Bicentenary of the triangulation of the Pyrenees (1825-1827) where history, geodesy and mountains meet (13827)

Bernard FLACELIÈRE and Pierre BRIOLE, France

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SUMMARY

In 2025, the bicentennial of the Pyrenees geodetic campaign (1825-1827) was celebrated, honoring military surveyors Jean-Baptiste Corabœuf, Pierre Peytier, Paul-Michel Hossard and Jacques-Prosper Testu. Their mission, conducted under extreme conditions, established a network of 42 geodetic points, 24 of which are still in use today by IGN (French Geographical Institute) with an accuracy of 10 cm compared to modern coordinates (RGF93). Two centuries later, the 28th Geographic Group (GG) repeated the ascent of Balaïtous, combining historical tribute, GNSS measurements, and solidarity (€8,500 raised for wounded soldiers). These commemorations highlighted the importance of sustainability of geodetic networks, rigorous documentation, and preservation of benchmarks, ongoing challenges for tectonic studies and modern cartography. An adventure blending memory, mountains, and technology.

RÉSUMÉ

En 2025, le bicentenaire de la campagne géodésique des Pyrénées (1825-1827) a été célébré, rendant hommage aux ingénieurs-géographes Jean-Baptiste Corabœuf, Pierre Peytier, Paul-Michel Hossard et Jacques-Prosper Testu. Leur mission, menée dans des conditions extrêmes, a établi un réseau de 42 points géodésiques, dont 24 sont encore utilisés aujourd'hui par l'IGN avec une précision de 10 cm par rapport aux coordonnées modernes (RGF93). Deux siècles plus tard, le 28^{e} Groupe Géographique (GG) a réitéré l'ascension du Balaïtous, combinant hommage historique, mesures GNSS et solidarité (8 500 € collectés pour les blessés de l'Armée de Terre). Ces commémorations ont mis en lumière l'importance de la pérennité des réseaux géodésiques, de la documentation rigoureuse et de la conservation des repères, des enjeux toujours actuels pour les études tectoniques et la cartographie moderne. Une aventure mêlant mémoire, montagne et technologie.

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INTRODUCTION

In 1817, France launched an ambitious cartographic project: to replace Cassini's map, deemed inaccurate, with a military *(État-major)* map (1:80,000), adapted to military and administrative needs. Among the key campaigns, the Pyrenees campaign (1825-1827) stands out. Four engineer-geographers, Corabœuf, Peytier, Hossard and Testu, took up the challenge of measuring 42 first-order points in extreme conditions: altitude, snow, fog and diplomatic tensions with Spain.

Armed with Gambey theodolites, revolutionary instruments for the time, they triangulated iconic peaks such as Balaïtous (3,144 m), where they camped for eight days in freezing temperatures. Their work went beyond simple planimetry: they innovated in altimetry, seeking to determine the relative altitude of the Atlantic and Mediterranean seas, thus laying the foundations for modern cartography.

Two centuries later, their legacy lives on: 24 of the 42 points are still used by the IGN, with an average accuracy of 10 cm compared to modern coordinates (RGF93). This exceptional longevity can be explained by rigorous protocols (choice of stable supports, exhaustive documentation) and meticulous conservation of the markers. Today, this network offers a unique window on the slow tectonic deformations of the Pyrenees, a major challenge for contemporary geosciences.

A scientific adventure in which rigour, innovation and perseverance led to the creation of a geodetic network that is still in use today, two centuries after its conception.

HISTORICAL BACKGROUND

1.1. From Cassini's map to the military map

The limits of Cassini's map (1756–1790)
In the mid-18th century, Cassini's map, the first systematic topographical map of France, marked a major advance. Comprising 181 sheets at a scale of 1:86,400, it covered the entire

territory and offered an unprecedented representation of the kingdom. However, despite its ambition, this map had two major limitations:

- A lack of precision: the techniques of the time, based on local surveys and approximate triangulations, did not provide sufficient accuracy for the military and administrative needs of the 19th century.
- The absence of altimetric data: Cassini's map focused on planimetric representation (towns, roads, rivers), but provided no information on relief, which was a handicap for military strategy and land use planning.

These shortcomings became glaringly apparent at the dawn of the 19th century, when France, emerging from the Napoleonic Wars, urgently needed accurate and reliable maps to modernize its administration and strengthen its defenses.

