Sea Chart* (New York, 1973), 23.

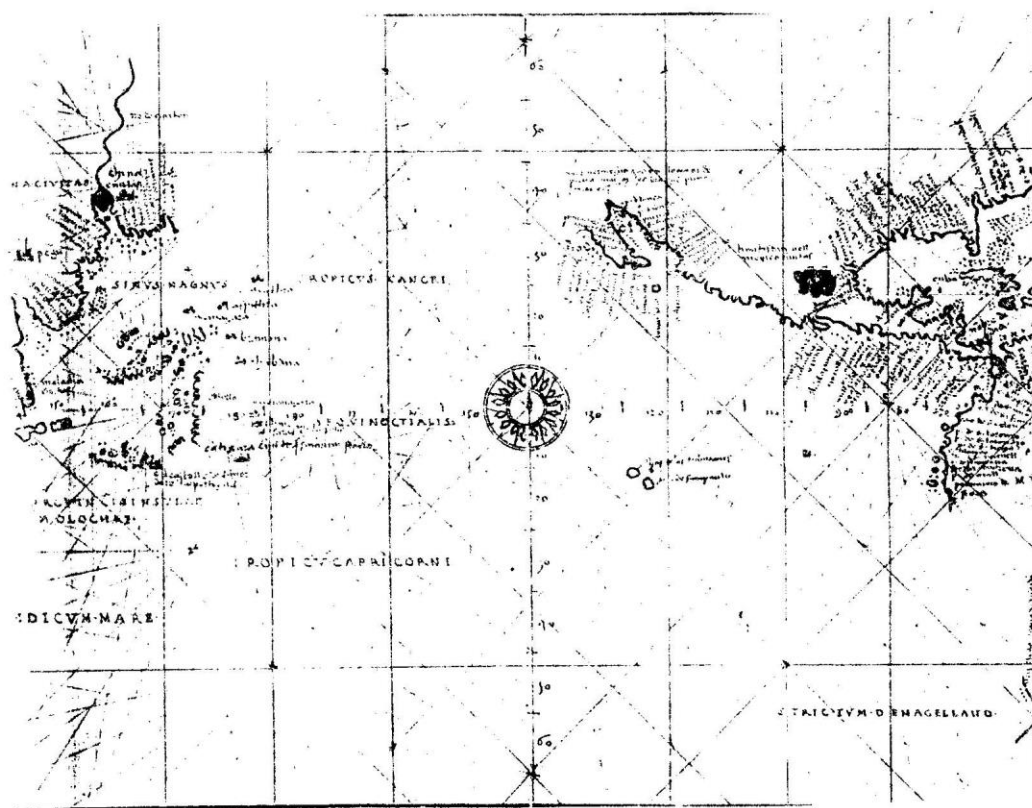


Figure 18
Pacific Ocean, by Battista Agnese, 1555.²²⁷

²²⁷Howse, *Sea Chart*, 33.

