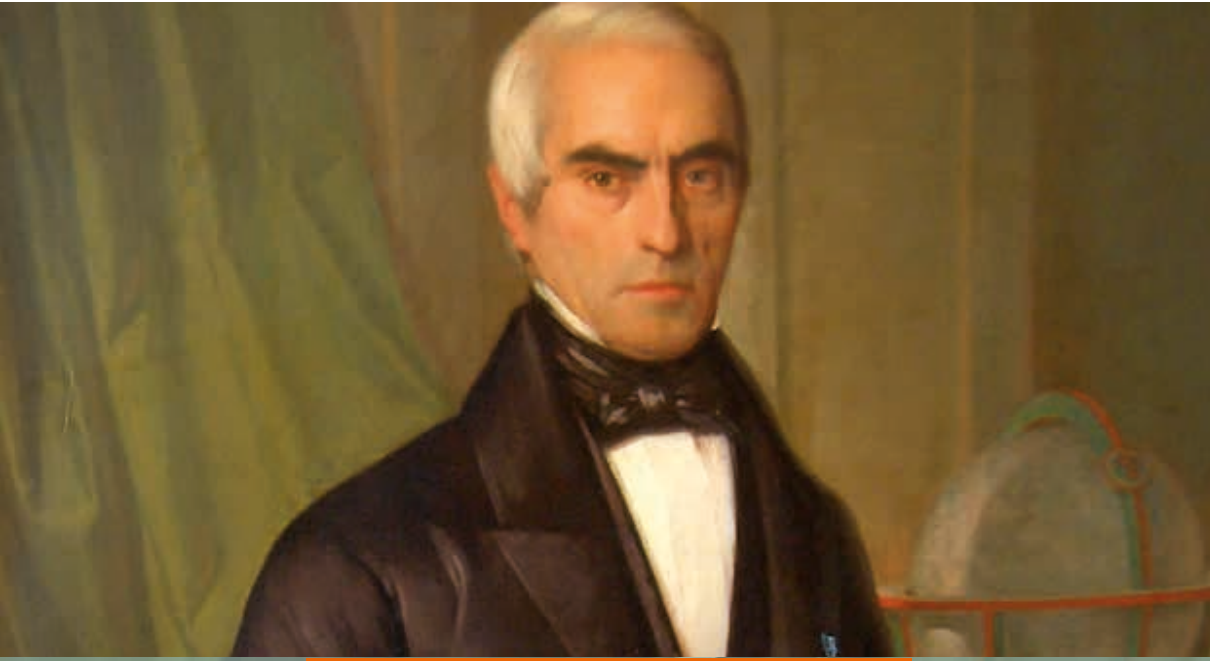

TEACHING UNIT

Domingo Fontán and the *Geometric Map of Galicia*

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Domingo Fontán and the *Geometric Map of Galicia*

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Introduction

The *Geometric Map of Galicia*. The 'face of the country' bequeathed to us by Domingo Fontán

The year 2017 marked two centuries since the time when the mathematician Domingo Fontán Rodríguez (1788-1866) began to work on his opus magnum, the *Geometric Map of Galicia*, a modern, rigorous map of our territory.

On the occasion of this anniversary, the Section of Science, Nature and Society of the Council for Galician Culture decided to prepare teaching material that would help to disseminate the outstanding contribution of Domingo Fontán among the general and school public. This work was carried out by a team coordinated by Elena Vázquez Cendón and Xosé A. Fraga Vázquez and made up of Margarita Barral Martínez (University of Santiago de Compostela), Xosé A. Fraga Vázquez (Álbum da Ciencia, Council for Galician Culture), Gonzalo Méndez Martínez (University of Vigo), Víctor Pollán Fernández (secondary mathematics teacher), Julio Rodríguez Taboada (secondary mathematics teacher) and Elena Vázquez Cendón (University of Santiago de Compostela).

The creation of a map of Galicia by means of geodesic measurements and field work was an unprecedented task. In 1820, Fontán measured a 2,291-metre base on the road from Santiago to A Coruña, between Formarís and A Sionlla, and started the triangulation. In 1828, he did the same with the base of O Corgo, on the road from Lugo to Castile: 4,989 metres. On the 1st of December 1834, he presented

his manuscript to the governing queen, Maria Christina of Bourbon. However, as a result of the need to find an expert engraver to publish the map, it was not printed until 1845.

Galicia was ahead of the rest of Spain in terms of knowledge of its territory. Fontán's map would be the cartographic basis for railway and road projects and a source for the production of other maps. Therefore, the *Geometric Map of Galicia* is a milestone in the history of cartography on the Iberian Peninsula and a symbol for Galicia.

While this material was being produced, we received the good news that the Royal Galician Academy of Sciences had named Fontán as Galician Scientist of 2018. This deserved distinction emphasises the importance of recognising and disseminating the work of our scientist.

Xosé A. Fraga Vázquez
Elena Vázquez Cendón

Santiago de Compostela, March 2018

LIFE AND WORKS OF DOMINGO FONTÁN

Who was Domingo Fontán?

1. Background and education

Domingo Fontán Rodríguez was born in Porta do Conde, in the municipality of Portas, on 17 April 1788, to a relatively well-off family. With a good disposition towards learning, he received a comprehensive, extensive education. His primary education began in the parish of Baliñas, in the municipality of Barro. A maternal uncle of his, Sebastián Rodríguez Blanco, the parish priest for the town of Noia, was responsible for educating the two boys in the family (Domingo and Andrés) during their childhood.

The house where Fontán was born in Porta do Conde

At the age of 12, Domingo began to study Philosophy at the University of Santiago, before graduating in 1802 and completing a PhD in Theology

Ruins of the Lousame paper mill, belonging to the Fontán family

Source: Elixio Vieites / patrimoniogalego.net

in 1811. He also focused on studying the three parts of St Thomas Aquinas' *Summa*, alongside Hebrew and the Holy Scriptures. In 1809, he began to study Exact and Natural Sciences and, for several years, attended the Mathematics lessons taught by Xosé Rodríguez. He also completed a degree in Philosophy and another in Art (1813), as well as a PhD in Art (1814). When he was already working as a university professor, he graduated in Law in 1828.

In April 1824, he married Manuela Ribas, a young woman born in the parish of Santiago, in the city of A Coruña. The couple had three children: Félix, Manuel and Rosendo. In 1843, together with his brother Andrés, he inherited the estate of their uncle Sebastián Rodríguez, which included shares in a paper mill in O Castro, in the municipality of Lousame (A Coruña province), which had been established in 1810. The brothers decided to invest the rest of their inheritence in purchasing most of the shares in the mill and, in 1857, they came to own the whole of the company, renowned for manufacturing stamped paper for the Spanish governmental agencies.

2. Fontán's teaching in Fonseca

In 1811, Fontán began his teaching career at the University of Santiago as a replacement for Antonio Sarmiento, a professor of Rhetoric. Over the follow-

ing years, he also became responsible for teaching other disciplines in the classrooms of the Pazo de Fonseca, including Fine Arts, Logic and Metaphysics. During the 1813-1814 academic year, he held the vacant Chair of Logic and Metaphysics, and between 1814 and 1818 he stood in for his teacher Xosé Rodríguez as the Chair of Sublime Mathematics. On 3 April 1818, he was awarded the latter, which he held until 1835, after taking a competitive examination; in the previous year, 1834, he had attained the Chair of Mechanical Geometry and Drawing Applied to the Arts at the Arts Conservatoire, and the Chair of Physics, Mechanics and Drawing of the Arts at the Economic Society of Santiago in April of the same year. In 1817, the Senate appointed him as the individual responsible for ensuring students' good behaviour and appropriate attire, which led to a number of clashes with students, whom he accused of unsuitable clothing and bad behaviour. As a teacher, Fontán had a reputation for being strict and intransigent.

