Physical analysis from scientific data in Pero Vaz de Caminha's letter

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Abstract

The scientific data presented in the letter by Pero Vaz de Caminha, the scribe of Pedro Álvares Cabral's fleet, were physically analyzed when they landed in Brazil in 1500. Initially, it was clarified that the temperature difference between the Equator and the poles, along with the Coriolis force, determined the maritime routes at the beginning of the Age of Discovery, between the 14th and 17th centuries. Our data analysis used modern technological tools such as dynamic internet maps, GPS, and satellite bathymetry data. From this scientific analysis, several conclusions contradict current historical truths. The main conclusions are that the true Mount Pascoal is today known as Mount Serra Verde, located near the city of João Câmara, that the landing site was at the mouth of the Punaú River, at Zumbir Beach, and that the fleet landed at Marco beach and not Porto Seguro, Bahia state. All of these locations are on the northern coast of Rio Grande do Norte state.

Keywords: portuguese navigations, finding Brazil, bathymetry.

Análise física a partir de dados científicos na carta de Pero Vaz de Caminha

Resumo

Foram analisados fisicamente dados científicos apresentados na carta de Pero Vaz de Caminha, escrivão da frota de Pedro Álvares Cabral, quando desembarcaram no Brasil em 1500. Inicialmente, esclarecemos que a diferença de temperatura entre o Equador e os polos, juntamente com a força de Coriolis, determinaram as rotas marítimas no início da Era dos Descobrimentos, entre os séculos XIV e XVII. Em nossa análise de dados, foram utilizadas ferramentas tecnológicas modernas, como mapas dinâmicos de internet, GPS e dados de batimetria de satélite. Dessa análise científica, várias conclusões contradizem verdades históricas atuais. As principais conclusões são que o verdadeiro Monte Pascoal é hoje conhecido como Monte Serra Verde, localizado próximo à cidade de João Câmara, que o local de desembarque foi na foz do Rio Punaú, na Praia do Zumbir, e que a frota desembarcou na praia do Marco e não em Porto Seguro, estado da Bahia. Todos esses locais ficam no litoral norte do estado do Rio Grande do Norte.

Palavras-chave: navegações portuguesas, achamento do Brasil, batimetria.

1. Introduction

In their scientific investigations, historians primarily rely on written records along with their investigation methodologies. Nowadays, they no longer adhere to the ideal of absolute truth, rejecting positivism according to the Annales School, founded in 1929. According to Silva Santos (2010), historians now must question, interpret, and even challenge various documents about a particular subject, which are common practices in the natural sciences, especially in Physics since the time of Galileo Galilei.

However, in the early 19th century, Francisco Adolfo Varnhagen, the father of Brazilian historiography, discovered a letter in the Torre do Tombo Museum in Lisbon, Portugal, aimed at defining the exact location of Brazil's discovery. This letter, known as the *Carta do Mestre João* (Mestre João's Letter) (Hue, 2021), indicates that the latitude measurement, determined using an astrolabe, was 17 degrees south of the equator. Varnhagen published these findings in 1843 in the journal of the Instituto Histórico e Geográfico do Brasil (Varnhagen,

1843), corroborating Porto Seguro as the landing site of Cabral's fleet. This location is supported by the sighting of a peak approximately 60 km south of Porto Seguro, named Monte Pascoal by Cabral according to Pero Vaz de Caminha's letter. Since then, the region has been recognized as the Discovery Coast, with museums, churches, and various tourist attractions that celebrate Brazil's birth on April 22, 1500, the date recorded in Caminha's letter. There is a blend of information between Mestre João's and Pero Vaz de Caminha's letters in determining the landing site of the Portuguese on Brazil's coast.

This article will conduct an analysis using numerical data described in Pero Vaz de Caminha's letter, based on the 2000 edition (Magalhães; Salvado, 2000). This analysis will involve discussions about the Coriolis force, and its influence on the wind and ocean currents that propelled the caravels and ships of that era. It will propose a route of arrival based on the distance traveled until land was sighted, and with the aid of a dynamic map, trace this route starting from West Africa, crossing the equator, and reaching the eastern coast of Brazil. Finally, using bathymetric data also contained in Caminha's letter and current information on the continental shelf's relief, trajectories of the fleet's arrival in Brazil will be constructed.

2. Materials and Methods

Understanding the origin of movements, wind circulation and currents in the Atlantic Ocean is crucial to understanding the importance of the Coriolis force during the Age of Great Navigations.

