Knowledge and power: the role of astronomy in the territorial expansion of Chile, 1883-1890

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Abstract

The article analyzes the role played by the National Astronomical Observatory (Observatorio Astronómico Nacional) in the territorial expansion of Chile at the end of the nineteenth century, through the relationship with three geographical explorations associated with this process. It is proposed that the Observatory played a central role in these geographic explorations, helping to obtain precise geographic coordinates to produce accurate maps of the territories annexed to the north and south of Chile. The results allow us to affirm that the National Astronomical Observatory provided strategic services during territorial expansion, and geography was an important part of its institutional scientific work.

Keywords: astronomy; territorial expansion; history of science; Chile; nineteenth century.

During the second half of the nineteenth century, Chile entered into a process of territorial expansion, characterized by the economic and military occupation and annexation of various territories. The expansion phenomenon was driven by a combination of global and local factors. At the global level, there has been a reduction in transportation costs, an increase in international trade, and a greater demand for raw materials by industrial powers. This reinforced the export scheme of Latin American countries, which tried to expand their borders in search of agricultural and mining products (Bertola, Ocampo, 2013, p.103-104). At the local level, the silver mining crisis and the end of the wheat cycle during the 1870s reoriented economic activity towards the search for and exploitation of mining products such as saltpeter in the north of the country. The strategic importance of this mineral was one of the factors that triggered the War of the Pacific (1879-1883), which resulted in the annexation of Arica, Iquique, and part of Atacama (Ortega, 2005, p.405-428). This process of territorial expansion was also experienced on the southern border. The lands south of the Biobío river, which had been maintained as quasi-autonomous Mapuche territory since independence, were progressively occupied by the Chilean State between 1861 and 1883 (Pinto, 2003).

Simultaneously, there was a cartographic boom in the country, motivated by the state's need to inventory resources, plan and build public works, set administrative and international boundaries in the recently annexed territories etc. In other words, the expansive desire required the survey of detailed charts with topographical and geographic information to more efficiently incorporate the new territories. Knowledge and power were intertwined, promoting a series of regional geographic explorations carried out by engineers, geographers, and naval officers, who specialized in topographic and hydrographic surveys (Rosenblitt, Sanhueza, 2010, p.XXIII). These tasks were imperative to define the latitude and longitude coordinates with reliable methods: a generic description of the territory, its geographical features, or reference points were no longer sufficient, as had happened with previous cartographic expeditions.[1] Then it became preponderant to reference the information through the coordinates and then place it exactly in space. This article deals with the role of the National Astronomical Observatory (Observatorio Astronómico Nacional) of Chile in these tasks related to the determination of coordinates in the cartographic production of three geographical explorations carried out in the 1880s. The Astronomical Observatory was founded in 1852 after the Chilean government bought the instruments and facilities erected on the Santa Lucía hill in 1849 by the astronomical expedition of the American James Gilliss (Sanhueza-Cerda, Valderrama, 2020). After this, the Ministry of Public Instruction assumed the administration of the institution, appointing directors and officials who were in charge of carrying out and managing the scientific work. From the direction of José Ignacio Vergara (1864-1889), there was an important development of tasks associated with meteorology and geography, an orientation that would also be maintained with the arrival of the next director, Alberto Obrecht (1890-1907).[2] For Alberto Obrecht, geography became a very important area of study and he even publicly stated that "geography is, without a doubt, the most important application of astronomy" (Obrecht, 1890, p.11).

From this background, we affirm that the technical capacity to adjust precision instruments, use telegraphic signals, and have trained personnel provided by the National

Astronomical Observatory, was crucial for geographical explorations in the new territories incorporated by the State of Chile. In turn, the sustained relationship between the Observatory and geographical explorations demonstrates the central role of geography within the astronomical institution.

The research uses two types of sources. The first is the written records of the geographical explorations, which allows for locating its strategic importance and the relevance that its cartographic products had. These records allow tracking of the presence of the National Astronomical Observatory, helping to identify when and in what ways this scientific institution collaborated with the expeditions. The second type of source is the institutional documents of the Astronomical Observatory, located in the National Historical Archive of Chile (Archivo Histórico Nacional de Chile), Ministry of Public Instruction Fund (Fondo Ministerio de Instrucción Pública). There are trades, annual reports, information about the staff etc. They provide information on the procedures carried out by the Observatory in its geographical work, allowing a deeper analysis of the relationship sustained with geographical explorations.

The text is divided into two parts. The first part explains the disciplinary and historical relationships of astronomy with geography and cartography, providing some illustrative cases in Europe and Latin America. This allows us to understand how astronomical observatories have participated in closely linked global and regional enterprises for political, economic, and military purposes during the second half of the nineteenth century. The second part studies the three geographical explorations in which the National Astronomical Observatory of Chile participated. They are the Araucanía Exploratory Commission, directed by Álvaro Bianchi Tupper (1883); the exploration directed by Alejandro Bertrand in the Puna de Atacama (1884); and the Exploratory Commission of the Atacama Desert, directed by Francisco San Román (1883-1889).