The Napoleonic project and its revival under Louis XVIII

In 1808, Napoleon I, aware of these challenges, entrusted Charles Rigobert Bonne (1771-1839), head of the Empire's topographical office, with the task of drawing up a new map of France. Bonne proposed an ambitious project, combining geodetic triangulation and cadastral surveys, but successive wars delayed its implementation.

It was not until 1817, during the reign of Louis XVIII, that the project was relaunched thanks to the impetus of Commander Maxime Auguste Denaix (1777-1844). Denaix advocated for a unified map that would meet both military (strategy, logistics) and civilian (cadastre, development) needs. His memorandum found decisive support from Pierre-Simon de Laplace (1749-1827), who presented the project to the government.

On 11 June 1817, a commission was created to define its foundations. A month later, a royal decree formalised the General Staff Map, which would be produced on a scale of 1:80,000 and comprise 274 sheets. Its production spanned from 1820 to 1866, mobilising generations of engineer-geographers.

This map breaks new ground by incorporating:
- A first-order geodetic network based on precise triangulations;
- Altimetric data obtained using trigonometric levelling techniques;
- Collaboration with the land registry for a representation of the territory that is both topographic and fiscal.

1.2. The geodetic grid: the foundation of precision

- To ensure the accuracy of the new map, geographical engineers are designing a geodetic framework structured around *(Figure 1)*.
- Meridians: north-south networks, with the Paris meridian (measured by Delambre and Méchain between 1792 and 1798) serving as the central reference point.
- Parallels: east-west networks, with the Pyrenees parallel becoming a key axis for connecting the triangulations of southern France.

This network is based on geodetic bases measured with extreme precision. The Perpignan base, established by Delambre and Méchain, is extended westwards by a second base in Dax (1827), allowing the scale to be controlled across the entire Pyrenean mountain range.

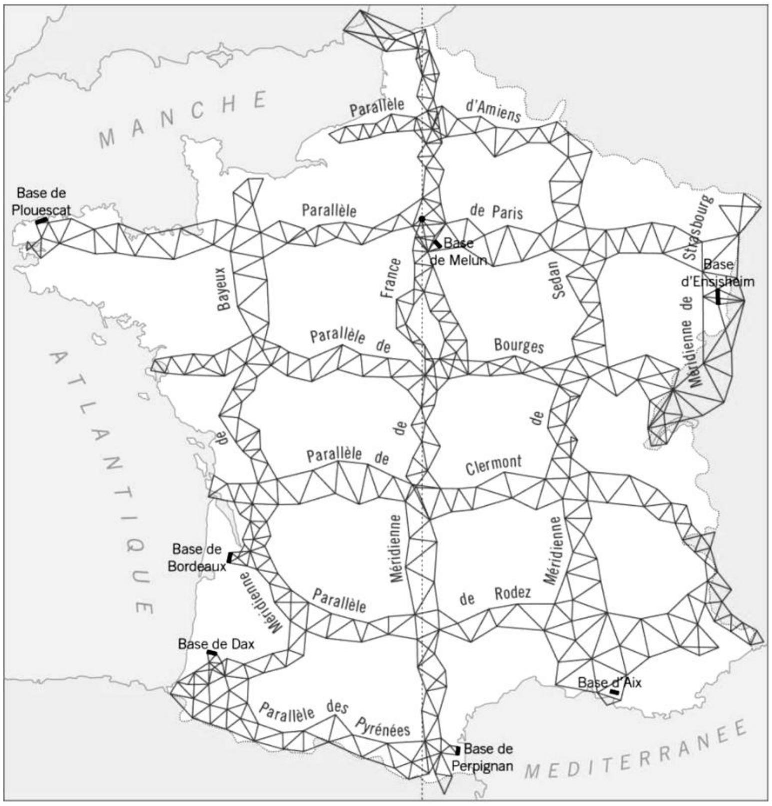

Figure 1. Map of the network of parallels and meridians in France (1825). (Source : Arnaud, 2022)

The 42 first-order points in the Pyrenees

In the Pyrenees, the 1825–1827 campaign aimed to establish 42 first-order points, spaced approximately 30 kilometres apart to optimize visibility and limit measurement errors. These points had to meet strict criteria:

- Mutual visibility: each summit must be visible from its neighbors to enable triangulation.
- Accessibility: despite the constraints of the terrain, the sites must be accessible to teams and their instruments.
- Stability: the signals, built of stone, must be able to withstand extreme weather conditions (wind, snow, frost).
- Respect for the Spanish border: a geopolitical challenge, as evidenced by the Altobiscar incident (1825), where Peytier and Hossard were expelled by the Spanish authorities while attempting to install a signal there.

