

# Mountain Cartography at the Cartographic Institute of Catalonia

BLANCA BAELLA AND MARIA PLA

*Institut Cartogràfic de Catalunya / Parc de Montjuïc / Barcelona / Spain*

## Abstract

The strategic position of Catalonia in the Mediterranean region, straddling the route between central Europe and Africa, propelled the development of cartography from the Middle Ages onward. Because the territory is rugged, detailed mountain maps are an important part of the Catalonian cartographic legacy. The *Cartoteca de Catalunya* – the Catalan map library – has nice examples of old maps centred in mountain areas. Today, advanced technologies are being implemented by the *Institut Cartogràfic de Catalunya* to generate a wide range of cartographic products, including mountain maps. These old maps and the current cartographic products, preserved or produced at the *Institut Cartogràfic de Catalunya*, contribute interesting examples of mountain cartography to be offered in a publication focused in this topic.

This paper is divided into two parts. The first – after a brief introduction describing the Catalan relief in order to locate the mountain areas in the territory – gives a historical overview of cartography in Catalonia, showing some examples of old maps. This overview is included in the context of mountain cartography because a large number of maps of Catalonia produced during the last two centuries were centred in mountain areas. This overview helps to explain the evolution of some mountain maps until the current production at the *Institut Cartogràfic de Catalunya*, which comprises the second part of the paper. Moreover, the thematic products related to mountain cartography – some series that include a large number of sheets of mountainous areas – will be also included in the paper. The paper is focused more on the presentation of mountain cartographic products than on a detailed description of the processes or the problems encountered in the production of each product. More detailed information about some of the products can be found on the Internet at <http://www.icc.es>.

## Catalonia: A Mountainous Country

Catalonia is located in the northeast of the Iberian Peninsula, occupying approximately 32,000 square kilometres, bounded by the Pyrenees in the north, the Mediterranean Sea in the east, and other regions of Spain in the west and south.

The mostly mountainous landscape, with more than 50% of the area being higher than 500 metres above sea level, can be classified into four physiographic regions. In the north, the Pyrenees reach altitudes greater than 3000 metres, and the pre-Pyrenees – a mountain range that runs parallel to the Pyrenees – has altitudes between 1000 and 2500 metres. In the east, 700-metre mountain ranges run parallel to the central part of the coast. Narrow flat areas can be found along the Mediterranean and between these parallel mountain ranges – which increase in elevation inland (the summits of Montseny, Montserrat, and Montsant reach about 1600 metres). In the southwest, the landscape is composed of high plateaus and eroded slopes that become gentler to the west. Also in this area, the basin of the Segre River forms a flat area with altitudes lower than 200 metres. Finally, in the southeast, the Ebre River flows into the Mediterranean Sea, where it has formed a delta.

The altitude and the relief are depicted in the hypsometric and shaded relief maps in Figures 1 and 2.

## Cartography in Catalonia:

### The Institut Cartogràfic de Catalunya

Catalonia has a long tradition in cartography. During the fourteenth century, the Kingdom of Aragon, which also included the regions of Catalonia, Valencia, and Majorca, founded an important school of cartography in Majorca. The school specialized in the production of portolans – nautical charts containing detailed information for sailors. The adoption of the compass as a navigational aid contributed to the increased use of portolans. In addition, at least two portolans were required by King Pere III (1319–1387) to be carried on all Catalan ships. Portolans depict navigation routes, landmarks, terrestrial features, and map names, mainly in Catalan. The coastline on these maps remained the most precise depiction available until the eighteenth century. One note-

Blanca Baella and Maria Pla, Institut Cartogràfic de Catalunya, Parc de Montjuïc, E-08038 Barcelona, Spain. Tel.: 34 93 5671500. E-mail: [blancab@icc.es](mailto:blancab@icc.es) and [maria@icc.es](mailto:maria@icc.es)