Astronomical observatories, geographic coordinates, and territorial expansion: a close relationship

The relationship between astronomical observatories and work related to geography and cartography is not an isolated or anecdotal event. This phenomenon is better understood by following the approaches of David Aubin, who shows how, during the nineteenth century, astronomical observatories were spaces where various observation practices met. There, astronomy converged and formed an integral part of disciplines that today we identify as meteorology, physics, and geodesy, among others (Aubin, Bigg, Sibum, 2010).

Aubin's proposal makes more sense if we observe nineteenth-century astronomy, where a close link with cartographic production can be seen thanks to the strong development of astrometry (North, 2005). This part of the discipline is concerned with measuring the position and distance of the stars, as well as studying their movement, which enabled to calculate the parallax of planets or the sun, determine orbits, and prepare star catalogs (or maps). There is, therefore, a double link with terrestrial knowledge. In the first place, to know the position of the stars, we need to determine the exact position of the observer. Consequently, stargazers had to calculate the coordinates of their observation points. In the

second place, determining the position of the stars and knowing their movement allows the construction of ephemerides or tables, which facilitate the calculation of terrestrial coordinates. With these considerations, it is not strange that the astronomical discipline has also been dedicated to terrestrial studies and is in charge of determining the geographical coordinates of latitude and longitude with great accuracy.

In more specific terms, astronomy helped solve some problems in determining geographic longitude [3] by improving cartographic accuracy during the nineteenth century. This is because the exact time is one of the key elements in calculating longitude. It is only possible to accurately set the time through astronomical observations, starting a clock at the precise moment when the sun or another star passes by the local meridian (Galison, 2005, p.110). Then, we need to compare the time of the local meridian with the time of a reference meridian to obtain the longitude. Astronomical observatories, using powerful telescopes to observe the sky and specially insulated and adjusted pendulum clocks to measure time, became the institutions that could deliver the most accurate time of any meridian. In this way, it was common for astronomical observatories to "distribute" the official time to different public institutions, and, in addition, they were the reference meridian for the construction of maps. The advent of the telegraph further improved accuracy in determining longitude. Through electrical pulses traveling down telegraph wires, astronomers were able to send the exact time of their meridians to distant places. Then, it was possible to simultaneously compare the time of two distant places, something impossible before the appearance of the telegraph.

The ability of astronomical observatories to improve the precision in the determination of geographic coordinates made them part of large projects and institutions in charge of cartographic production, such as the Bureau des Longitudes or the US Coast Survey (Schiavon, 2010; Galison, 2005). This converged towards the middle of the nineteenth century with a streamlining of communications as the telegraph spread globally across land and sea. Telegraphic expansion made it possible to determine longitude differences between places as far apart as the Greenwich and Harvard astronomical observatories. Later, the commercial and imperial expansion of the powers increased these episodes in such a way that, between 1873 and 1884, the United States and France began a joint operation in which they laid submarine cables to form an enormous polygon with its vertices in Paris, Greenwich, Washington, Panama, Valparaíso, Buenos Aires, Rio de Janeiro, and Lisbon. Sailors and astronomers were dedicated to calculating the longitude of these and other points on earth. Thus, in the last two decades of the nineteenth century, the world could be drawn on a map more and more accurately (Galison, 2005, p.151-159).

Latin America also became part of these dynamics, and the observatories were part of the territorial expansion, cartographic production, and geographic studies. In the Brazilian case, the role played by the astronomical expeditions to Brazil during the nineteenth century has been addressed to the extent that they helped develop a new method to determine lengths through photography (Barboza, 2010, p.278). At the same time, the training role of the Royal Military Academy of Rio de Janeiro has been highlighted, linking the teaching of astronomy with geodetic applications through the practical use of various instruments (Carolino, 2012, p.245). The work of Bruno Capilé and Moema de Rezende Vergara is very

special for this article. They have explored the work of the Brazilian Border demarcation commissions during the territorial disputes with Argentina. Their work emphasized that, from the end of the Empire to the First Republic, astronomy became an active agent in the territorial construction of the Brazilian State thanks to the fact that it greatly facilitated the demarcation of international limits (Capilé, Rezende Vergara, 2013).

For the Argentine case, Marina Rieznik (2011, p.128) has shown how the La Plata Observatory (founded in 1882) had among its objectives to "link astronomical study to the needs of cartographic surveys of the province". The newly created City of La Plata not only needed institutions that would legitimize it as an important administrative and cultural space but also data that would allow clear and precise geographical delimitations to be established. For this reason, in 1883 the government passed a law that urged the La Plata Observatory to determine the geographical location (coordinates) of fifty different points to collaborate in the construction of a geographical map.

The case of the National Astronomical Observatory of Bogotá is also illustrative. Camilo Quintero (2005) analyzes how the arrival of engineer Julio Garavito as director in 1892 reoriented the scientific production of the institution towards geographic studies, contributing to the economic modernization of the country. From then on, a series of articles were published in the Annals of Engineering indicating the fastest methods for obtaining geographic coordinates. Garavito managed to simplify the calculation of latitude which, in combination with the publication of astronomical ephemerides, helped to draw maps and plans for the construction of public works. The situation would crystallize with the great influence that the Bogotá Observatory had on the guidelines of the Office of Longitudes, the body in charge of cartographic production in Colombian border delimitations at the beginning of the twentieth century (Quintero, 2005).