A lasting legacy: today, 24 of these 42 points are still part of the IGN's geodetic network, an exceptional rate of durability for measurements that are two centuries old. Their accuracy, verified by comparison with the RGF93, averages 10 centimeters, a testament to the rigor of the engineers of the time.

Technical constraints and innovations, the Pyrenees pose unique challenges:

- Weather conditions: persistent fog, early snowfall, and strong winds delayed measurements and forced prolonged bivouacs (up to 8 days at Balaïtous in 1826);
- Logistics: transporting instruments (Gambey theodolites) and materials for constructing markers, sometimes on the backs of men or mules;
- Diplomacy: negotiations with Spain to gain access to certain border peaks, often unsuccessful.

To overcome these obstacles, teams are innovating:

- Stone markers: designed to withstand the elements and remain visible from 30 km away;
- Trigonometric leveling: a revolutionary technique for measuring altitudes accurately, without relying on barometers, which are unreliable in the mountains;
- Scientific bivouacs: camps set up at high altitudes (such as at Montcalm or Tuc de Maupas), where engineers endure cold and isolation to complete their surveys.

THE 1825-1827 CAMPAIGN, A GEODETIC EPIC

2.1. Key players: engineers in the service of science

The Pyrenees geodetic survey (1825-1827) was led by four engineers and geographers from the École Polytechnique, whose skills and determination left their mark on the history of French cartography. Jean-Baptiste Coraboeuf (1777-1859): a veteran of the Egyptian campaign, he was the head of the mission. His experience and leadership were crucial in organizing the fieldwork and coordinating the teams. In particular, he supervised the measurements in the eastern part of the Pyrenees.

Pierre Peytier (1793-1864): a rigorous and enduring officer, he was responsible, along with Hossard, for the western part of the network. His name remains associated with the heroic ascent of Balaïtous in 1825, a feat that symbolizes the audacity of this campaign.

Paul-Michel Hossard (1797-1862): a close collaborator of Peytier, he shared with him the challenges of the most hostile peaks. Their duo is famous for having braved the elements for eight days on Balaïtous in 1826, while taking measurements of unparalleled precision.

Jacques-Prosper Testu (1797-1864): he worked alongside Coraboeuf in the eastern part. His sketches and surveys, such as those of Montcalm, testify to his scientific rigor.

Together, these men embody the alliance between science, courage, and perseverance, qualities essential to the success of such an ambitious mission.

Methodology: precision and innovation

To accomplish their mission, the engineer-geographers relied on methods that were revolutionary for the time:

- First-order triangulation: a technique that involves measuring the angles between distant points (up to 30 km apart) to deduce their relative positions. This method, already used by Delambre and Méchain for the Paris meridian, was adapted here to the mountainous terrain of the Pyrenees.

- Trigonometric leveling: to answer the scientific question of the relative altitude of the Atlantic and Mediterranean seas, engineers measured the differences in elevation between points using trigonometric calculations, thus avoiding the inaccuracies of barometric leveling.
- Gambey theodolites *(Figure 2)*: relatively light and robust instruments, specially designed for work in the mountains. Their accuracy (to within one arc second) allows for reliable angular measurements, even in difficult conditions.
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Figure 2. Gambey Théodolite (1825).

2.2. Challenges and achievements: between heroism and precision

The teams led by Peytier, Hossard, Corabœuf, and Testu face unprecedented natural and logistical challenges:

Harsh weather conditions: persistent fog, strong winds, snowfall even in summer, and freezing temperatures. In August 1826, Peytier and Hossard were stranded for eight days at the summit

of Balaïtous (3,144 m), where the temperature dropped to -8°C. They had to camp in a tent torn by the wind, with their biscuit rations almost exhausted.
Hostile terrain: peaks such as Balaïtous and Montcalm require mountaineering experience to reach. Rockfalls, cliffs, and snowfields make every climb perilous.
Complex logistics: transporting instruments (theodolites, tripods) and materials to build stone markers, often on the backs of men or mules.
The teams also had to improvise shelters at high altitude, such as the shepherd's hut where Coraboeuf and Testu stayed at Montcalm.