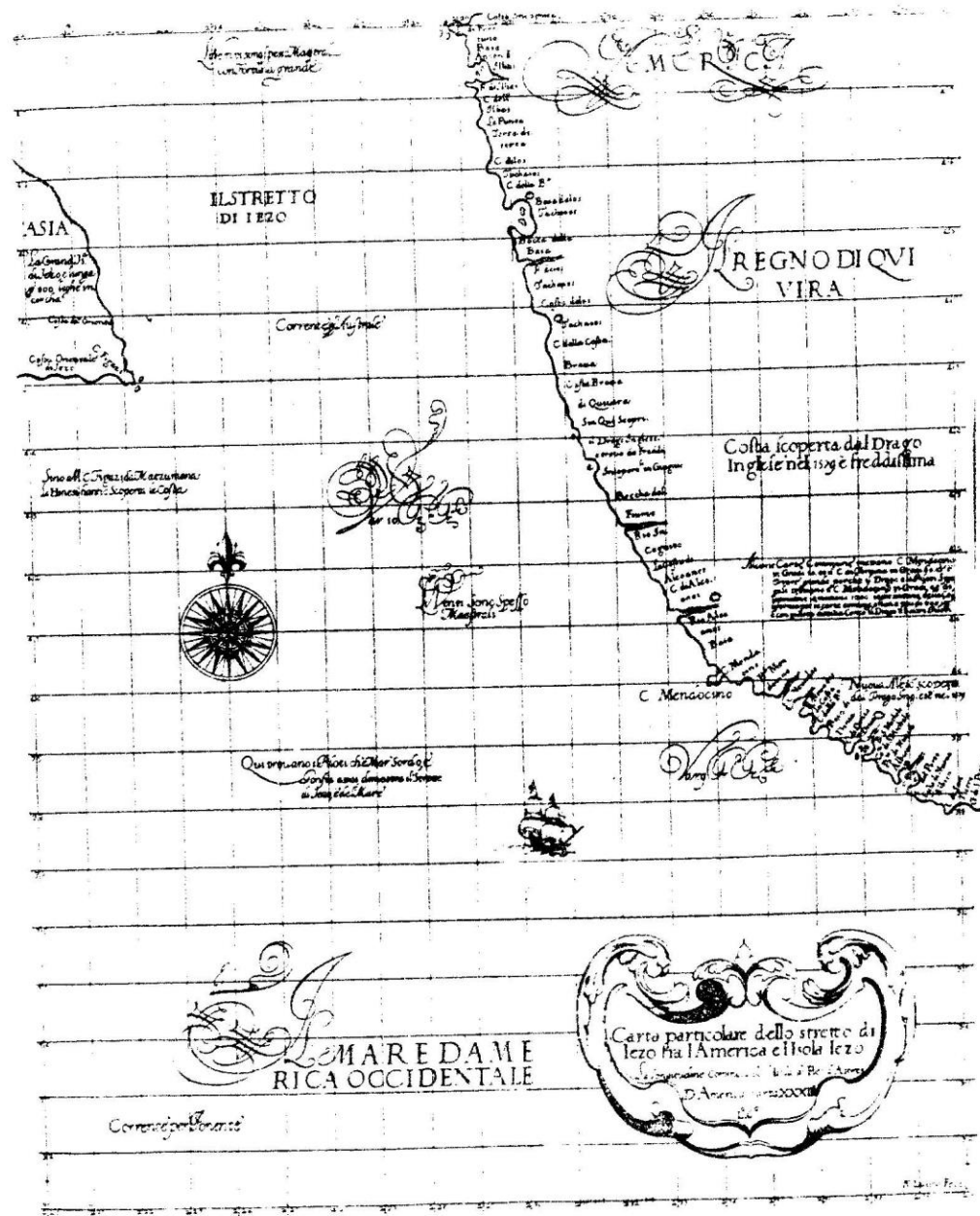


Figure 19
Pacific Coast of North West America, by Sir Robert Dudley, 1647.²²⁸

²²⁸Howse, *Sea Chart*, 55.