Occupation and mapping of the Araucanía: the Exploratory Commission of the Araucanía, 1883

In the south of Chile, between 1881 and 1882, the military incursions in Araucanía reached their final phase. Occupying this portion of territory located between the Biobío and the Toltén rivers had become a matter of "national dignity" for the oligarchy, in pursuit of giving administrative continuity to the country (Herrera, 2002). It was also a strategic issue, given that the land was suitable for growing wheat and close to the flourishing coal mines in the gulf of Arauco (Ortega, 2005, p.202-231). On the other hand, the colonization policies, which included the expropriation and distribution of land – as well as the construction of military forts, cities, and public works (roads, railways, telegraphs) – required security that had to be provided by the State of Chile (Pinto 2003, p.75-84).

Around 1883, the need for cartography that would account for the little-known characteristics of the incorporated territory became evident. An exact map of the area would allow the correct planning and execution of public works, would facilitate the distribution of land, and would establish the exact coordinates of the forts and cities. However, the cartography built by Amado Pissis – the most accurate general map available – was especially deficient between the southern part of Arauco, Valdivia, Chiloé, and Magallanes (González

Leiva, 2007, p.31; Greve, 1946, p.42-47). To make up for these cartographic-strategic deficiencies, the Ministry of War organized in November 1882 the Araucanía Exploratory Commission under the charge of Navy Officer Álvaro Bianchi Tupper.[4]

Together with military and state interests, the Hydrographic Office (Oficina Hidrográfica) established that the main objective of the Commission was "to form, as closely as possible, the geographic map of the Araucanian zone that will be occupied by our Army, establishing in them the routes traveled, the topographic features of the land, the course of the main rivers and, in general, all kinds of details that contribute to a better understanding of this region" (Vidal Gormaz, 29 dic. 1882, p.2306).

To prepare the map, one of the main tasks was to "astronomically fix the geographical coordinates of the largest possible number of points, preferring towns, forts, main peaks etc." (Vidal Gormaz, 29 dic. 1882, p.2306). This implied establishing a close relationship with the National Astronomical Observatory for the determination of longitude, given that "preference should be given to the use of the electric telegraph, for which [Bianchi Tupper] will agree with the general director of the branch [of telegraphs] and with the director of the Astronomical Observatory" (p.2306). In this way, the explorations had to begin in Angol and end in Valdivia, both locations that required particular care to determine their coordinates precisely as expressed by the Hydrographic Office.

The collaboration between the Commission and the National Astronomical Observatory was early. Before leaving Santiago for the south, Bianchi Tupper (1883, p.337) had to calibrate his precision instruments so as not to hinder the work on the ground, going personally to the Astronomical Observatory to adjust the progress of his chronometers. With these preparations complete, the Commission began work in January 1883, concentrating on determining the coordinates of forts, the river passes, and summits from Angol to Villarrica. For this task, Bianchi Tupper made astronomical observations on the ground and then contacted José Ignacio Vergara by telegraph to make "hourly comparisons between the chronometer of the expedition and the pendulum of the Observatory" (p.337). Since time is an interdependent variable with longitude, keeping the chronometer adjusted and verifying the time difference with Santiago through the telegraph were actions that had to be carried out continuously and with special care. For this reason, the Commission and the Astronomical Observatory continued exchanging telegraphic signals between January and February to calculate the longitude of Traiguén and Temuco (Vergara, 18 mayo 1883).

In February 1883, communications between the National Astronomical Observatory and the Commission were suspended due to a deterioration in Vergara's health, who had to leave the city of Santiago during that month. Without the director, the Observatory had no other employee to maintain the exchanges of telegraphic signals with the Commission. This situation is explained by the difficult moment that the institution was going through, which since 1882 only had three employees with occupations unrelated to geographical work. According to Vergara, for more than a year he dealt with "the almost absolute lack of assistants, and this lack must have exerted his inevitable influence on scientific work" (Zegers, 1883, p.252).[5] In the meantime, the Commission dedicated to drawing up a map of lake Villarrica and the Toltén river, which involved climbing the Villarrica volcano from mid-February to the end of March.

Vergara returned to the National Astronomical Observatory at the beginning of March and tried to resume communications with Bianchi Tupper. However, the Commission traveled through Andean territories that were not covered by the telegraph network, hindering the Observatory to communicate and cooperate at that time. Only when the Commission arrived in Valdivia some telegraphic exchanges were verified, "and on the 5th of this month [May], we made a final telegraphic comparison to determine the length of that city" (Vergara, 18 mayo 1883). With this action we completed the determination of the coordinates of the Araucanía Exploratory Commission.

The results of the expedition were well received by the public world and were linked to the strategic goals projected by the State for the efficient annexation of the territory. According to Bianchi Tupper (1883, p.340), "the astronomical positions obtained and some other geographical data have already been or are being used for the drawing of some charts of Chile that are being constructed to date." Here, the plans of the Victoria-Valdivia railway that began to be built in 1883 and that had as one of their references the work of the Exploratory Commission (Greve, 1944, p.67-73) acquired relevance.