Diplomatic challenges, the Spanish border
The proximity of Spain adds a geopolitical dimension to the mission. Two notable incidents illustrate these tensions:

Refusal of access to Montardo d'Aran (1825): Spain prohibited the French from measuring this strategic peak in the Aigues Tortes massif. Engineers were therefore forced to create a substitute point, the Grandan de Montagu, which introduced a detour into the network.
Expulsion from Altobiscar (October 1825): Peytier and Hossard, who attempted to install a signal there without authorization, were arrested by an officer of the Spanish army.
Expulsion from Altobiscar (October 1825): Peytier and Hossard, who attempted to install a signal there without authorization, were arrested by a Spanish officer accompanied by fifteen men. Colonel Brousseau reported:
"*Mr. Hossard was busy directing the work on October 12 when a senior Spanish officer [...] came to ask him if he had authorization from the Spanish government. When he replied in the negative, the Spaniard asked him to suspend [the work].* "
The point was finally established on Lissératéca, on French territory, but this solution remained suboptimal for the continuity of the network towards Spain.
These incidents reveal the political stakes of cartography: the delimitation of borders and sovereignty over the Pyrenean peaks, which were still disputed at the time.

The construction of signals
In order for triangulations to be possible, engineers must mark points in a visible and durable manner. They therefore build stone markers, pyramids 2 to 3 meters high, designed to:
- Be resistant to weather conditions (wind, snow, frost);
- Be visible from 30 km away, even in bad weather;
- Serve as stable reference points for future measurements.

Some of these signals have survived for centuries:
- The one at Pic de Maupas *(Figure 3)* was still visible in 1930, as shown on a postcard from that period;
- At Balaïtous, Charles Packe reported in 1864 that the remains of the 1825 signal were still standing, proof of its solidity;
- At Pic de Troumouse, the signal that collapsed in 1913 was restored by cartographer Maurice Heid.

These structures, although no longer standing today, symbolize the tangible legacy of the work.

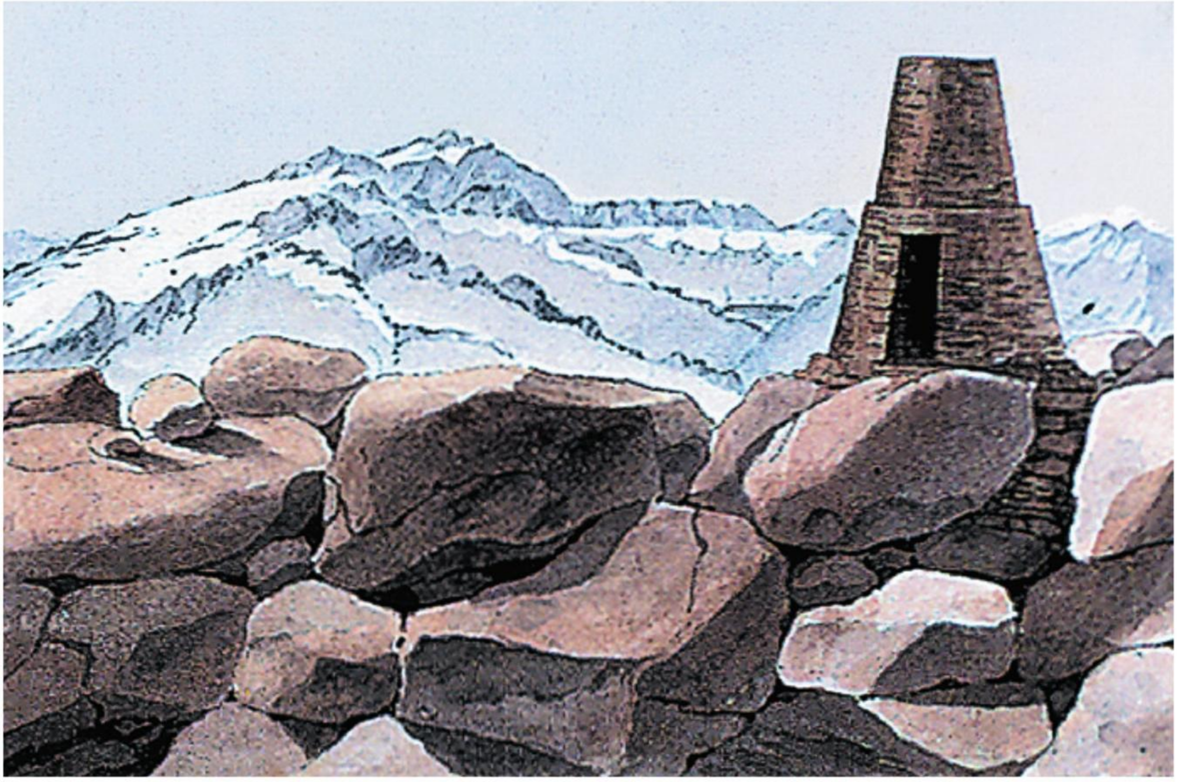

Figure 3. Watercolor painting of the Pic de Maupas signal (1825).