3. A liberal politician

In 1814, Fontán was appointed undersecretary of the Royal Economic Society of Friends of the Country of Santiago. He was among the most prominent liberal individuals in the Fonseca Senate and had links with the group of liberals based in A Coruña who met in the café La Esperanza. After the restoration of absolutism, and because of his liberal stance, on 23 May 1914 he was reported to the Senate by Freire Castrillón. However, he was acquitted on 3 June 1815 and obtained his first political position in 1817, when he was appointed member of the Tax Distribution Board for O Salnés, Pontevedra province. It was also in 1817 that he started his great piece of work, the *Geometric Map of Galicia.*

In 1820, following the creation of the Provincial Council of Galicia, he was named secretary of the institution. In 1822, he went on to hold the same position in the Provincial Council of A Coruña, a body that had only just been created, until it was discontinued on

23 October 1823. After the absolutist restoration of Ferdinand VII, Fontán was suspended from his Chair and from the position of secretary of the Provincial Council in July and October 1823, respectively. However, a decree dated 22 August 1826 declared him 'purified' and he was able to return to teaching.

In 1826, he was placed in charge of the judicial and municipal division of Galicia and, in 1829, was appointed as the individual responsible for the layout of the roads to be opened across the Galician territory. In 1834, he was appointed 'fellow of the Provincial Limit Rectification and Judicial District Arrangement Commission', i.e., the commission in charge of the municipal division and the provinces. The following year, 1835, he was entrusted with establishing the Civil, Mining and Forestry Engineering Corps and was assigned the positions of director of the Madrid Astronomical Observatory and director of the newly-formed Special School of Geographer-Engineers. As an expert in metrology, in 1836 he was made a member of the commission established to design the weight and measurement system.

4. Parliamentary career

Fontán was elected Member of Parliament for Pontevedra on five occasions and for Lugo on four occasions in the elections held in 1836, 1837, 1839, 1841 and 1843. Following Espartero's military uprising, on 4 September 1840 Fontán experienced political reprisal for the third time and was removed from teaching and from his position as director of the Observatory, although he was reinstated a few days later, on 20 September 1840. Over his eight terms of legislature as a Member of Parliament, he was part of different parliamentary committees and was the fourth secretary of the Chamber of Deputies. In this political and public forum, Domingo Fontán always demonstrated his independence when it came to discussing and voting on governmental amendments. He would attempt to focus on specific, real-life sit-

uations to tackle general issues, often introducing issues and facts that had arisen in the reality of Galicia as he knew it. He also believed that his homeland was being slighted, as compared with other regions on the Peninsula.

Among his multiple interventions on very varied topics in the Chamber of Deputies, those regarding the organisation of the state, the treasury and the draft constitution should be highlighted as particularly significant:

- With regard to the organisation of the state, although he always declared himself in favour of centralisation, he took a stance in support of provincial councils for better governance of the land, on the condition that they would be provided with the necessary budgets. When the provinces were delimited (1833), the resurgence of territorial conflicts was more than evident, leading to both the emergence of provinces that had ceased to exist in 1822 and claims from areas to restore their former status through battles over the seats of provincial capitals, as was the case of Pontevedra versus Vigo. On this occasion, thanks to his geographical knowledge and the data taken from his *Geometric Map*, Domingo Fontán backed Pontevedra as the provincial capital. Where organisation of municipalities was concerned, Fontán maintained that law enforcement should be conditioned by the true circumstances of the territory; as a result, he believed that local councils, civil governors and provincial councils should have effective power over their areas. Along the same lines, he also believed that excessive control by the central government (centralisation, in short) would have a negative effect.

- As for the treasury, his civic-mindedness led him to insist on discussing issues of misappropriation of public funds. He requested more than once for poor governance in terms of payments not to become widespread and for public accounts to be examined by Parliament, as he believed that order and sound administration were lacking.

■ In the debate on the draft text of the Constitution, Fontán showed a conciliatory attitude towards the different proposals put forward in the Chamber of Deputies. He defended the principle of national sovereignty that had already been laid down in the Constitution of Cádiz and accepted bicameralism and the view that members of Parliament and senators should do their job entirely unpaid. As a defender of national sovereignty and of greater influence from the Chamber of Deputies on the government's decisions, he was against personal privileges, particularly in the case of the clergy and specific territories, and so rejected the reestablishment of local privileges for Navarre and the Provincias Vascongadas (Basque Country).

5. His final years and his work championing a railway for Galicia

On 10 December 1851, at the then-advanced age of 64, Fontán requested that the Queen declare him retired from his job as a professor on physical health grounds. This was granted in May 1852 by the Public Instruction Council, which assigned him a pension of 24,000 reales per year.

During his final years, he settled in Santiago again – on Rúa da Acibechería and Rúa do Vilar – and, together with his brother Andrés, devoted his time to the Lousame paper mill and to Galicia. In 1858, he was made a corresponding partner of the Catalan Agricultural Institute of San Isidro and took part in the exhibition held in Santiago, as well as in the magazine that resulted from it: *Exposición Compostelana*. He was also actively involved in the Economic Society of Friends of the Country, becoming its archivist-librarian in 1858, its director in 1860 and an honorary member in 1862.

However, his greatest contribution to Galicia in his final years was his role in producing different reports on the railway in Galicia, as was the case of the lines Santiago-Carril (1860), Santia-

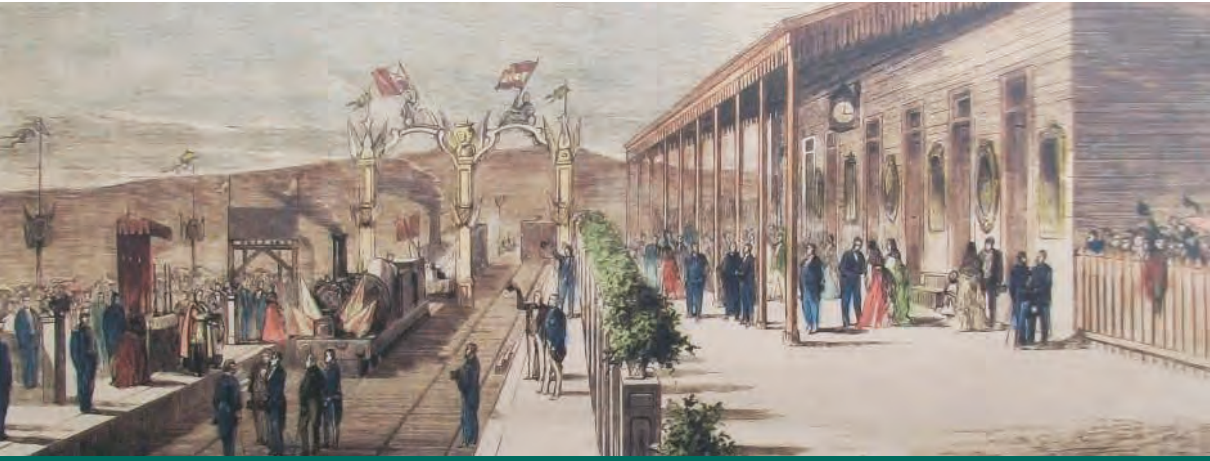
Cornes-Carril railway line

Plan of Thomas Rumball's project, 1860. Archive of the Museum of Pontevedra

go-Betanzos-Ferrol (1863) and the theoretical Central Railway of Galicia (1860), which would run west to east following the course of the Ulla River. Accordingly, on 4 January 1861, Parliament granted Domingo Fontán, Joaquín Caballero and Inocencia Vilardebó the concession of the Compostela railway, the Santiago-Carril line: the first Galician railway line, launched in the summer of 1873. For these operations, a number of cartographic documents were prepared based on the *Geometric Map*, for example the *Map of the Compostela Railway*, published on a 1:50,000 scale by the senior engineer Tomás Rumbal.