Wind and water movement, and consequently the ocean winds and currents, are created by temperature (pressure) differences between the Equator and the poles (Britannica, 2023), and the circulation of these waters is influenced by the Coriolis force (Coriolis, 1835). This circulation is clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere (Chesman, 2023).

In the early navigations across the "Dark Sea," as the Atlantic Ocean was known in the 14th and 15th centuries, sailors initially traveled close to the coastline. It was only in 1434 that Gil Eanes rounded Cape Bojador (Diffie; Winius, 1977), making the first maritime round-trip in a clockwise direction, departing and returning to Lisbon, which follows an exact clockwise rotation in the North Atlantic Ocean.

In an attempt at reaching India and seeking a route that avoided the Genoese and Venetian merchants who dominated all trade passing through Constantinople, and also bypassing Muslim-controlled North Africa, the Portuguese invested in maritime routes, first conquering the "Dark Sea." They discovered that circulation was reversed beyond the equator, with currents moving counterclockwise. In a mnemonic sense, the shape representing the Atlantic Ocean route resembles the infinity symbol, tilted almost vertically, as shown in Figure 6 of the reference (Chesman, 2023). Bartolomeu Dias was the first European to reach the Cape of Good Hope in early 1488 (Diffie; Winius, 1977), discovering this route known as the "volta do mar" ("turning of the sea").

Upon crossing the equator, sailors needed to perform a maritime maneuver and head southwest, propelled by the trade winds (blowing from east to west below the equator). Along the eastern corner of South America, off the coast of Rio Grande do Norte, these trade winds take two paths—one heading east-west and the other north-south—see the relevant figure on the website (brasilescola.com.br, search for Guyana and Brazilian currents). Vasco da Gama's logbook (Velho, 1488) describes following the "turning of the sea" maneuver and observing signs of land after the Cape Verde Islands, approximately 800 leagues away. This route can also be viewed in a video available at the Maritime Museum of Portugal (Maritime Museum of Portugal, 2021), clearly showing Vasco da Gama's fleet passing near the northeast coast of Brazil on its journey to India in 1498.

The information presented here demonstrates that in addition to the determination of the Avis dynasty—specifically King João II (reigned between 1477 and 1495) and King Manuel I (1495-1521)—and the Catholic imperative to expand Christianity into new lands, scientific knowledge such as the Coriolis force, which drives these wind and ocean current circulations, was also crucial to the success of this epic journey.

2.1. Scientific data in Caminha's letter

Initially, all numerical data were selected and cataloged, accompanied by the page and paragraph where they were found. Data on the trajectory of the discovery route linked to the distance traveled between the Cape Verde Islands and the first signs of land were analyzed, in addition to conducting expeditions into the ocean to photograph the "land ho" sighting from the distance reported in the letter, constructing atlas maps of the mountains sighted, and finally, establishing a landing trajectory using bathymetry. This information was compiled to construct the narrative and determine the arrival and landing locations of Cabral's fleet, as well as

the true location of Monte Pascoal.

2.2. Discovery route

The first numerical distance information was written on page 5, paragraph 4, at the first signs of land, "And so we followed our course across this sea until Tuesday in the Octave of Easter, which was the 21st day of April, when we saw some signs of land, being, according to what the pilots said, about 660 or 670 leagues..." Using this distance in the current International Metric System, where 1.0 league = 6.0 kilometers, that is approximately 4,000 kilometers between the Cape Verde Islands and the signs of land, since paragraph 2 on page 5 states that they passed Cape Verde on March 22nd, "And on Sunday the 22nd of the said month, at 10 o'clock, a little more or less, we sighted the islands of Cape Verde..."

This distance can be plotted on a current dynamic map, for example, at www.mapy.cz (maps & navigation), to trace routes linking these 4,000 kilometers. These routes would follow the wind and ocean currents between these two locations and adhere to the "turning of the sea" maritime maneuver invented by Bartolomeu Dias.

2.3. Sighting "Land Ho" from the Atlantic Ocean

Oceanic expeditions were undertaken with vessels to locate the mountains sighted by Cabral's fleet. The aim was to photograph the terrain at the same sighting distance as described in the letter: "And on this day (Wednesday, April 22), at dusk, we sighted land, that is, first of a very high and round mountain, and other lower hills to the south, and flat land with large woods..." written on page 5, paragraph 5. This terrain was sought based on the description of a very high and round mountain and smaller hills to the south, at a distance of 30 to 40 kilometers, as described on the same page 5, now in paragraph 6, "...at sunset, about 6 leagues of land, we anchored in 19 fathoms..." These two excerpts from the letter lead us to conclude that they sighted the mountain and hills at a distance slightly greater than 36 kilometers.