Despite its usefulness, the construction of the geographic map was not definitively completed in the summer of 1883. Its provisional character motivated a new incursion into Araucanía four years later, which would be led by Bianchi Tupper. The records of this expedition are very scarce and it is only possible to trace a common aspect that occurred with the first company: the presence of the National Astronomical Observatory. On this occasion, the circulation of instruments is recorded, since the Ministry of Public Instruction acted as an intermediary for Vergara to facilitate a circle of reflection with its respective artificial horizon (Valderrama, 20 dic. 1886). As before, Bianchi Tupper personally assisted the Observatory to adjust its chronometers before leaving for the field, and the exchange of telegraphic signals was recorded to determine the longitude of the cities of Mulchén and Los Angeles (Vergara, 27 feb. 1887).

Alejandro Bertrand and the Puna de Atacama, 1884

The end of the War of the Pacific meant the annexation of a vast territory rich in minerals, with great potential for the Chilean economy. However, some areas of the Atacama desert were not considered sufficiently explored, which resulted in a lack of accurate mapping, which could affect future mining. Added to this economic problem, there was the interest that neighboring countries such as Bolivia and Argentina had in the region, being able to claim part of the territory recently acquired by the State of Chile. For these reasons, the Ministry of the Interior promoted a series of geographical expeditions, including the one of engineer Alejandro Bertrand.[6]

At the beginning of 1884, Bertrand (1885, p.9) reported that in the face of imminent border conflicts and strong economic interests in the area, the purpose of his mission was "to offer a secure geographic base for future territorial demarcations." This implied that it was necessary to "explore the mountain range of the Atacameño territory in its most unpopulated and unknown part" (p.5). The Ministry emphasized that territorial knowledge was key to defending Chile's interests, particularly in the Puna de Atacama. Thus, Bertrand

was exhorted to gather "data that would establish with some precision certain notable points and that would shed some light on the topographical configuration of a region destined to be the border between three Republics" (p.5).

Based on these guidelines, the expedition had to study the dividing lines of the Andes Mountain Range between Chile, Bolivia, and Argentina up to the 24th parallel. On the other hand, San Pedro de Atacama was given great importance as a geodetic base point, so Bertrand was ordered to fix the coordinates of this locality as accurately as possible. Additionally, it was necessary to fix the coordinates of the "station and lodging" sites in the desert (Bertrand, 1885, p.9-10).

With the objectives established, Bertrand (1885, p.12) dedicated to gathering the instruments and materials essential for geographical work, highlighting the chronometer. With this instrument, it would have been "easy to determine as many geographical coordinates as desired by isolated observations of stars." However, the imbalances in the chronometers were frequent due to the inevitable accidents of land travel, forcing caution in their use and transfer. For example, the marine chronometer, despite being very precise, could only be transported on foot and with great care, since "its half-second stroke is too slow to be affected by any sudden shake, no matter how slight" (Bertrand, 1885, p.12). Given that shakes and irregular movements were inherent to land travel, Bertrand preferred to carry with him a pocket chronometer from the English manufacturer Dent "which was already used by Vidal Gormaz and Bianchi Tupper during several explorations" (p.13).

Once in the north, at the beginning of February 1884, Caracoles was the first place where Bertrand had to determine the coordinates. From this mining town, the engineer asked the National Astronomical Observatory for an exchange of telegraphic signals to compare the exact time of Santiago with that of Caracoles. The operation would allow obtaining data to calculate the length and also to adjust the chronometers for the rest of the expeditions through the desert. However, when using the northern telegraph lines special care had to be taken due to their frequent interruptions (Bertrand, 1885, p.78). This was caused by the poor layout of the lines, which did not follow the shortest or most accessible path, making it difficult to monitor and repair the wires (p.267).

With the necessary precautions, on February 1st Bertrand began exchanging signals with the Observatory through the Caracoles telegraph office. The methodology used in this procedure was selected by Vergara. First, several sets of ten seconds would be chosen, sending a preparatory signal for both ends to get ready. Next, from one end of the line, the sending operator had to hit the telegraph key every one of the ten seconds of the chosen series. At the other extreme, the receiving operator had to carefully follow the blows with his ear, noting the time marked by his chronometer when he perceived the last blow of each series. Once this process is finished, it would be repeated but exchanging the role of sender and receiver. Thus, the telegraphic exchanges between Caracoles and Santiago extended over twelve series (Bertrand, 1885, p.78-79, 27-28, 125).

From the National Astronomical Observatory, the person in charge of executing communications with Bertrand was director Vergara. However, his availability as an employee of the Observatory was severely limited, since from June 1883 he simultaneously

served as minister of Public Instruction (Herreros, 1944, p.68). His new public position had had negative effects on the work of the institution he directed, even stopping astronomical observations. In the little time available to dedicate to the Observatory, Vergara had to give precedence to geographic and meteorological work. This involved making "observations to study the progress of the chronometers of this establishment [as well as] those of the commissions that have gone to the north of the Republic" (Letelier, 30 abr. 1884).

It should be noted that the limitations faced by Vergara could not yet find a solution through the rest of the workers of the National Astronomical Observatory. Although two more assistants had joined the institution, all of them were dedicated exclusively to meteorological observations and the publication of meteorological yearbooks (Letelier, 30 abr. 1884). Efforts to find foreign astronomers to fill the positions of first and second astronomers and to be dedicated to astronomical-geographical work had been in vain until the beginning of 1884.