Domingo Fontán passed away on 24 October 1866 in Cuntis, Pontevedra, where he had gone to take medicinal water baths; the cause of death was acute cystitis. He had been named Knight of the Order of Charles III, awarded by Queen Isabella II on 28

November 1848, and held the diplomas of Member of the Royal Academy of History and the Paris Geography Society. He was buried in a tomb which he owned, no 306, in Santiago General Cemetery; his remains were later transferred to funerary urn no 51 of the municipality after consent was requested from his family on 21 May 1913. The aim was for them to be moved to the Pantheon of Illustrious Galicians, which only happened on 30 December 1988. Several streets in Madrid, Santiago de Compostela, A Coruña, Lugo, Ourense, Pontevedra and Poio have been named after this geographer. In 2004, the descendants of this individual who put Galicia on the map created the Domingo Fontán Foundation to preserve his legacy.



Opening of the Cornes-Carril railway line

Domingo Fontán: a member of a valuable generation of scientists

1. Rodríguez: Fontán's teacher and mentor

Domingo Fontán's contact with Xosé Rodríguez proved critical for the former's future. Xosé Rodríguez González (1770-1824), 'the Mathematician of Bermés', was an innovative individual who was in favour of knowledge and science as tools for social change and actively participated in the transformation of different institutions and the creation of new ones. His position as professor of Mathematics at the University of Santiago was short-lived, as he embarked on several scientific trips, but he never failed to stay in touch with Fontán and other colleagues and friends. The important missions entrusted to him and the positions that he held reinforced his role as an intellectual authority within the group of scientists in favour of modernisation. For example, between 1806 and 1808 he participated in the project to lengthen the Dunkirk-Barcelona meridian arc to Formentera and Ibiza, alongside the Frenchmen F. J. Domenique Arago and Jean-Baptiste Biot, with a view to calculating the exact value of a metre. Moreover, in 1808 he was commissioned the task of making the measurements and calculations required for producing an 'Accurate Map of Spain'.

A number of scientists gathered alongside Rodríguez and Fontán, sharing

Portrait of Domingo Fontán by Antonio María Esquivel, 1852. Meeting room of the School of Geography and History of the University of Santiago de Compostela

their liberal stance – when liberalism was an option for political and social change – and their desire to modernise higher education institutions. These scientists included the mathematician José Alonso López y Nobal, the surgeons and physicians Eusebio Bueno Martínez and José Francisco Vendrell de Pedralbes i Estaper del Mas, the chemist Gabriel Fernández Taboada, the pharmacist Julián Suárez Freire and the physician Juan Bautista Camiña, who received the support of some of their colleagues, of disciples such as Ramón de la Sagra Peris, Casiano de Prado y Vallo and Benito Sotelo and of figures from the political world, such as Jacobo María de Parga y Puga.

2. The attempt to modernise higher education

This group, who constituted one of the most renowned generations of scientists working in Galicia, shared a critical view of contemporary university education, which in Galicia was limited

to the University of Santiago. Teaching at this university was anachronistic, with lessons taught in Latin, based on the reading of texts also in Latin and on abstract discussions, detached from reality and with insufficient tools and hands-on activities. Towards the end of the 18th century, a number of legislative changes and the work of certain teachers contributed to limited reform; however, the process was very slow and frustrating, with great difficulties where incorporating new sciences was concerned.

As a result of the demands of the social, economic and even military system, and of the obstacles met by projects for reform in the university sphere, the modernisation of higher scientific education took routes unrelated to the university world. In the case of Galicia, this meant experiences in the medical field, the Ferrol Midshipmen Academy, the practical schools of Santiago, the Economic Society of Friends of the Country of Santiago and the Consulate of A Coruña. Fontán and his colleagues became actively involved in all these initiatives.

The scarce presence of the sciences in the university sphere was apparent in multiple ways. One of these was related to Fontán's teacher himself, Rodríguez, who was awarded his Chair by an examining board formed of experts from institutions unrelated to the university: José Alonso López y Nobal, a teacher of Mathematics at the Ferrol Midshipmen Academy; Francisco Roldán, a hydraulic engineer, who had worked for A Coruña's maritime postal service, and Francisco de Yebra, a teacher of Mathematics at the Royal Consulate of A Coruña.

3. The practical schools of Santiago

These institutions were separate from the university, although students and teachers from both the university and these schools shared teaching and some facilities. They also included a number of citizens' forums and initiatives, such

as the notable Economic Society of Friends of the Country of Santiago.

The Santiago Military School was an establishment that operated between 1811 and 1823, an institution that had stemmed in the context of the Peninsular War as a result of the then-pressing need to train qualified military personnel for the conflict. Courses in Fortifications, Algebra, Tactical Instruction, Military Drawing, Arithmetic, Geometry, Trigonometry, Geography and others were taught here. Its educators included Domingo Fontán himself as an English teacher. Pedralbes was a doctor at this institution from April 1812 to July 1815 and the chemist Fernández Taboada had a certain relationship with the school, as he set up a military laboratory with the help of Suárez Freire during the war against the French.

The School of Surgery was established in 1799 and operated until 1823. Its commitment to natural sciences and its inclusion, for the very first time, of disciplines such as Chemistry and Natural History in Galician higher education made this institution uniquely important in the scientific landscape of early 19th-century Galicia. Eusebio Bueno Martínez (1774-1814) and José Francisco Vendrell de Pedralbes i Estaper del Mas (1776-1850) were the most notable teachers at this school in Compostela.

Rodríguez, who had promoted the School of Pharmacy (1815-1821), pulled a number of strings in Madrid, where he boasted good relationships, including with the Natural Science Museum Protection Board, an institution which counted Jacobo María de Parga (1774-1850) – an official of the Office of the Secretary of the Treasury – amongst its members. At a local level, his point of reference was his friend Julián Suárez Freire (1751-1832), who would later work as the School's head. The chemist Fernández Taboada (1776-1841) taught there and was in charge of the secretary's office.

4. The Ferrol Midshipmen Academy and the Consulate of A Coruña

The Midshipmen Company and its Academy, both created in Cádiz in 1717, were key foundations for training officers in line with the new requirements for navigation and war. The Ferrol Academy was created in 1776 and its teaching staff included two outstanding individuals: Cipriano Vimercati Benítez (1730-1808) and Bernardo José Alonso López (1763-1824), who worked as an assistant at the Astronomical Observatory of the Midshipmen Company and, by virtue of his merits, was assigned a permanent post at this Observatory. He joined the Academy on a permanent basis in 1797, attaining the position of third teacher in the area of Mathematics.