As such, several maritime expeditions were conducted along the northern coast of Rio Grande do Norte. In the third expedition, three mountains were sighted approximately 30 kilometers offshore near Maxaranguape Beach. Additional trips were necessary to better photograph the mountains and perform bathymetric measurements along this region of the continental shelf.

2.4. Arrival trajectory by bathymetry

Bathymetric data from Caminha's letter begins on page 5, paragraph 6. "They cast the lead and found 25 fathoms, and at sunset, about 6 leagues from land, we anchored in 19 fathoms, with clear anchorage. There we stayed all that night. And on Thursday, we set sail..." continuing on page 6, paragraph 1, "...straight for the land and the smaller ships ahead, going from 17, 16, 15, 14, 13, 12, 10, and 9 fathoms to half a league of land, where we all anchored right at the mouth of a river. And we arrived at this anchorage at around 10 o'clock."

From the above paragraph, a bathymetric table was created with distances to the coast and depths, considering two reliable points, that is, taken directly from the letter. The first is the departure point in the morning, 6 leagues and 19 fathoms, in current International Metric System units (36.0 km; 41.8 m), where 1 league is 6.0 km and 1 fathom 2.2 meters. The second reliable aspect is the arrival point, which is (3.0 km; 19.8 m). Using these two points, the average speed can be calculated assuming that departure was at 6 a.m. Since the arrival time is stated in the letter as 10 o'clock, they traveled 33.0 km in 4 hours, corresponding to an average speed of 8.25 km/h. As written on page 5, one paragraph before (paragraph 5), "they sighted the mountain at dusk," meaning between 3 and 6 PM, traveled at 8.25 km/h for 1 or 2 hours until sunset and cast the lead, having traveled 16.5 km, which added to the 36 km from anchorage totals 52.5 km, at a corresponding depth of 55 meters. Thus, the first point in the bathymetry table is (52.5 km; 55 m). The other points from the early morning departure, from 6 to 10 a.m., can be interpolated using the average speed of 8.25 km/h."

3. Results

Figure 1 depicts a maritime route that adheres to the three criteria mentioned earlier, namely, 4,000 km between the Cape Verde Islands and the first signs of land, following wind and ocean currents, and using the maritime maneuver invented by Bartolomeu Dias. This route is a winding path along the western coast of Africa and, after crossing the equator, follows the "turning of the sea," a path also followed by Vasco da Gama, as described in

Álvaro Velho's diary (Velho, 1488). The route ends near the northern coast of Rio Grande do Norte, where, based on the sighting location of Monte Pascoal discussed in the next section, should align with the current line of sight from the São Roque lighthouse in the municipality of Maxaranguape. This region is where the trade winds diverge, allowing sailors to choose between east-west winds heading towards Ceará state or north-south winds descending towards Paraíba.