After communications with the Observatory in Caracoles, Bertrand headed towards San Pedro de Atacama, a geodesic base that required the determination of its exact longitude. Since February 11, there have been attempts to resume telegraphic contact with the National Astronomical Observatory. Stable communication, though, was only achieved during the night of February 18, since the transmission was interrupted for several days due to "obstructions in the intermediate telegraphic offices" (Bertrand, 1885, p.33). On this occasion, there was a variation in Bertrand's use of the instruments: to simplify the procedures, he chose to use an ordinary pocket watch and not the Dent chronometer. This was because, while the Dent was suitable for field travel, it was not the best choice for telegraph signal exchanges. Indeed, the march of this chronometer made five strokes every two seconds, complicating the listening and recording of time. A common pocket watch, although less precise, enabled to follow the second hand with the eye and facilitated the corresponding records. To reduce inaccuracies, Bertrand (1885, p.126) proceeded to compare both chronometers before and after the communications to ensure a uniform march of time.

Once the longitude of San Pedro was determined, at the end of February the commission continued the journey south towards the Socompa volcano. From then on, Bertrand's trip would extend until the end of April 1884, but no further communications with the National Astronomical Observatory would be recorded. Because the commission went into the desert and the mountains, there were no telegraphic offices that would allow any type of communication between the two.

The expedition settled on a map of the region that covered the parallels 21º to 27º south latitude. According to Bertrand, the precision of this cartography represented an advance in the knowledge of the area, insofar as there was "no fancy detail or any data that is no longer justified" (Bertrand, 1885, p.6). In this sense, the map was projected as a potential input for boundary disputes and/or future mining prospecting. Bertrand's career pointed in both directions by becoming a key figure for the Limits Commission and, later, as a fiscal inspector of the Propaganda Salitera, using the knowledge acquired in this expedition (González Miranda, 2013).

An extended relationship: the Exploratory Commission of the Atacama Desert and the National Astronomical Observatory, 1883-1890

The great interest of the State in the Atacama desert was demonstrated by the other geographical expedition of Alejandro Bertrand. This was also promoted by the Ministry of the Interior, which commissioned the engineer Francisco San Román[7] in 1883 to lead the so-called Exploratory Commission of the Atacama Desert.

The objectives of the Exploratory Commission show the breadth of the work, with emphasis on the construction of a "topographic map of the desert with the details of its orography and hydrography, demarcation of the natural springs and the points where they can be opened" (San Román, 2012, p.5). In this map, it was also necessary to trace "the roads that facilitate the communications of the desert and that are best adapted to its development and industrial prosperity" (p.5). Finally, the land had to be geologically classified according to its mineralogical importance and, at the same time, gather a collection of minerals from the area (p.5).

As we can see, the Ministry's request pointed to the need to acquire precise knowledge about natural resources and possible trade routes in a territory that would become the economic pillar of the State. The domain and administration of the northern territories would inaugurate the so-called "saltpeter cycle" ("ciclo salitrero"), which meant an expansion of tax revenues and the economic consolidation of the Chilean State (Rodríguez, 2018, p.124-148). With this, it is possible to understand the exhaustive work of San Román who, unlike Bertrand's expedition that only focused on the Puna, had to include the entire Atacama desert in his explorations. Traveling through this extensive territorial margin (240,315km^2) forced the Exploratory Commission to carry out successive expeditions that lasted between 1883 and 1889, and to establish relationships with other scientific institutions, such as the Observatory. The records of the trips show that the relationship with the National Astronomical Observatory was constant and became very relevant in the last two years of expeditions (Cornejo, Meier, 2016).

The first contact between the Observatory and the Exploratory Commission occurred when San Román was collecting instruments before starting his trips in 1883. Through the Ministry of Public Instruction, the engineer requested a portable reflection circle that was "with little or no use at [the] Observatory" (Vergara, 12 mayo 1883). The instrument was very useful, given that the Commission could not have chronometers during the first year, so "astronomical observations have had to be reduced, due to [this] lack of chronometers, to the determination of meridian heights, either with the circle of reflection or with the transit theodolite" (San Román, 2012, p.30).

After the early circulation of instruments, telegraphic communications with the National Astronomical Observatory were recorded regularly in 1884 and 1885. This procedure was especially important in Copiapó, a base point that required a very precise determination of coordinates since it would be used for the chaining of the measurements made in the desert. At the beginning of 1884, when the Exploratory Commission was able to obtain two Dent chronometers, the Observatory was contacted by telegraph to adjust the timing of the chronometers and also to have an approximation of the longitude of Copiapó.

During this operation, the progress of the chronometers was very irregular, forcing the commission to obtain another chronometer to carry out the signal exchanges (San Román, 2012, p.34, 256). Although this operation was successful, the length obtained could not be considered a definitive result and meant that, in the future, the city would be "the object of repeated tests and numerous observations due to the imperfection of the instruments and the difficulty of the means available" (p.251).

In 1885, the largest number of exchanges of telegraphic signals between the National Astronomical Observatory and the Commission were recorded. These operations aimed to determine and re-determine the length of key points for the map of San Román, in which the city of Copiapó was again found, as well as San Pedro Atacama and the port of Antofagasta (San Román, 2012, p.107-112).