The Royal Consulate of A Coruña, the Maritime and Land Consulate, was established in 1785 and operated until 1833. In the scientific field, the Consulate created technical schools specialising in navigation and drawing. At the end of this period, the mathematician Benito Sotelo Rivas (1796-1874), a disciple of Fontán's, joined the Consulate. The initial curriculum covered Numerical Arithmetic, Cosmography, Astronomy, Geography, Art of Navigation, Flat and Spherical Trigonometry and Mapping. The disciplines of Geography and Algebra began to be taught in 1806.

5. Some of Fontán's disciples and colleagues

Two of his most prominent students were Ramón de la Sagra (1798-1871) and Casiano de Prado (1797-1866). Sagra would later become a naturalist and sociologist-economist and Casiano de Prado would become an important geologist. These students moved in the liberal circles of Santiago and were persecuted by absolutists. One of their peers, José Varela de Montes, who would go on to be a professor at the University of Santiago de Compostela and an outstanding figure in Medicine,

acted as an informer against a colleague of Casiano de Prado's and Sagra's, Juan Antonio del Río, mentioning 'certain suggestions from Prado' in his report. Sagra and Fontán's collaborative relationship lasted for their entire lives; indeed, in 1849 this A Coruña-born scientist supervised the second printing phase of the *Geometric Map* in Paris.

To carry out the work involved in his *Geometric Map*, Fontán had a number of co-workers, including his brother Andrés, José Valladares, the topographer Domingo Lareo and his brother José, the architect and assistant civil engineer Alejo Andrade Yáñez and the teacher Manuel Rufo Fernández, all of whom provided support during field work or helped with a variety of tasks. Additionally, Xosé Rodríguez purchased some materials in Paris for the Department of Astronomy, Mathematics and Experimental Physics Tools at the University of Santiago, which Fontán used for his work. We cannot forget to mention his politician friends, such as Antonio Loriga Reguera, since it was precisely in the latter's manor house in Sobrecarreira, Sigrás, that Fontán carried out his initial triangulation practices.

6. The generation's downfall

Absolutist repression, in 1814 and 1823, crippled the first great generation of scientists linked to Galicia, of which Fontán was a member. This downfall worsened as a result of the dismantling or suspension of valuable institutions established during those times, seeing the first take-off of science in Galicia thwarted shortly after it began.

As we have seen, Fontán suffered this repression directly, although he was able to resume his teaching and field work. His former student Casiano de Prado virtually disappeared from the public sphere from 1823 to 1828 and later played an outstanding role in science, making remarkable

contributions to mining engineering, geology and palaeontology. Another of his disciples (and friends), Ramón de la Sagra, had to flee to Cuba, returning only after the death of Ferdinand VII. Both Sagra and Casiano left Galicia and, although they stayed in touch with one another and with their former teacher, they undertook their scientific work outside of Galicia. Xosé Rodríguez, who was removed from the Chair of Astronomy at the Central University by Ferdinand's authorities, fled for Portugal and died in Santiago in 1824, accompanied by Julián Suárez Freire and Gabriel Fernández Taboada.

For the sciences, absolutist repression meant a huge step backwards in scientific development. Almost all the scientific institutions created over decades of enlightened and liberal modernising efforts were dismantled, and the very limited progress made in the university sphere was challenged by a return to an anachronistic curriculum: that of the Minister Calomarde. Lost decades for the sciences, in the century when scientific progress was the hallmark of the times. A disconnection with highly pernicious effects: among these, the loss of a valuable generation of liberal scientists committed to change.

Domingo Fontán's *Geometric map of Galicia*

1. The rationale behind producing the map

The idea of creating a map of Galicia stemmed from Fontán's involvement in developing the region and was supported by his teacher Xosé Rodríguez. In Fontán's view, solving some of Galicia's problems, such as the layout of its infrastructures, its territorial organisation or its development in general, required a precise map of the area to be made.

He had decided to begin the map despite only being supported by his teacher and colleagues and only holding a university permit. In his opinion, the map needed to fulfil the reliability requirements set out by the development of physical-mathematical sciences, but with the limiting condition of being an individual piece of work. Fontán understood and defended the need for cartographic form as a repository and point of reference for all spatially-locatable socioeconomic events. This perspective would later inform some of the characteristics of the map.

2. Methodological and technical design

The scientific and technical progress of the 18th and early 19th centuries had not been felt in Peninsular Spanish cartography efforts, except in the case of Vicente Tofiño de San Miguel and his work on the *Maritime Atlas of Spain*. Military engineers focused

solely on mapping military enclaves, points of military interest and itineraries, particularly overseas. Mapping of the land had been left in the hands of cartographers who applied unsatisfactory methods, as evidenced in Tomás López' *Geographic Map of the Kingdom of Galicia* (1784), which indicates the seven former Galician provinces.

Even so, the need for a precise map of Spain had been identified and the problem formulated. Jorge Juan Santacilia had already expounded, in reports to the Crown, the methodology that should be applied and estimations of means and time required. In the second of his reports from 1751, entitled 'Reflections on the method for producing a general map of Spain,' he suggested that chains of triangles be used as a base; however, in the end, that map of Spain was never completed.

As we have seen, Fontán's relationship with Xosé Rodríguez was very important for developing the *Geometric Map of Galicia* project, and certain parallels can even be seen between the two men's biographies. Fontán owed to Rodríguez the idea of carrying out the triangulation and mapping of Galicia. Through Rodríguez' travels abroad, Fontán kept abreast of progress made in Europe and obtained the tools required for his measurements. Among the instruments purchased in Paris by Rodríguez was, for example, the legal metre built and compared by Fortín. Also from Paris and in 1821, Fontán received the theodolite or 'Gambey astronomic repeating circle' held by the University of Santiago, which he used for mapping, alongside another Troughton theodolite mentioned by the author and a pocket sextant held in the Pontevedra Museum.

Fontán applied the same procedure planned by Jorge Juan in the mid-18th century to produce the map of Spain: measuring a central base and a fundamental network of triangles. However, he added other measurements

The theodolite used by Fontán for the *Geometric Map*

Source: José Caruncho / Council for Galician Culture

which increased the map's precision and provided it with additional values, such as the altitude of its main peaks.

One of the most important characteristics of the map is its scale. 'Designed and built using the one hundred thousandth scale' (1:100,000), Fontán was ahead of the official maps from other European countries, for which the same proportion would later be chosen. Nevertheless, perhaps owing to Fontán's scarce means, or to him not fully maximising his field notes, the result is a map with low information density but which can be easily read by non-experts and can also be represented on a smaller scale. This choice of scale implied something very important for both Galicia and the rest of the nation: the introduction of the metric system. This solved all the unit conversion problems caused by the multiplicity of units. It also made it possible to set the scale as a fraction or proportion in round numbers, as in the case of this 1:100,000 scale. This

Lemercier's workshop in Paris, Semanario *Pintoresco Español*, 09.11.1851, p. 353

Source: National Library of Spain

said, altitude is expressed in traditional units: 'Heights above sea level are in Castilian rods' (0.835 m).

In 1791, the French National Assembly adopted a measurement system which featured the 'metre' as its basic unit of length, but the first prototype was only archived on 22 June 1799. Thanks to this decision, metrologists' problems began to be solved, including the need for a universal unit to serve as the basis for a system of equal measurements for all countries, the reproduction of base patterns with the precision required by scientific development and continuity over time or invariability. Fontán soon became aware of, and adopted, the new unit of measurement. His decision to use the metre as the map's unit was made at the start, from the moment that he ordered the perches required for measuring the base. We should remember that, whilst he had been using the metre since at least 1817, it only became an official measurement in Spain when the law

of 19 July 1849 was passed, unifying all measurements and weights.