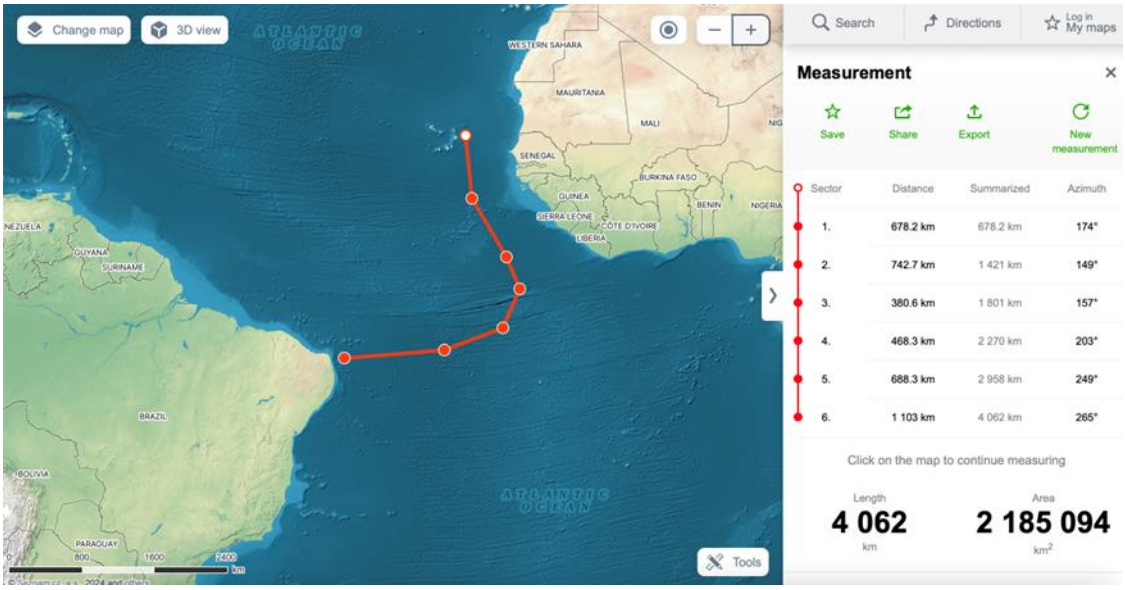

Figure 1. The image shows a photograph of the map.cz software screen, a dynamic map of a sea route between the west coast of Africa and the east coast of Brazil, illustrated by a red dashed line with small circles, following the course of wind and ocean currents, approximately 4,000 km in length. It starts near the Cape Verde islands and ends close to the northern coast of Rio Grande do Norte. This route also follows Bartolomeu Dias' maneuver, which, after crossing the equator, heads southwest to encounter the trade winds. Source: Authors, 2024.

Creating a trajectory to end at the city of Porto Seguro in southern Bahia, extending 4,000 km, the route appears as a straight line starting from the Cape Verde islands. This path is completely at odds with the winds that propelled the ships during the age of exploration, and it does not adhere to the maritime maneuver known as the "turning of the sea."

During maritime expeditions along the northern coast of Rio Grande do Norte, on the third oceanic expedition, three mountains were sighted from 30 kilometers offshore at Maxaranguape Beach. Observing the photograph in Figure 2, it is difficult to find these mountains in the original photograph. However, with an enlarged view of the coastline displayed in the lower part of Figure 2, it is possible. As stated on page 5, paragraph 5 of Caminha's letter, the three mountains are visible in the photographs of Figure 2.

Figure 2. Photograph of the "land ho" moment, observed with the naked eye without the use of any image amplification instrument, from 30 kilometers off the coast at Maxaranguape Beach, with a view from east to west. The photograph placed at the bottom is a vertical enlargement of the "land ho" image to highlight the mountains observed. In this vertical enlargement, a wider mountain is seen on the right, with two lower ranges to the left. According to geographical positioning, the larger mountain on the right in the enlarged photograph is currently known as Serra Verde, near the city of João Câmara, RN, and here it is named Monte Pascoal Potiguar. Source: Authors, 2024.

Through geographic and topographic study using qgis.org software, mountainous regions corresponding to those observed in Figure 2 were identified. Two mountains stand out: Monte Amarelão (273 m) and Monte Serra Verde (318 m), with their respective altitudes in parentheses. The very tall and round mountain is Monte Serra Verde, which will be referred to here as Monte Pascoal Potiguar (MPPotiguar).