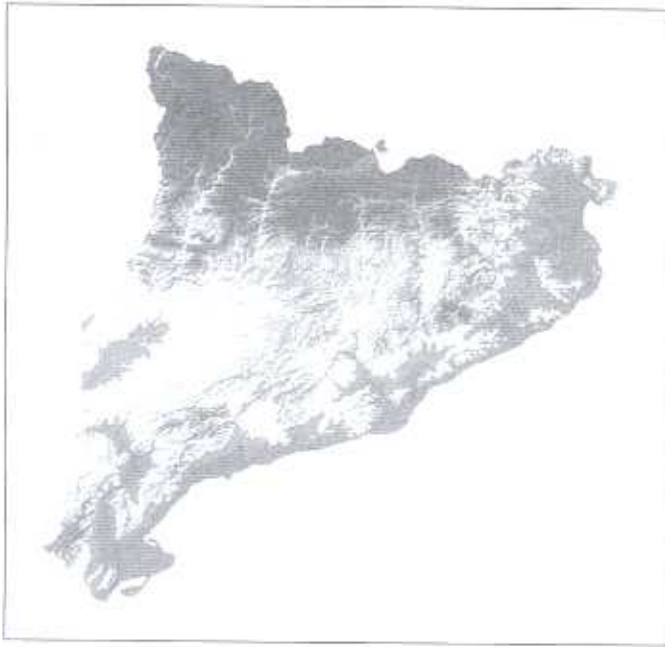


Figure 1. Hypsometric map of Catalonia. Institut Cartogràfic de Catalunya.

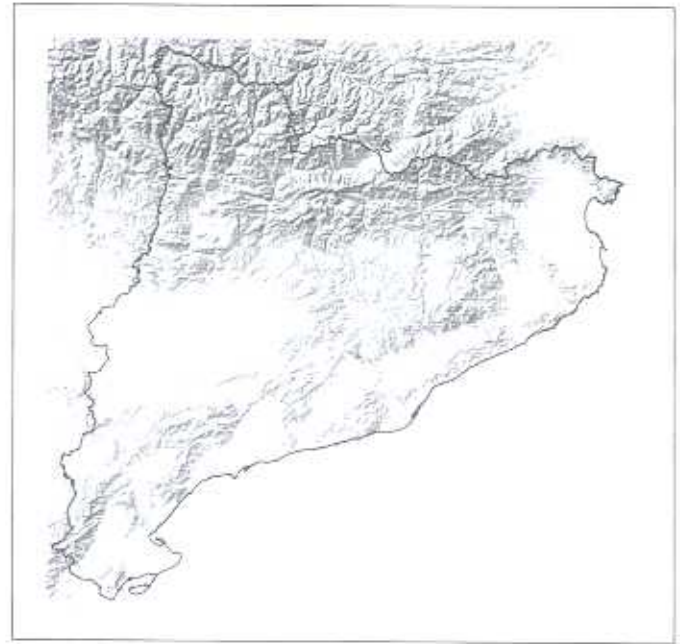


Figure 2. Shaded relief map of Catalonia. Institut Cartogràfic de Catalunya.