The map was designed by applying the modified Flamsteed projection, also known as the Bonne projection. Because distortions increase quickly when using this projection as one moves away from the meridian of origin, Fontán decided to use the meridian of the San Fernando observatory.

Fontán's cartographic work can be considered to have launched the introduction and development, among Spanish non-nautical cartographers, of techniques and methods that would lead to cartography via scientificism from then on. For many years, Fontán's map made Galicia the best cartographically-represented area in Spain, only comparable with certain European regions. For the rest of the 19th century, and in the early 20th century, the 'geometric map' would act as a necessary point of reference for elaborating new maps.

3. Process and stages

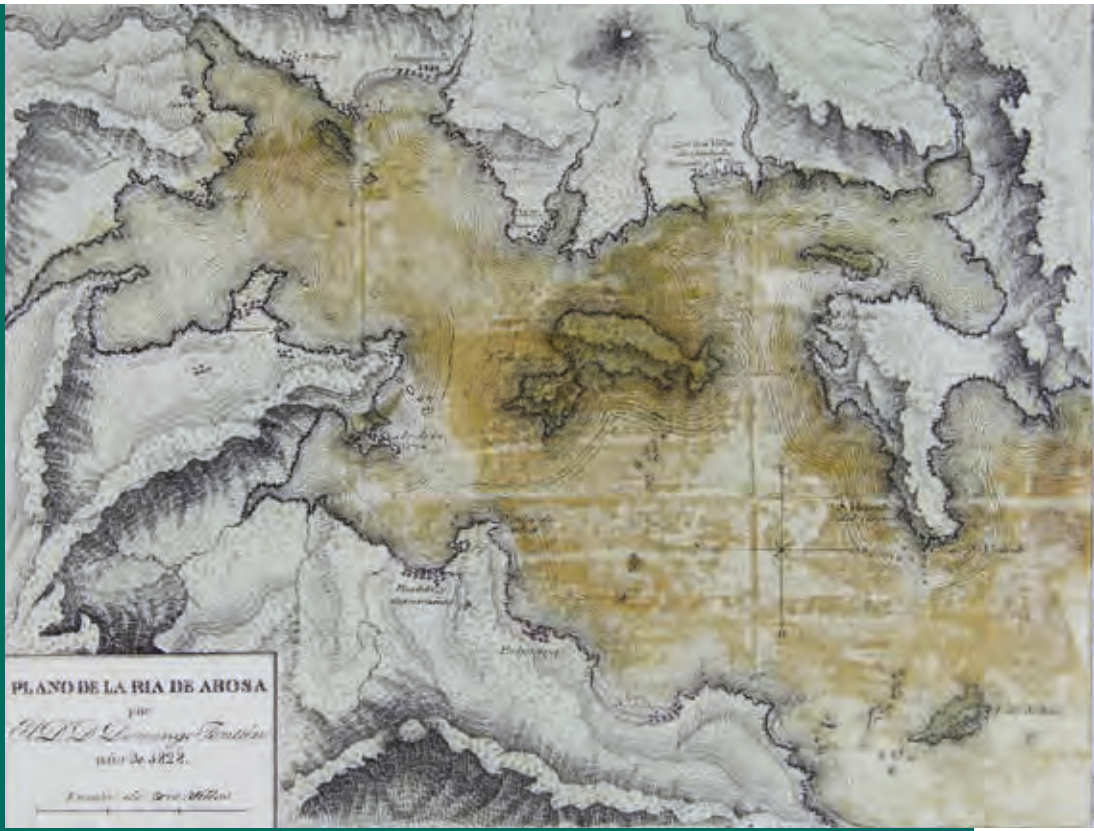
Following a number of trials or preliminary operations carried out the previous year, Fontán began working on his *Geometric Map* in 1817 and continued until 1834. The first step that he took in 1817 was to obtain, by astronomical observation and as accurately as possible, the longitude, latitude and azimuth of the Clock Tower of the Cathedral of Santiago. This was a suitable start within the framework of a correct method: to determine a point and measure a base. Fontán measured two bases, one for each of two networks, which he later linked up. Creating a map of Galicia by means of geodesic measurements and field work was an unprecedented effort. Until then, the geographers who represented Galicia or other regions had generally based their maps on other previous or partial maps, as well as on descriptions, without doing any field work.

In 1820, Fontán measured a base of 2,744 rods (2,291 metres) on the road from Santiago to A Coruña, between Formarís and A Sionlla, and could then start triangulation. The novelty of this method is illustrated by the fact that the central base of Madridejos, established for elaborating the map of Spain, was only measured in 1858. In 1823, Fontán had already surveyed western Galicia (the modern-day provinces of A Coruña and Pontevedra) and, in 1826, he published a partial preview of his map in Sebastián Miñano's *Diccionario geográfico-estadístico de España y Portugal* ('Geographical and Statistical Map of Spain and Portugal'). This includes, for example, the 'Map of the lands adjacent to the three rias of La Coruña, Betanzos and Ferrol, called Las Mariñas' and the 'Map of the Ria of Arosa'.

In 1828, he measured the base of O Corgo, on the road from Lugo to Castile, with a result of 5,975 rods (4,989 metres). After this point, he surveyed the eastern half of Galicia and the nearby areas of Asturias and El Bierzo. The two bases measured by Fontán are marked on his geometric map.

Heights, given in Castilian rods, were determined at sea level in Noia. Fontán was helped in these tasks by his brother, the doctor Andrés Fontán Rodríguez, who at pre-established times – and whilst Domingo made observations at the points where height needed to be measured – conducted meteorological observations (pressure and temperature) in Noia, so that subsequent corrections and calculations could be made. Not all heights were determined with a barometer; some were calculated trigonometrically.

Following the criteria of European cartographic bodies regarding the representation of relief, Fontán chose to use hachures to engrave the *Map*. This system consists in conveying the appearance of relief using small strokes, known as hachures, the direction of which is perpendicular to contour lines,



Map of the Ria of Arousa (1828)

Source: Library of Galicia, Santiago de Compostela

i.e., they are drawn in the direction of the steepest slope. Hachures are flawed in that they do not indicate ascent or descent and may, consequently, lead to confusion. Fontán did not use any of the systems developed to inform of gradients and employed his own graphic system, which successfully conveyed a good appearance of relief, even though gradients could not be quantified.