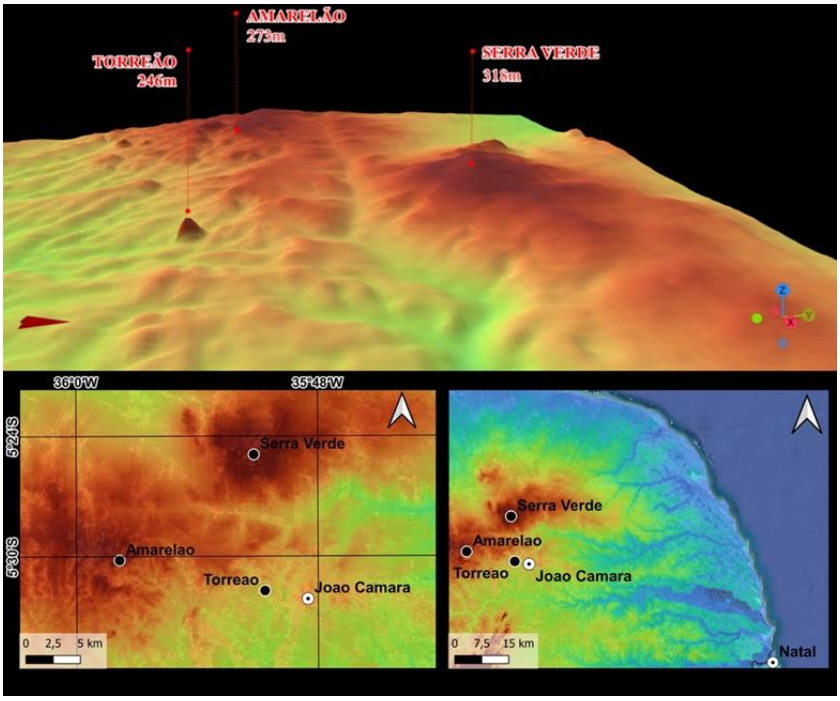

Figure 3. Geographic atlas and its topographies consisting of 3 maps. At the top of the figure is a 3D visualization of the region depicting the locations of 3 mountains: Torreão, Amarelão, and Serra Verde (Monte Pascoal Potiguar). At the bottom left is a flattened map of the mountainous region and their positions in geographic coordinates. At the bottom right is another map outlining the land and ocean, showing the relative positions of the mountains and the cities of João Câmara and Natal. Notably, MPPotiguar matches the description from Caminha's letter, "...very tall and round...". Indeed, MPPotiguar has a mountainous shape, extensive area, and a median altitude of 318 meters, with a base extending several kilometers, similar to its southern ranges. Source: Authors, 2024.

Figure 3 shows an atlas with 3 maps. At the top of Figure 3 is a 3D image of the mountainous terrain of the region, centered around two larger ranges now known as Amarelão and Serra Verde. A flattened map with altitude shades (redder tones indicating higher altitudes) of the mountainous region, displaying geographic positions in latitude and longitude, appears at the bottom left of the figure. A map with altitude classification shades, outlining the mountainous region with the northern coast of Rio Grande do Norte and the Atlantic Ocean, is shown at the bottom right of (Figure 3).

This mountainous region is located near the municipality of João Câmara, 65 km inland from the coast at Maxaranguape Beach, where the "land ho" moment was photographed. Two lighthouses mark Monte Pascoal Potiguar geographically: the Cabo de São Roque and Calcanhar Lighthouses. Sailors, driven by the trade winds, upon sighting one of these lighthouses, decide whether to follow the Guiana Current east-west or the Brazil Current north-south. These currents circulate in opposite directions, one returning to Europe (clockwise in the North Atlantic Ocean currents) and the other flowing towards the south of South America and eventually to southern Africa (counterclockwise in the South Atlantic Ocean currents) (Morrison, 1993).

The Torreão peak does not seem to be present in the photograph, since it is described as a high and narrow peak with a base and height of only a few hundred meters, completely different from the Amarelão and Serra Verde ranges, which extend for several kilometers, with altitudes of 273 and 318 meters, respectively. The range between these two larger mountains, visible in the photograph of Figure 2, appears to be located at what is now called Riacho Seco (5°28'07.85" S and 35°50'30.97" E). An aerial expedition using helicopters or airplanes could precisely map and name these mountainous regions sighted from 30 to 40 km off the northern coast of Rio Grande do Norte. A similar atlas was created around Monte Pascoal in Bahia, which is shown in Figure 4.

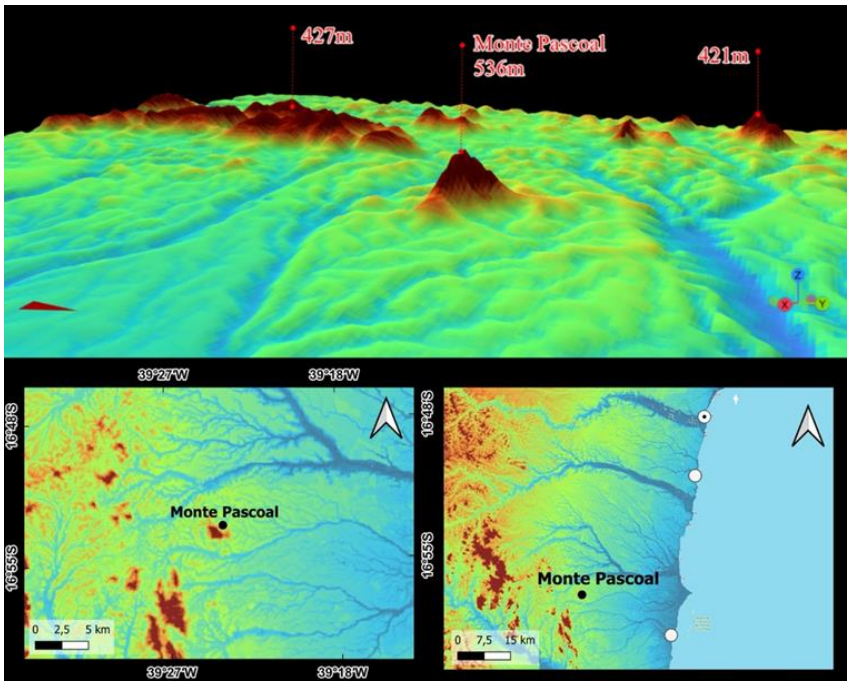

Figure 4. The geographic atlas and its topographies consist of 3 maps around Monte Pascoal in southern Bahia. Source: Authors, 2024.