2.3. Results and precision, an unmatched scientific legacy

Remarkable accuracy for the time

The measurements taken in 1825-1827 were compared two centuries later with modern RGF93 data. The results are spectacular:

- Average quadratic deviation of 10 cm between the 1826 coordinates and those of RGF93 for the 24 common points, a level of precision that demonstrates the rigour of the protocols and the quality of the instruments *(Figure 4)*;
- Accuracy of the Perpignan base: adjustment of the network reveals a scale bias of 2 ppm (parts per million), i.e. an error of 25 mm over 12.5 km. This performance complies with the requirements of Delambre and Méchain.

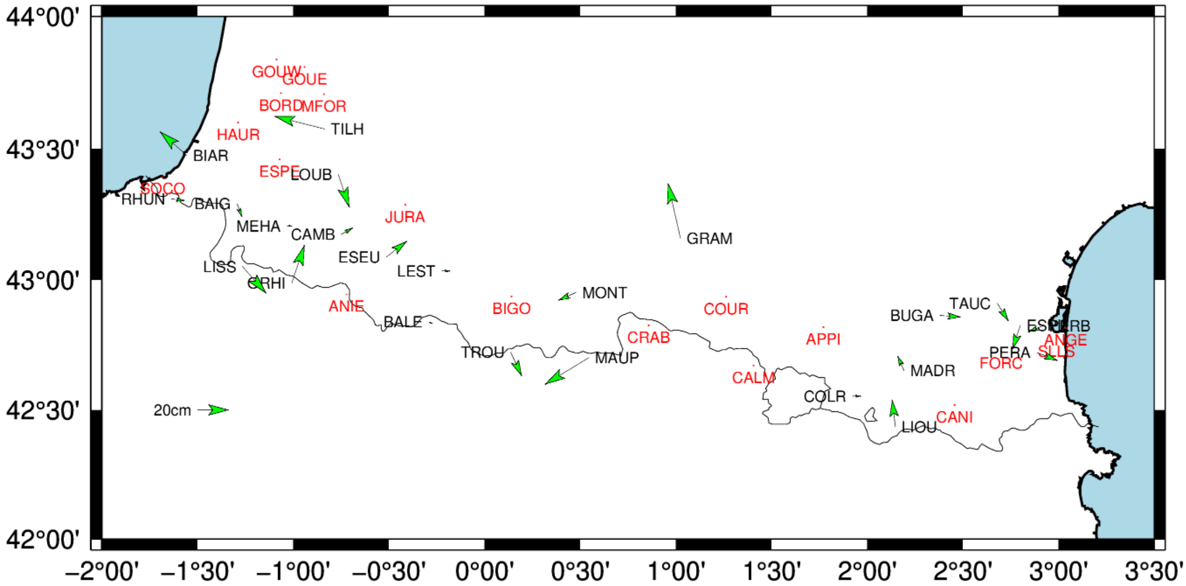

Figure 4. Graph showing coordinate differences between 1826 and RGF93.

A network that is still relevant today

Today, 24 of the 42 points measured in 1826 are still part of the IGN's (French Geographical Institute) geodetic network, an exceptional rate of durability (57%). This longevity can be explained by:

– Site selection: stable peaks (bedrock) that are accessible and offer optimal visibility.
– Measurement quality: strict protocols (triangulation, trigonometric levelling) and redundant observations.
– Preservation of benchmarks: transmission of knowledge between generations of geodesists, from the IGN to contemporary researchers.