4. Results

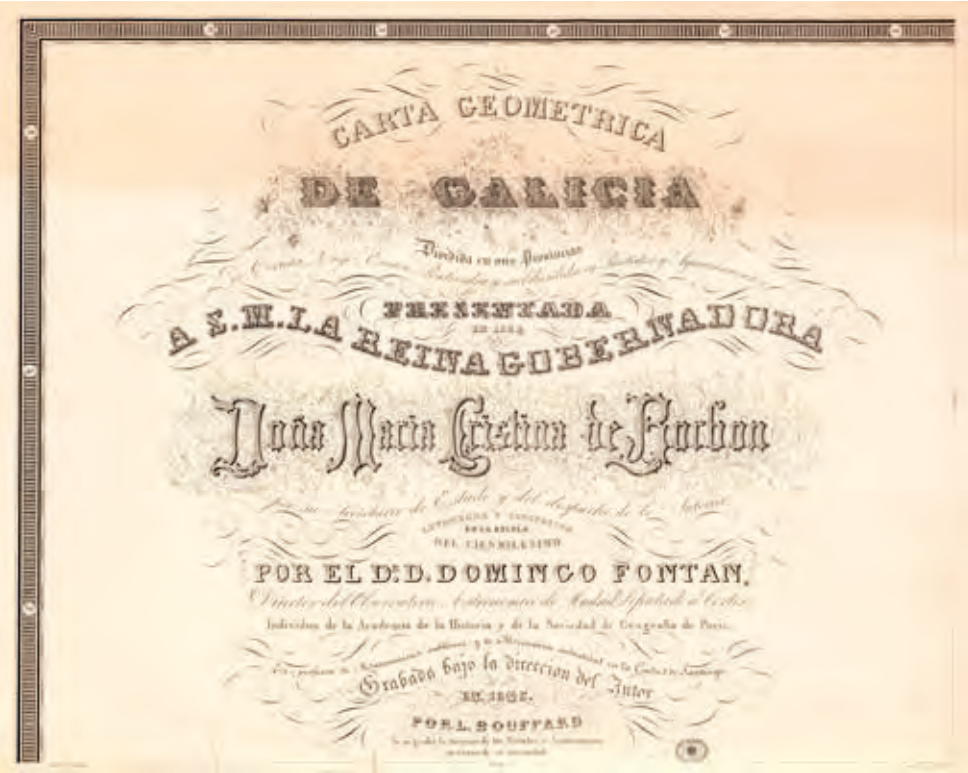
On 1 December 1834, Fontán presented his manuscript before the governing queen, Maria Christina of Bourbon. Seventeen years had passed since he had begun his work. As a result of the need to find an expert engraver to publish the map, it was only printed in 1845. The task was carried out in Paris by L. Bouffard. In view of the large size of the map, Bouffard used a 215 cm × 234 cm box to engrave the *Geometric Map of Galicia* in twelve sections and inserted another small 1:800,000 scale map indicating the 'fundamental triangulation' and as guide to join the twelve sheets. Fontán travelled to Paris in 1838 to personally oversee the engraving of the map.

One of the twelve sections of the resulting map is its cartouche, with a lengthy text containing the title, Fontán's name and a dedication. This engraved cartouche reads: 'Geometric Map of Galicia Divided into its Provinces of Coruña, Lugo, Orense, Pontevedra and subdivided into Judicial Districts and Municipalities: Presented in 1834 to H. M. the Governing Queen Maria Christina of Bourbon by her Secretary of State and of the office of the Interior: produced and built on the one hundred thousandth scale by Mr Domingo Fontan (PhD), [...] Engraved under the direction of the author in 1845 by L. Bouffard. Division into Judicial Districts and Municipalities was not engraved by reason of their temporary nature.'

Lastly, the geometric map represents not only the Galician territory but also

Detail of the *Geometric Map of Galicia*

Source: National Library of Spain



Cartouche of the *Geometric Map of Galicia*

Source: National Library of Spain

a whole strip of Asturias, León and Zamora, as well as some sections of Portugal. This is the logical consequence of one of the goals pursued by Fontán for this project: to lay out infrastructures for access to Galicia. This type of perception of the region was not common, since the land was represented by the map's creator not simply up to its borders but also within its immediate context, and because it maintained continuity of information as far as it was useful. The added surface area constitutes approximately a ninth of that surveyed.

Drawing on his unquestionable experience, Fontán produced his 'Report on the elaboration of the topographic maps of the provinces and general map of the Kingdom [of Spain],' published in the *Revista Jurídica y Administrativa de Galicia* in 1852, although it had been written several years previously.

Because Fontán's map was the best to be created in Spain during the first half of the 19th century, and the only high-quality map of the Galician territory for almost the entire century, Galicia surpassed the rest of the nation in terms of familiarisation with its land. Fontán's map would be the cartographic basis for railway and road projects, amongst others. It would also be a source for producing other maps, most notably including those of the four Galician provinces in Francisco Coello's *Atlas of Spain and Its Overseas Possessions*, published between 1856 and 1865 and which state: 'All the locations and main details of this map have been taken from Mr Domingo Fontán's magnificent map…' On maps of Galicia from the second half of the 19th century, it is common to see the *Geometric Map* indicated as the source for their elaboration or, at least, for the influence of the *Geometric Map* to be detected.

Based on all of the above, Domingo Fontán's *Geometric Map of Galicia* constitutes both a milestone in the history of cartography on the Iberian Peninsula and a symbol for Galicia.

ACTIVITIES AND PROBLEMS

Activities and exercises for the historical section

- Draw up a table of the individuals who lived in Fontán's times who appear in the text and in the Álbum da Ciencia (http://www.culturagalega.org/albumdaciencia/).
- Compile relevant data about them, reflecting the following aspects: years of birth and death, scientific disciplines, institutions where they worked, places where they undertook their professional careers, main discoveries and relationships between them.
- Compare today's map of Galicia with that drawn by Fontán, select your district and examine the changes that have taken place over the time which has elapsed
- In the early decades of the 19th century, absolutists attempted to curb the dissemination of liberal ideas. Find out the details of absolutist repression in the periods 1814-1820 and 1824-1833.
- What did Xosé Rodríguez's work towards the exact calculation of the value of a metre involve?
- Was Galicia organised into provinces in Fontán's times?
- Fontán was involved in developing the first railway lines across Galicia. Find out about the early stages of the railway in Galicia and create a map showing the railway lines at different points of the 19th and 20th centuries.

Biographical and historical test on the famous figure of Domingo

1. In which Galician province is Domingo Fontán's hometown (Porta do Conde, municipality of Portas)?
   a. Ourense
   b. Lugo
   c. Pontevedra

2. Aside from being a geographer and scientist, Domingo Fontán was a liberal politician and held the position of Member of Parliament on several occasions. Which provinces did he represent?
   a. A Coruña, Pontevedra and Ourense
   b. A Coruña and Lugo
   c. Pontevedra and Lugo

3. As a result of his liberal stance, Domingo Fontán underwent several 'cleansing' processes between 1814 and 1840. How many in total?
   a. 3
   b. 5
   c. 2

4. In his capacity as a Member of Parliament between 1836 and 1843, and because of his geographical knowledge, did Domingo Fontán take a stance on the dispute between Pontevedra and Vigo over the provincial capital in 1833?
   a. Yes, he backed Pontevedra.
   b. Yes, he backed Vigo.
   c. He did not defend either location.

5. Which other Galician scientist and mathematician was a teacher of Fontán's and a key figure in the future design of his *Geometric Map*?

   a. José Alonso López y Nobal
   b. Ramón de la Sagra
   c. Xosé Rodríguez González, 'the Mathematician of Bermés'

6. Which two disciples of Fontán's were the most prominent in the scientific world?

   a. Manuel Rufo Fernández and José Valladares
   b. Ramón de la Sagra and Casiano de Prado
   c. Xosé Rodríguez González and José Alonso López y Nobal

7. What was the scale used by Fontán when designing the *Geometric Map*?

   a. He did not use a scale.
   b. The one hundred thousandth scale (1:100,000).
   c. The ten thousandth scale (1:10,000).

8. Why was Domingo Fontán's choice of scale for designing the *Geometric Map* important?

   a. Because this scale was widely used in the world of cartography.
   b. Because of the level of detail implied by the scale.
   c. Because the scale served to introduce the metric system.

9. How long did it take Fontán to create the *Geometric Map*?

   a. 17 years (1817-1834)
   b. 10 years (1817-1827)
   c. Three years (1817-1820)

10. What was the main reason behind Domingo Fontán creating his masterpiece, the *Geometric Map*?

a. To lay down the infrastructure routes for access to Galicia.
b. For him to enter an international geography competition.
c. For him to complete a general map of Spain which already existed.