At the top of the figure is a 3D visualization of the region showing the location of Monte Pascoal. At the bottom left is a flattened map of the mountainous region and its positions in geographic coordinates. At the bottom right of the figure is another map outlining the land and ocean, displaying the relative positions of the mountain, the city of Porto Seguro, and Cay Beach.

Figure 4, on the 3D map, shows that Monte Pascoal is peak-shaped, with altitude and base dimensions roughly equal (about 600 meters). This mountain is isolated on a plain, shaded in blue tones indicating altitudes consistently lower than 100 meters. To the north and south of Monte Pascoal are other mountain ranges, not just to the south as recorded in Caminha's letter. The mountain is approximately 25 km from the coast, suggesting it could have been visible from a much greater distance than the 30 to 40 km recorded during the fleet's anchoring on April 22, 1500, when they first sighted this mountain.

Table 1 presents all points obtained from the analysis used to construct arrival trajectories based on bathymetry data contained in Caminha's letter. The first and second columns list the distance from the coast and respective depths, while the third column provides textual observations on how each point was collected or interpolated.

Frame 1. Bathymetry data (distance to the coastline and coastal depth on the continental shelf) in columns 1 and 2, collected from Caminha's letter and interpolated to determine respective distances to the coast with an estimated average speed of 8.25 km/h. Columns 4 and 5 contain points from two possible arrival trajectories, ending at Rio do Fogo and Zumbir Beaches, both on the northern coast of Rio Grande do Norte. Column 6 lists points from a possible arrival trajectory at Cay Beach on the southern coast of Bahia.

Distance to the coast (kilometers)	**Depth (meters)**	**Observation contained in Caminha's letter**	**Trajectory from the north to Rio do Fogo Beach**	**Trajectory from the south to Zumbir Beach**	**Trajectory from the north to Cay Beach**
52.6	55.0	Sighting point of Monte Pascoal on the afternoon of 22/04/1500, page 5, paragraph 6.	(52.7; 55.0)	(53.0; 55.0)	(52.8; 43.0)
36.0	41.8	Anchorage site on the evening of 22/04/1500. Departure point on the morning of 23/04/1500. Page 5, paragraph 6.	(36.8; 41.0)	(36.5; 41.0)	(38.0; 29.0)
31.9	37.4	Depth described on page 6, paragraph 1.	(32.2; 33.0)	(32.0; 37.0)	(32.0; 27.0)
27.9	35.2		(28.0; 35.0)	(28.0; 32.0)	(28.0; 30.0)
23.6	33.0		(25.5; 31.0)	(25.5; 28.0)	(24.4; 24.0)
19.5	30.8		(22.5; 26.0)	(22.0; 22.0)	(20.0; 30.0)
15.4	28.6		(17.5; 22.0)	(15.4; 16,0)	(17.0; 28.0)
11.5	26.4		(10.0; 20.0)	(12.5; 13.0)	(11.5; 12.0)
7.1	22.0		(8.1; 22.0)	(7.0; 10.0)	(7.7; 14.0)
3.0	19.8	Arrival point at 10 a.m. on 23/04/1500 (4 hours after setting sail), page 6, paragraph 1.	(3.0; 19.0)	(3.0; 10.0)	(3.5; 7.0)

Source: Authors, 2024.

In Frame 1, the points in columns 4, 5, and 6 were generated using georeferencing images via QGIS software (https://qgis.org), which is open-source and provides geographic and geological data on the internet. To generate these points, the initial data from columns 1 and 2 of (Table 1) served as starting points. Distance to the coast was linked to find the corresponding depth pair, initially with a difference of less than 10%, increasing until the closest pair was found. The numbers in red in columns 4, 5, and 6 are outliers (differences greater than 20% from Caminha's letter data) that do not exactly match the written data in the letter, but current depth measurements recorded by qgisbrasil with corresponding distances to the coast. In Figure 5, illustrated on the left, on the trajectory starting from the south, the last 5 points in the table show depth differences from 40 (30.8/22.0) to 90% (19.0/10.0). This significant difference can be attributed to the region being in front of a river mouth that, over more than 500 years, must have experienced sedimentation. The trajectory closest to the arrival points, according to bathymetry data from the letter, begins from the north where the continental shelf is wider, descends southward, and curves, currently arriving near the city of Rio do Fogo.