THE BALAÏTOUS, SYMBOL OF THE CHALLENGES OF THE PYRENEES

3.1. The historic ascent of 1825: a founding achievement

The conquest of a giant

On 3 August 1825, after four unsuccessful attempts, officers Pierre Peytier and Paul-Michel Hossard finally managed to climb Balaïtous (3,144 m), a summit reputed to be inaccessible. Their ascent, carried out as part of the Pyrenees geodetic campaign, marked a turning point in

the history of French cartography. Equipped with Gambey theodolites and unwavering determination, these pioneers braved extreme conditions.
Their first attempt, in July 1825, led them astray to the Pic du Palas, neighbouring the Balaïtous. A ridge of this peak would henceforth bear the name *Arête des Géodésiens* in their honour (Geodesists' Ridge).
In 1826, while taking triangulation measurements, they were stranded at the summit for eight days, facing temperatures dropping to -8°C, fierce gusts of wind, and a tent torn by the elements. Food supplies were running low, and fragile instruments had to be protected at all costs. Their improvised bivouac, described in their reports, reveals their exceptional resilience.
Their achievement was not limited to the ascent: they marked the summit by building a stone signal, designed to withstand the elements and serve as a landmark for future triangulations. This marker, the remains of which were rediscovered in 1864 by British Pyrenean mountaineer Charles Packe, bears witness to their lasting legacy. Packe, convinced that he was the first to conquer the Balaïtous, was astonished to discover traces of their passage, proving that history is sometimes written in oblivion before being rediscovered.

3.2. The Bicentennial in 2025: between tribute and innovation

A commemorative climb

On 3 August 2025, exactly two centuries after Peytier and Hossard's feat, a team from the 28th Geographic Group (GG), the only regiment of military geographers in France, repeated the ascent of Balaïtous. This expedition, which is scientific, historical and charitable in nature, pays tribute to their predecessors while incorporating modern technology:

- A demanding route: 1,500 metres of elevation gain, including technical passages such as the Beraldi ledge (2,900 m), a vertiginous rocky ridge where the soldiers progress roped together with mountain guides;

Figure 5. GNSS survey on top Balaïtous.

- Scientific mission *(Figure 5)*: At the summit, military geographers conduct a GNSS (Global Navigation Satellite System) survey to update the coordinates of Balaïtous with centimetre precision. The data is processed using Leica Infinity software, based on the French Permanent GNSS Network (RGP).

- As the original geodetic point no longer exists, the coordinates are compared with those of the pillar of the *Instituto Geográfico Nacional*, Spain (1981 to 2009), in ETRS89, UTM30N, with a decimetre discrepancy.
- Solidarity tribute: the climb is also an opportunity to support wounded Army personnel, as a fundraising campaign launched in partnership with Terre Fraternité - ADO has raised €8,500, which will be donated to the association at a ceremony on 26 September 2025.

A bridge between two eras

This commemoration illustrates the continuity between past and present:

- Same challenges, different tools: while Peytier and Hossard used theodolites and surveyor's chains, their successors here use GNSS receivers, yet the spirit remains the same: measuring, mapping, anticipating;
- Living memory: as expressed by an officer of the 28th GG: *'We are not just soldiers or geographers. We are the guardians of a memory that transcends borders and eras.'*;
- Transmission of expertise: the 2025 ascent is also an opportunity to train young military geographers in mountain and surveying techniques, thus perpetuating two centuries of expertise.

Precision that stands the test of time

These comparisons reveal several lessons:

- The rigour of the 1825 protocols: the engineer-geographers used redundant methods (cross-triangulation, repeated levelling) to minimise errors, and their attention to detail explains the durability of their measurements;
- The stability of geodetic points: the Pyrenean peaks, chosen for their geological stability, have moved very little in two centuries, validating their strategic choice for establishing the signals;
- The contribution of modern technologies: GNSS measurements taken in 2025 confirm historical data while providing additional accuracy (to the order of centimetres), which is useful for contemporary tectonic studies.

A symbol for future challenges

Today, Balaïtous is much more than just a geodetic peak:

- A place of remembrance: it recalls the courage of pioneers and the importance of passing on knowledge;
- A scientific laboratory: its coordinates, measured two centuries apart, provide a reference point for studying the slow tectonic deformations of the Pyrenees;
- A human challenge: climbing it, yesterday as today, requires resilience, collaboration and innovation, values that are still relevant today for geographers and scientists.

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CONTACTS

Bernard FLACELIERE
Association francophone de topographie
73 avenue de Paris
94165 Saint-Mandé Cedex
FRANCE
Tel. +33 6 77 97 72 83
Email: bernard.flaceliere@orange.fr
Web site: https://www.aftopo.org/

Dr. Pierre BRIOLE
Directeur du département des géosciences de l'ENS
CNRS/ENS/PSL
45 rue d'Ulm
75230 Paris Cedex 05
FRANCE
Tel. +33 6 08 60 12 74
Email: briole@ens.fr
Web site: https://www.ens.psl.eu/