The greater frequency of telegraphic contacts in the period 1884-1885 is explained by an increase in personnel at the Astronomical Observatory. In July 1884, the German Guillermo Wickmann was hired as the second astronomer. His functions were closely linked to geography, since he was in charge of "comparing pendulums and chronometers, [and] making the necessary astronomical observations to determine their state and movement" (Astronomical Observatory..., 1886, p.9). The situation seemed to improve even more with the hiring of the German Adolfo Marcuse, who held the position of the first astronomer in February 1886. The arrival of the new astronomers became very important since director Vergara immediately took over as minister of the Interior after leaving the Ministry of Public Instruction, once again limiting his work to the interior of the Astronomical Observatory.

The greater availability of employees – which was to translate into greater support for geographical expeditions – was short-lived. Five months after Marcuse's arrival, a controversy broke out involving the National Astronomical Observatory and the National Congress, calling into question the Observatory's credibility. The controversy exposed the tense relations within the institution and culminated in Marcuse's dismissal in September 1886 and Wickmann's resignation in February 1887 (Sanhueza-Cerda et al., 2020).[8] This had an impact on the relationship with the Exploratory Commission: in 1886 no communication was recorded, and this situation continue until mid-1887.

Despite the internal problems of the National Astronomical Observatory, its assistance was required by the Exploratory Commission. In the middle of 1887, San Román had to return to the base points of his geodetic triangulation to begin the definitive survey of his map. This involved calculating as accurately as possible the coordinates of Copiapó, Caldera, and San Pedro de Atacama. From this last place, telegraphic contact was resumed, where the need to deepen the work between the Exploratory Commission and the scientific institution can be seen: "After finishing our work of triangulating the mountain ranges, it is time to determine with the possible precision the astronomical position of our extreme bases in Copiapó and this town of Atacama. Please answer me if you now have an employee available who could come well prepared for the object" (San Román, 7 jun. 1887).

This request was justified because, according to San Román (2012, p.261), "the approximation of our geodetic work with the definitive and rigorous work of astronomers is much greater." In other words, from then on, collaboration with the National Astronomical Observatory deployed directly over the territory and not only from Santiago was necessary.

Vergara's response to this requirement was conditioned by the departure of Marcuse and Wickmann, replying: "I currently do not have and I will not be able to have an employee for six, eight or more months to entrust the delicate work that you refer" (Vergara, 9 jun. 1887). However, Vergara offered to continue exchanging telegraphic signals, which would be executed by himself.

The personnel problem was resolved with the hiring of French astronomers Alberto Obrecht, Javier Devaux, and Irenee Lagarde. The new employees arrived in Chile in February 1888, occupying the positions of first astronomer, second astronomer, and third assistant, respectively. Aware of the situation, San Román again requested that the astronomers move north (Puga, 24 jun. 1888). This request became more urgent when the financing of the Exploratory Commission was considerably reduced at the beginning of 1888.

On this occasion, Vergara's response was positive, and a delegation composed of Alberto Obrecht and Irenee Lagarde was created to move north. Javier Devaux would stay in Santiago to support the delegation in the operations that had to be carried out from the capital. In Vergara's opinion, this new dynamic was necessary since the telegraphic communications with the Exploratory Commission until then had not obtained "satisfactory results due to the difference in the observation elements that in that city [Copiapó] has been available." To make up for this deficiency, Obrecht would be equipped with the necessary material to build a small portable observatory (Vergara, 26 jun. 1888).

The arrival of the delegation – called "Longitudes Commission" – to Copiapó occurred in July 1888. Its first task was to build a portable observatory at the foot of the Chanchoquin hill (one of the ends of the base used by San Román), to later generate a telegraphic connection with the Copiapó State Telegraph Office (Anales…, 1890, p.VI-VII). After the preparations, the Longitude Commission focused on determining coordinates and dividing the work in the most efficient way possible. Irenee Lagarde was in charge of obtaining the latitude, while Obrecht took on the tasks related to longitude. From Santiago, Javier Devaux was in charge of exchanging signals with Obrecht, to obtain this last coordinate. According to the account of the second astronomer, preparations were made to expedite communications, including the installation of a new chronograph and the constant determination of the exact time, "which was indispensable for the success of our work" (Devaux, 8 mayo 1888).

However, when everything was ready for the exchange of signals, winter was well advanced. Heavy rains cut the telegraph lines several times and cloudy skies prevented astronomical observations from being made in Santiago and Copiapó (Anales…, 1890, p.IX). When the weather improved, Devaux had to ask for assistance to repair the Santiago telegraph wire, which had problems transmitting the current. To do this, they called Fernando Cabrera Gacitúa, a telegraph engineer-electrician who "changed some poles ... and removed an insulator from a tree through which the current was lost" (Devaux, 8 mayo 1888), to then put the provision of astronomers "an employee to send and receive the communications they needed" (Annals..., 1890, p.XI). Thanks to the good arrangement of the telegraph line, the Longitude Commission was satisfied with the results obtained in the city and left for Caldera on October 8.