However, the reference of being 60 km from Marco Beach is lost, now being approximately 10 km less, making the current distance 50 km. This 60 km distance is described on page 7, paragraph 3. "And, being along the coast, about 10 leagues from where we departed, the said small ships found a reef that contained a very good safe harbor, with a very wide entrance." These 10 leagues are exactly 60 km, which today is precisely at Marco Beach, a natural harbor where a Portuguese marker stands. Taking this point as a reference and moving 60 km back along the coast, one reaches the mouth of the Punáu River, not near the city of Rio do Fogo, as recorded in the best trajectory in (Figure 5) starting from the north.

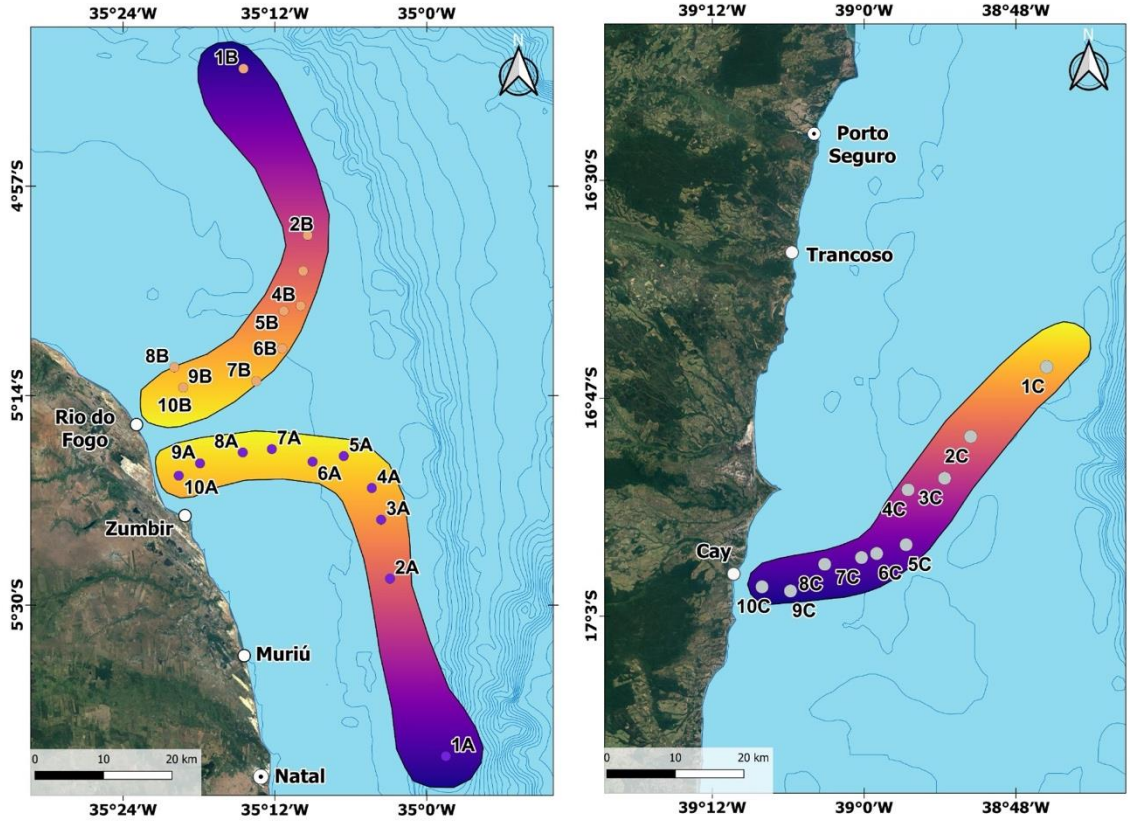

Figure 5. Arrival trajectory on the northern coast of Rio Grande do Norte on the left, and on the southern coast of Bahia on the right. For the northern coast of Rio Grande do Norte, there are two possible arrival trajectories of Cabral's fleet, represented by numbered contours from 1 to 10, starting in blue and ending in yellow. One trajectory starts from the south, beginning at point 1A, and the other from the north, beginning at point 1B. These trajectories were traced based on bathymetry data collected from Caminha's letter and interpolated (assuming the ships had a constant average speed of 8.25 km/h), departing early in the morning (assumed to be 6 a.m.) and reaching the river mouth view by 10 a.m., covering 33 km along this path. On the right of Figure 5, the illustration corresponds to a possible arrival trajectory at Cay Beach, 60 km south of the city of Porto Seguro, starting from point 1C. Source: Authors, 2024.