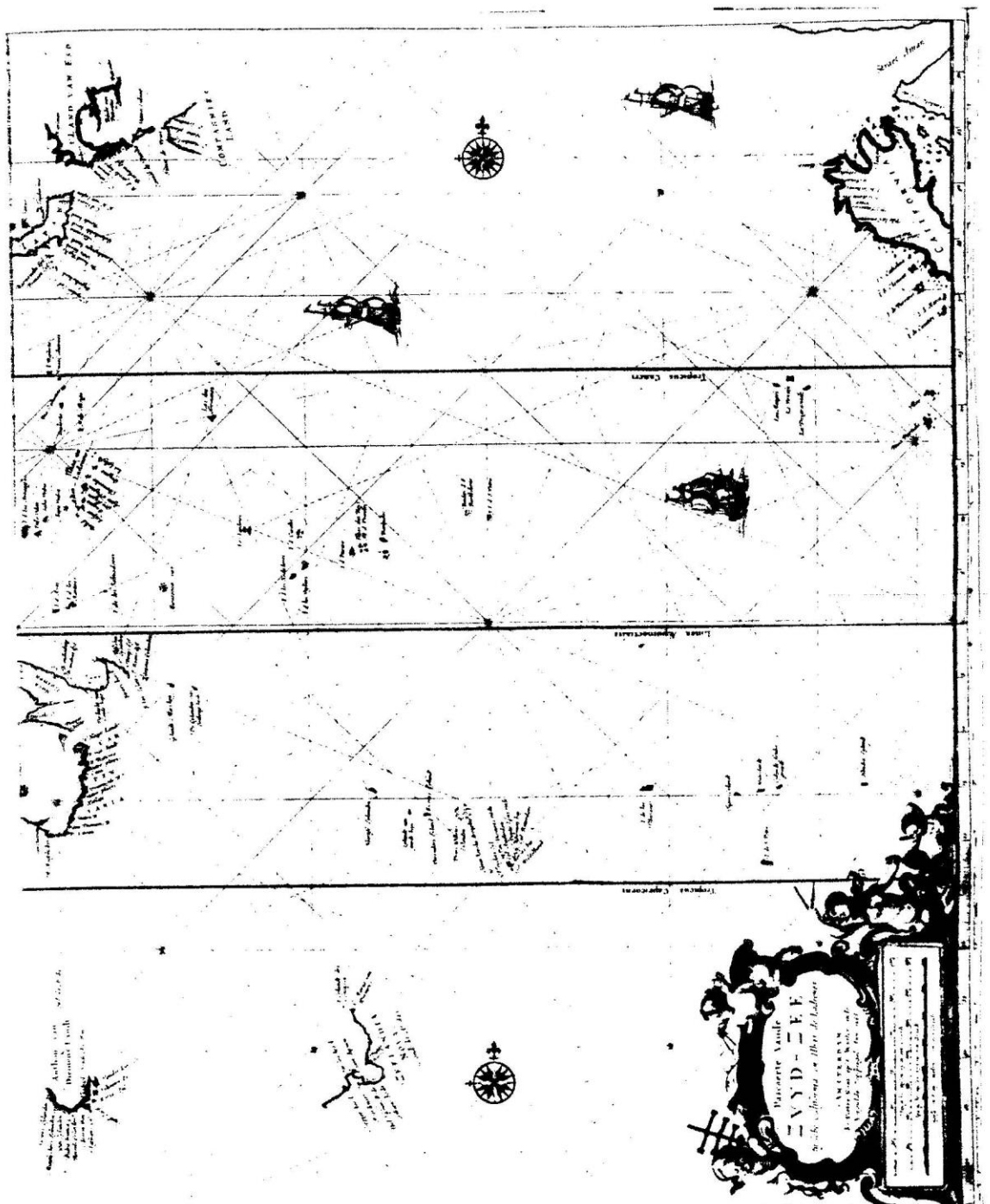


Figure 20
Pacific Ocean, by Pieter Goos, 1666.²²⁹

²²⁹Howse, *Sea Chart*, 63.

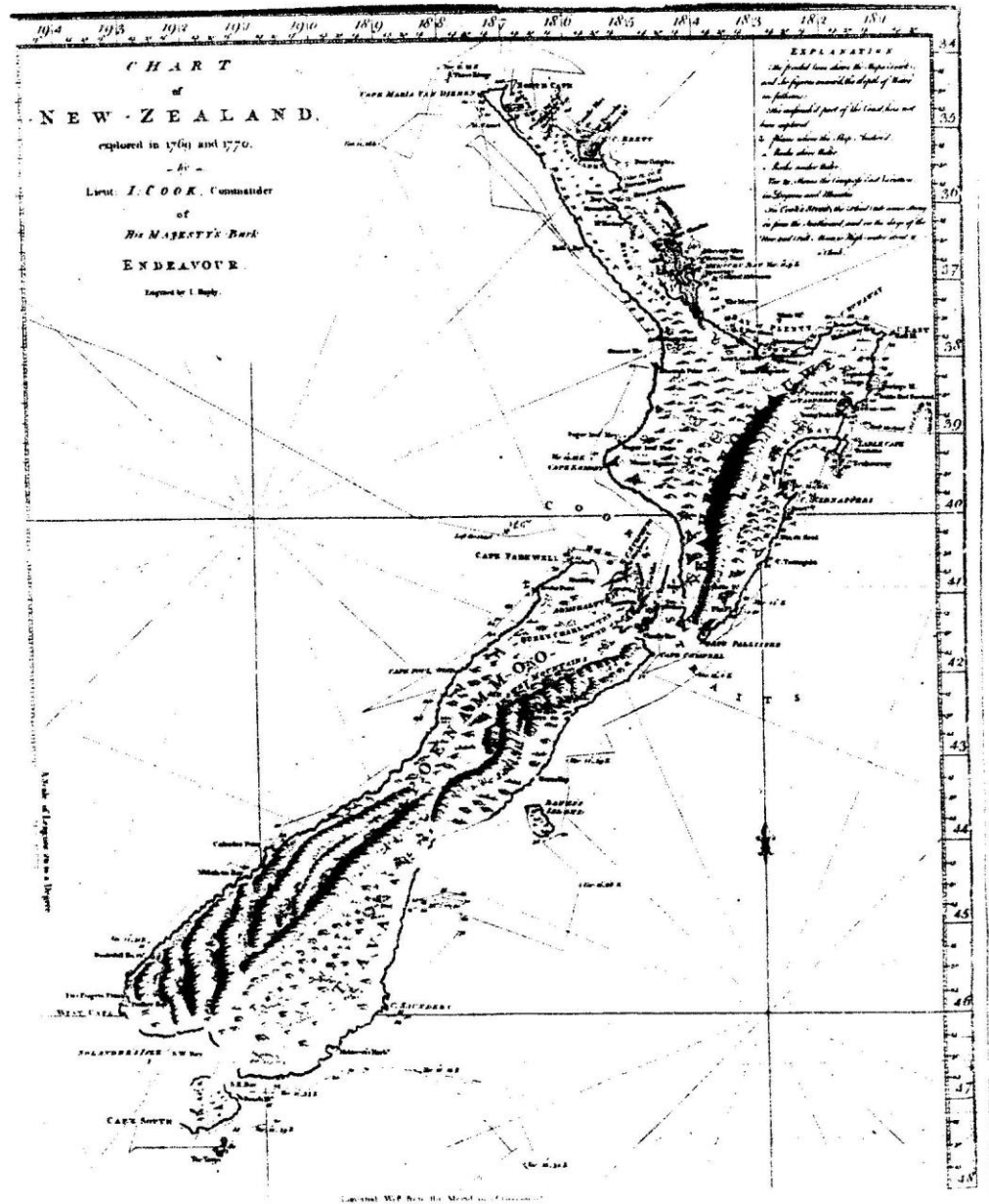


Figure 21
New Zealand, James Cook, 1772.²³⁰

²³⁰Howse, *Sea Chart*, 99.

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