In Caldera, only two nights were necessary to obtain a satisfactory length value. After that, the Longitude Commission received orders from the government to determine the coordinates

of other important cities in the north: Antofagasta, La Serena, and Coquimbo (Anales..., 1890, p.XII). For the new mission, it became necessary to mobilize more instruments and Javier Devaux moved from Santiago to Caldera taking with him a chronograph, a precision instrument that should increase the accuracy of the results (p.XV). After this, the second astronomer returned to Santiago to continue his assistance to the Longitude Commission from the National Astronomical Observatory (Devaux, 8 mayo 1888). From then on, and until April 19, 1889, the Longitude Commission was in charge of determining the requested coordinates. Thus, after almost ten months of work on the ground, the operation of the delegation chaired by Alberto Obrecht was deemed to have ended.

The results obtained were well evaluated by the members of the Astronomical Observatory, mentioning that "the error in the lengths does not exceed 2 or 3 hundredths of a second" (Devaux, 8 mayo 1888). San Román was also satisfied with the coordinates obtained by the Longitude Commission, whose data would help him make the final calculations for his geographical map. The base points of the geodetic triangulation (Copiapó and Caldera) and also the port of Antofagasta had been a constant source of concern, and "only after various attempts and verifications, it was finally possible, with the security of the procedures astronomical data, a well-defined starting point and well-established means of verification ... thereby achieving the satisfactory accuracy of our work" (San Román, 2012, p.251, 184).

San Román managed to finish the geographical map in 1890. His perception of the cartography was very positive since it indicated "with precision the most important features of the terrain," which included mines, mountains, and the places "where the waters flow, ... the precise location of the watering places and points of refuge and salvation in the solitudes of the desert" (San Román, 2012, p.240). The engineer's appreciation is justified since the map became the most complete of the Atacama desert that was available up to that time. This helped define the geographic unit of the desert and gave a nomenclature to the main accidents in the area (González Pizarro, 2012, p.XXXVI-XXXVII), contributing to better regional knowledge in the context of territorial expansion.

Final considerations

Throughout this work, the role of the National Astronomical Observatory in territorial expansion has been examined, through the different forms of relationships with three geographical explorations. The origin of the explorations is explained by the need of the State of Chile to generate precise cartographies in recently annexed, strategic, and high economic value territories, but also little known. In Araucanía, it became necessary to have a map indicating the exact coordinates, of military forts and cities, and also to provide data to facilitate the construction of public works and land distribution. In the north, the imminent boundary disputes with neighboring countries and the enormous resources that the desert kept made it imperative to draw up cartographies that would precisely indicate from the highest peaks to waterholes that would allow mining activities.

The cartographic specialization, motivated by this heterogeneous set of interests, allowed the participation of the National Astronomical Observatory, because engineers and sailors

in charge of directing the explorations turned to the institution to improve the accuracy of their maps. The persistent contact indicates a recognition of the practical function that the Observatory performed, since astronomy provided the possibility of obtaining exact geographic coordinates. This is how the National Astronomical Observatory was in charge of determining coordinates of geodetic bases or specific locations for cartographies that had strategic purposes in economic, diplomatic, and military terms. Thus, the performance of the Chilean Astronomical Observatory must be understood as a phenomenon inserted into regional and global logic: both in Europe and Latin America the practice of astronomical observatories was linked to political, economic, and military purposes, such as the territorial expansion.

The forms of relationship showed how the Observatory specifically collaborated with the geographical expeditions. First of all, it highlights the adjustment of precision instruments such as the chronometer. Being the chronometer one of the most important objects for determining longitude, its march needed to be precise and mark the local time correctly. For this reason, the explorations went to the National Astronomical Observatory since the instruments of this institution allowed correcting the errors in the march of time. On occasions, the adjustment of the chronometers was done in person, on other occasions, the procedure was carried out by telegraph. Also, the National Astronomical Observatory was the institution that could more accurately obtain the time in the capital, a key element for comparisons. This indicates that the Observatory was a recognized institution for the management of space-time data that were used by these expeditions.

A second element was the exchange of telegraphic signals, a procedure that became one of the pillars of the relationship established between geographic explorations and the National Astronomical Observatory. The exchange of signals produced an information flow that compared the time between two distant points and adjusted chronometers, obtaining the necessary data to calculate the geographical longitude. Since the appearance of the telegraph, this method became the most reliable and fastest to determine lengths, so this action was unavoidable in cartographic production. The exchange of telegraphic signals, however, required very good coordination between various human and material elements: telegraphic wires in good condition, the electric current flowing without problems, officials who assisted the operation, among others. Given the great precision required by cartographic work and the rigorous standards of astronomy in the nineteenth century, a small mismatch in any of these elements could lead to errors that had to be corrected over and over again until the desired results were obtained.

The telegraph allows us to understand how technology is an inseparable element of scientific work. As material support, the telegraph enabled the phenomenon of long-distance simultaneous communication, becoming, on many occasions, the limits of the relationship established between the explorations and the National Astronomical Observatory. Without properly functioning telegraph lines, there was no possibility of simultaneously knowing the time of two distant places for the determination of geographic coordinates.