Much later in Caminha's letter is a passage indicating the marking of the discovery on Marco Beach. On page 26, the second line of paragraph 5, "...we landed with our flag and went ashore above the river, towards the south, where it seemed to us that it would be better to plant the cross to be more visible...," and continues on page 27, paragraph 3, "After planting the cross with Your Majesty's arms and motto, they set up an altar by its side. Friar Henrique said mass there" From this excerpt, it is interpreted that Cabral placed a marker during his voyage to Brazil in 1500, a common practice among Portuguese fleets during exploratory voyages, that is, using a marker made of Lioz limestone with the royal coat of arms and the Cross of Christ (Bueno, 2019).

In Figure 5, the trajectory of points 1A, 2A, ..., 10A begins in front of the city of Natal, since this region corresponds to the first point, 52.7 km from the coast and 55.0 meters deep, pair (52.7; 55.0). The distance cannot be parallel east-west because the continental shelf, which starts at the coast, ends around 40 km offshore with an average slope of 1 meter per kilometer, followed by the oceanic slope where depths increase sharply to 500 or even 1,000 meters. To adhere to the data in columns 1 and 2, the trajectory heads south-north, then curves east-west to align with the 60 km distance from the initial landing point (at the river mouth) to the so-called safe harbor, reaching the mouth of the Punáu River at Zumbir Beach.

In the trajectory arriving at Cay Beach (on the right of Figure 5), which is 60 km south of Porto Seguro, there are several outliers, totaling 7 out of 10 points, as presented in column 6 of (Table 1), marked in red numbers. For the first point in column 6, a depth of 55.0 meters was not found on the continental shelf, only at the beginning of the slope where the maximum depth measured was only 43.0 meters, a difference of 28% (55.0/43.0), making this first point an outlier. Similar to the trajectory arriving at Zumbir Beach, significant differences are also observed as the trajectory approaches the mouth of the Queimado River, with differences exceeding 100%, such

as 120% (26.4/12.0) and 171% (19.0/7.0).

4. Discussion

By collecting the scientific data from Pero Vaz de Caminha's letter, it is evident that using modern scientific tools can lead to new and surprising interpretations. Here, were presented an analysis starting from an understanding of how wind and ocean currents are generated and how they influence the navigation routes of sailing ships.

Using new technological knowledge with the numerical data from Pero Vaz de Caminha's letter, were simulated, via dynamic maps, the route of the discovery of Brazil with the landing point being the northern coast of Rio Grande do Norte (RN).

Expeditions were conducted with vessels to photograph the "land ho" moment approximately 30 km off the northeastern coast of RN, where three mountains near the city of João Câmara were observed. Based on this photographic evidence, a topographical study was conducted to geographically identify these three mountains. Using 3D satellite imagery, it was determined that the northernmost, largest, and widest mountain is likely the true Monte Pascoal, now known as Monte Serra Verde.

With the geographic location of the sighting of Monte Pascoal Potiguar established and considering the information about the marker left by Cabral's fleet, likely at Marco Beach in the municipality of Pedra Grande, it was identified that the first landing beach of this fleet was at the mouth of the Punaú River, at Zumbir Beach.

In the final section of the analysis of the information collected from Caminha's letter, a bathymetric investigation was conducted via satellite images. Three possible arrival trajectories of the ships were drawn, starting from the entrance of the continental shelf in northeastern Brazil to the coast. Of the three trajectories drawn, two on the northern coast of Rio Grande do Norte and one on the southern coast of Bahia, the trajectory that best aligns with the description in the letter ends near the mouth of the Punaú River at Zumbir Beach.

5. Conclusions

All these elements presented here, i.e., numerical data, simulations, dynamics maps, photographs of the "land ho", topographical study, bathymetric investigation, and three trajectories are drawn, all these data from Pero Vaz de Caminha's letter lead to the conclusion that the arrival of Pedro Álvares Cabral's fleet was likely on the northern coast of Rio Grande do Norte.

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7. Authors' Contributions

Cláudio Benedito da Silva Furtado: conceptualization, writing – review and editing, funding acquisition. *Carlos Chesman de Araújo Feitosa*: conceptualization, experimental investigation, writing – original draft, funding acquisition, supervision.

8. Conflicts of Interest

No conflicts of interest.

9. Ethics Approval

Not applicable.

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