11. How did Fontán spend the last years of his life?

a. Contemplating.
b. Working for his family business and designing Galicia's first railway line, the Santiago-Carril line.
c. Travelling.

12. What is the name of the Galician geographer who put Galicia on the world map?

a. Antonio López Rodríguez
b. Domingo Fontán Rodríguez
c. Francisco Manuel Otero Rodríguez

TEST SOLUTIONS

1. c; 2. c; 3. a; 4. a; 5. c; 6. b; 7. b; 8. c; 9. a; 10. a; 11. b; 12. b

Activities and exercises for the geographical section

- Domingo Fontán's *Geometric Map of Galicia* (*GMG*) was made to a 1:100,000 scale. What is the field value of a length of 7.3 cm, as measured on the map?
- And how much does a length of 11 km, as measured on the field, measure on the map?
- What is the surface area of a square with a side length of 3 cm, as drawn on the map? What about the surface area of a square with a side length of 6 cm?
- Draw the applicable graphic scale on the part of the *GMG* corresponding to the area where you live.
- We know that compasses help us to orientate ourselves. Why do you think that Fontán did not use a compass to create the *GMG*?
- If we are at the port of Carril, on the Ria of Arousa, and wish to take a boat to the port of Santa Uxía de Ribeira, what direction, in relation to the north, should we take and what distance should we cover?
- [Where there is smoke, there is fire.] A forest ranger on Mount Lobeira (south of Vilagarcía) sees a column of smoke in the N 315° E direction and

another ranger on A Curota (northwest of A Pobra do Caramiñal) sees the same column in the N 80° E direction. Where is the fire?

- Look at the coordinates on the map. They refer to the 'western longitude of the meridian of San Fernando' in Cádiz. Why do you think Fontán used this meridian? What meridian is currently used on official Spanish maps? Has the same one always been used?

- Select a section of the map that is close to your town or city. Place several transparent (acetate) sheets on top of one another and trace different layers of information from the map (places, rivers, roads, etc.) on each sheet. Is there any information missing? Is certain information wrong or obsolete? Look up the information you need on a current 1:100,000 scale map and correct or update as necessary. You are creating a geographical information system!

Problems

All the activities in this teaching unit have been designed for students to work interactively and simultaneously with Fontán's *Geometric Map,* the GeoGebra program (which allows the user to insert images, so as to work with angles, triangles, etc.), Google Earth Pro and the SIXPAC viewer, https://sixpac.xunta.es/visorhtml5/#.

The partial images of the *Geometric Map* have been taken from http://bibliotecadigital.rah.es/dgbrah/es/consulta/registro.cmd?id=15909 and the image of its fundamental triangulation has been taken from http://blogs.lavozdegalicia.es/mapafontan/files/2012/07/triang3.jpg.

Problem no 1. The base of O Corgo. First triangle

Once the work to determine the outer edges of the base of O Corgo was complete, a new station needed to be located. Fontán decided to place it on Mount Bidueiros, near the village of Espasande, facing the north. Using this piece of Fontán's map, we will now calculate the height of this mountain (spelt 'Vidueiros' on the map), knowing that it was the first station calculated by Fontán after seeing that the base of O Corgo measured 5,975 rods (a Castilian rod corresponds to 0.835 m). Using the three stations, Fontán built his first triangle in Galicia's eastern area.

The angles of elevation that Fontán calculated by focusing his theodolite on the summit of Mount Vidueiros from the two ends of the base were a = 1° 10' 25" from the western end and b = 1° 29' 21" from the eastern end. Considering that the difference in height between the two ends of the base is insignifcant, can you calculate the height of this new station?

Problem no 2. An impossible line of sight?

Is it possible to see the peak of San Pedro da Porta from San Bartolomeu da Mota, by means of a line of sight over Boimorto?

Below are some details, alongside part of Fontán's map, for you to find out the answer.

	A	B	C	D	E	F
1	Location		1 rod = 0.836 m	Measurements on the *G. M.* (height)		Distances (SIXPAC)
2	Latitude	Longitude	Name	Rods	Cells	Metres
9	43° 0' 14,9" N	8° 7' 57,30" W	San Pedro da Porta	599		
11	43° 0' 14,69" N	8° 7' 57,30" W	Boimorto	565	C11-C9	9,810
12	42° 59' 6,55" N	8° 12' 21,18" W	San Bartolomeu da Mota	542	C11-C12	6,350

Problem no 3. The A Gudiña-A Canda-Chaguazoso (O Cabezo) triangle

To calculate the height of the next station, located on O Cabezo (Chaguazoso, Ourense), Fontán placed two stations in two well-known places: the first in A Gudiña, at an altitude of 1,191 rods, and the second in A Canda, at an altitude of 1,451 rods. Fontán knew the distance between the two towns (13,510 m) from previous measurements. Taking measurements using the Gambey theodolite, Fontán calculated the angle of elevation from A Gudiña to O Cabezo, with g = 0º 18′ 6″, and the angle of depression between A Canda and O Cabezo, obtaining d = 0º 44′ 6″.

Based on this data, can you provide the height of the station located on O Cabezo?

Do you know what type of triangle he obtained?

The top of Mount Cabezo, with Chaguazoso in the background

Problem no 4. Surveillance with drones

The *Geometric Map* includes four stations located at the following points: C, Mount Sabucedo, in the mountain range with the same name, 768 rods in height; D, Pico de la Torre (O Pico), 837 rods; E, Pena Guhía (Goía), 1,053 rods, and F, Coriscado (Guriscado), 1,121 rods.

If we were to join up these points, they would form the most basic skeleton of a geometric body. Do you know which one?

To watch out for potential forest fires, we use a drone that covers the area by moving from one position to another along a straight line, departing from and going back to Mount Sabucedo after passing over points D, E and F. How many kilometres would our drone travel?

What is the maximum angle of elevation that the drone would have to face?

Problem no 5. A cable car in Ourense

As part of a tourism plan for promoting the Galician mountains, the Galician Regional Government is considering the installation of a cable car on Penagache, with an altitude of 1,482 rods according to Fontán's *Geometric Map* and located southwest of Celanova, near the border with Portugal. The potential locations for this cable car are the parishes of Xacebáns (680 m) in the municipality of Quintela de Leriado, Santa María de Gorgua (650 m) in the municipality of Padrenda, or Bangueses de Abaixo (740 m) in the municipality of Verea. According to a local who works in the Land Registry, the heights of these locations appear in SIXPAC and, seemingly, do not coincide with the heights indicated on the *Geometric Map*.

The ideal angle for laying the cables must be between a minimum of 8° and a maximum of 10°, although the lowest possible value is preferable.

Under these conditions, what is the best option? Bear in mind that some locals point to the Aguillón mountain range as a potential obstacle.

Problem no 6. From Mount Faro to Fontardión Peak

In this image, taken from Fontán's *Geometric Map*, find the stations located on Mount Faro, near Mugardos, on Fontardión Peak, north of the town of Eume, and on Mount Marraxón, just outside Fene.

Draw the triangle formed by these stations and analyse the type of triangle that they create, based on its sides and angles.