A third element present in the relationship was the circulation of precision instruments. Unlike the previous two, this phenomenon was less frequent but no less relevant. The instruments provided by the National Astronomical Observatory were used for astronomical

observations on the ground, supplying material deficiencies experienced by the exploring commissions, as shown by the case of San Román and Bianchi Tupper. This circulation of instruments shows that the instruments of the National Astronomical Observatory were not reserved for limited use within the institution, but rather were made available to meet the national needs derived from territorial expansion.

The last form of relationship between the National Astronomical Observatory and geographic explorations was the circulation of personnel. This dynamic is explained by the high levels of precision required in cartographic surveys to determine the coordinates of triangulation base points. Faced with this need, the geographic companies requested the Observatory mobilization on the ground. In this way, this institution deployed its employees on the territory, equipped with instruments to astronomically determine the coordinates of key points with great precision. However, this dynamic was limited due to the constant shortage of personnel that the Observatory had during the 1880s.

These forms of relationship, prolonged for almost a decade, sustain that geographic work was an important part of the tasks within the National Astronomical Observatory: there was a work agenda in geographic matters, stimulated by territorial expansion and cartographic production, that constantly made the Observatory allocate human and material resources for this purpose. Despite all the limitations that the aforementioned institution had in the 1880s, it always responded positively to the explorations when its internal organization allowed it. Thanks to this, the National Astronomical Observatory became an active participant in territorial expansion, which also allows to affirm that the institution was not only financed by a discursive concern in national science, but also by the practical and strategic services that such knowledge could deliver.

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NOTES

[1] At the beginning of the 1880s there were only two general maps of the country. The first, made by Claudio Gay between the 1830s and 1840s, became the first continuous representation of the national territory between latitudes 25º and 44º, but it suffered from a series of inaccuracies. The second, prepared by Amado Pissis and published in Chile in 1873, used the geodesic triangulation method to improve precision. However, the scale of the chart (1: 250,000) required a level of detail that the geologist could not achieve, earning him a series of criticisms for the omission or inaccuracy in the location of rivers, lakes, farms etc. (Sagredo, 2018; Rosenblitt, Sanhueza, 2010; González Leiva, 2007; Gangas, Santis, 1987; Greve, 1946).

[2] Although the National Astronomical Observatory has been dedicated to geographic work since its foundation, and strongly since the 1880s, little is known about this facet. This is explained, in part, due to the scarce literature on the observatory, which has tended to narrate chronologically the succession of directors with an emphasis on the observation of celestial bodies (Minniti, Paolantonio, 2005; Keenan, Pinto, Álvarez, 1985; Aldunate, 1975; Grandon, 1952). New trends have recently appeared, with works that study astronomy in Chile from a critical perspective, showing how the installation of the astronomical observatory on San Cristóbal hill was part of global projects (Silva, 2019) or the strong overlap between astronomy, public space and amateurs (Ramírez, Leyton, 2020).

[3] The determination of longitude has three difficulties. The first corresponds to the need to define a universal reference meridian, since the calculation of longitude will depend on the meridian used as reference. The second is the need to know the exact time simultaneously in two distant places, an impossible matter

before the introduction of the electric telegraph and very complex due to the constant misalignments of the chronometers. Although the telegraph solved the problem of temporal simultaneity, telegraph wires had to be taken, on many occasions, to remote and inhospitable places. The wires used to be cut or the electrical signal was very weak, making communication impossible (Galison, 2005, p.159-171).

[4] Navy officer who participated as secretary of the Chilean commission in the Washington Meridian Conference in 1884. The delegate in charge was Francisco Vidal Gormaz, director of the Hydrographic Office. Chile's participation was limited to voting in favor of the Greenwich Meridian and informing the government of the resolutions of the Conference. According to Vidal Gormaz (1885, p.484), "only the one in Greenwich could have the vote of Chile, as it is the best known in the country, in addition to our national meridian, and the only one in use in our marina and Hydrographic Office."

[5] Since the resignation of the first and second astronomers in 1882, Vergara was the only employee in charge of the National Astronomical Observatory. By 1883, it had only been possible to hire two assistants in charge of meteorological tasks and Luis Grosch, an optical engineer in charge of instrument maintenance. According to Vergara, the lack of personnel was because it had not been possible to find foreigners who wanted to occupy the position of first and second astronomers. At the local level, in the opinion of the director, there was no trained personnel to carry out astronomical work (Vergara, 18 mayo 1883).

[6] Engineer from the Universidad de Chile who, in his long and prolific career, was the head of the Charts and Plans Section of the Hydrographic Office; first engineer of the Boundary Commission during the boundary disputes with Argentina; general director of Public Works; fiscal inspector of the Propaganda Salitrera, among other positions (González Miranda, 2013).

[7] Born in Copiapó (1838), San Román was an outstanding student at the College of Mining and would graduate as a mining engineer at the Universidad de Chile. He practiced his profession privately, always linked to the mining and railway world of the region (González Pizarro, 2012).

[8] The controversy arose from a publication on the situation of scientific institutions in Chile, setting up the discussion in the National Congress. The focus revolved around the poor condition of the main instruments of the Astronomical Observatory and the responsibility that Vergara had in this matter. The controversy exposed the close link between the political and techno-scientific spheres in the administration of the observatory, the knowledge disputes within the institution, and the political influence of José Ignacio Vergara in his capacity as director. For a detailed analysis, see Sanhueza-Cerda et. (2020).

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