Problem no 7. Straight lines and angles in the area of O Pindo

a) Measurements of heights on the *Geometric Map* are indicated in Castilian rods: the most common unit in Fontán's times. Calculate the heights in metres of Mount O Pindo, Mount Ézaro (M. Ezaro on the *Geometric Map*) and Mount Aros.

b) Draw the straight line that crosses O Pindo and Mount Ruña.

c) Draw the straight line that crosses Coiro and Dumbría. What is its relationship with the previous line?

d) Draw the straight line that crosses Grixoa (Grijoa) and Landeira.

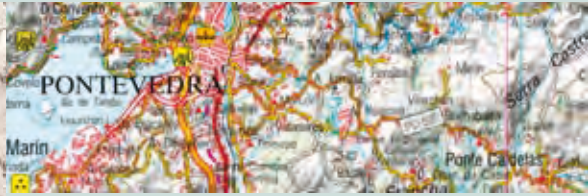
e) What is the relationship between all these lines?

Problem no 8. Pontevedra-Ponte Caldelas

In view of two specific portions of maps of the area of Pontevedra, one from the *Geometric Map* and another, current map obtained from the page http://sigpac.mapama.gob.es/fega/visor/#, it is particularly interesting to stop and analyse the changes that have taken place over the last two hundred years.

What conclusions can you draw? What changes can you detect in the towns and cities shown on the two maps?

Using any IT tools that you deem necessary, can you name the peaks just north of Caldelas? What are their heights in both metres and rods?



Problem no 9. 'I can see Vigo, I can see Cangas…'

There is a Galician folk song that goes: 'I can see Vigo, I can see Cangas, / I can also see Redondela…'

Although the song goes on, where do you think the best place to sing it is? Explore the possibilities by looking at the *Geometric Map* and the image taken from Google Earth Pro.

Justify your choice formulating the three alternatives: by land, by sea and by air. You should keep in mind the Alto de Sidades, located north of Moaña.

Problem no 10. The particle accelerator

There is a project for building a particle accelerator and the technicians involved have decided that, because of the geographical characteristics of the area, the ideal place for it would be near Celanova, in the province of Ourense.

As you know, an accelerator is round in shape and is buried several tens of metres under ground level.

The length of its circumference must be 44 km and its core must be vertically below a town; Celanova has been chosen for its characteristics.

Another condition is that, for safety reasons, the cooling and evacuation towers for the staff working inside the accelerator must be situated vertically in relation to at least four towns or populated areas.

A variation of ±10 metres (ideally ±5 m) is accepted for measuring the radius. Look at the *Geometric Map*: is it possible to build this facility whilst meeting the requirements given?

Problem no 11. A bizarre researcher

A bizarre detective has taken to studying the area around the base of O Corgo on Fontán's map, so as to find out in what order the cartographer built his triangles starting from this base.

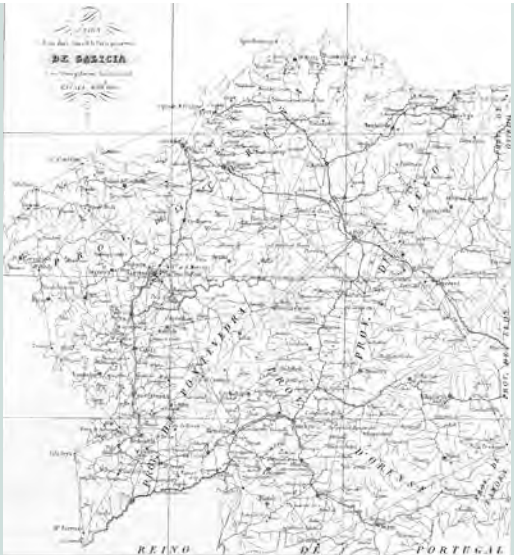
If you take a close look at the image, you will also find this out. How many triangles can you build in order?

Hands-on activity

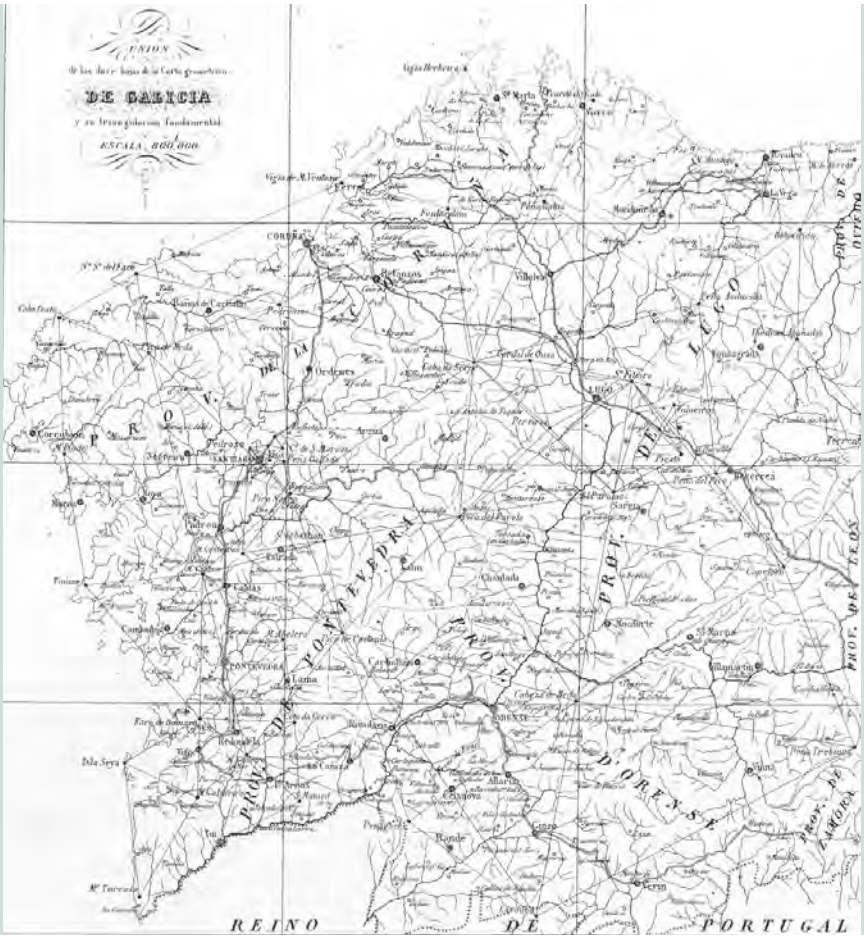
The *Geometric Map* jigsaw puzzle

Taking the map that shows the fundamental triangulation as your starting point, build a jigsaw puzzle of the map of Galicia.

It will not be difficult, as you can choose the number of triangular pieces and the twelve rectangular parts that the map is divided into are already available. This can serve as an initial approach to the *Geometric Map*. It can simply be an easy game intended for children if the dividing units are big enough, or a more complex game if the pieces are smaller.



See the enlarged map on the next page.


UNION
DE GALICIA
ESCALA 800.000
CORUÑA
Villalba
Lugo
Ordenes
Arzua
Pontevedra
Lalin
Chantada
Ribadavia
Orense
Ronda
Cerin
REINO DE PORTUGAL

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d. Fontán's mill in Paderne, Lousame:
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Films and exhibitions

- *Domingo Fontán: la pasión por la cartografía*, 1 videocassette (VHS), 28 min, Madrid, Centro Nacional de Información Geográfica, 1996 [finalist at the Premios Agapi 96 in the category of Best Documentary].

- Exhibition *Portas e Fontán: a memoria histórica do territorio*, Arquivo da Deputación Provincial de Pontevedra, 2011.

- Video *Domingo Fontán: la pasión por la cartografía* (TVG, 1996, 26 minutes, director: V. Carrera).

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