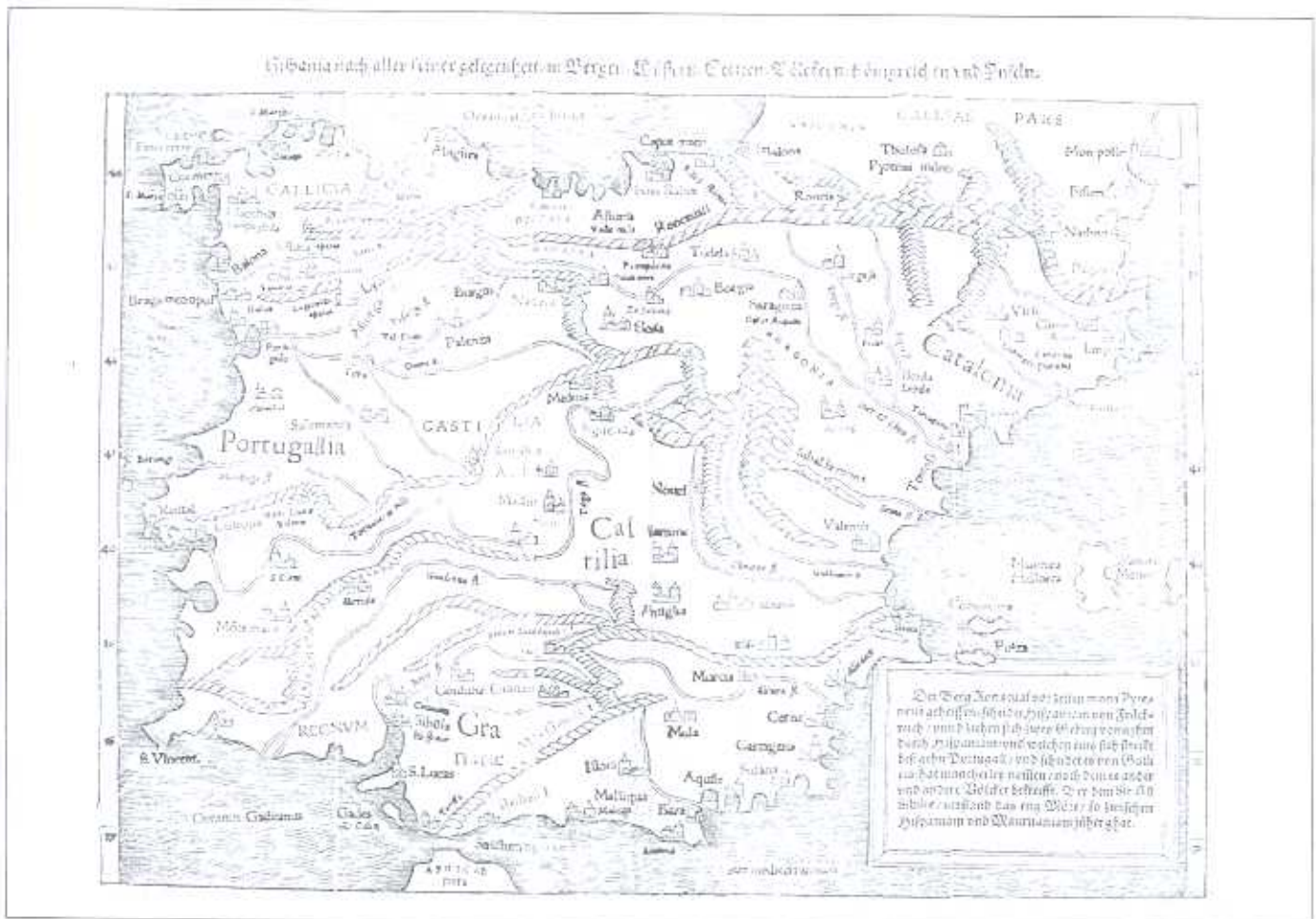


Figure 3. Ptolemaic map of the Iberian Peninsula. Probably by Sebastian Münster, Basel, ca. 1550. Cartoteca de Catalunya, Institut Cartogràfic de Catalunya.





Figure 4. *Detail of Cataloniae principatus descriptio nova. Published in the Atlas sive cosmographicae meditationes de fabrica mundi et fabricati figura, by Gerardus Mercator (Gerhard Kremer), Amsterdam, 1613. Cartoteca de Catalunya, Institut Cartogràfic de Catalunya.*

worthy Majorcan portolan is the *Atlas Català* of Abraham and Jafudà Cresques. Edited in 1375, it is preserved in the Bibliothèque National of Paris and is considered a masterpiece of medieval cartography.

Portolan production continued until the eighteenth century. In the fifteenth century, however, most Majorcan cartographers emigrated to Italy. Thereafter, during the sixteenth and seventeenth centuries, foreigners employing the Pays-Bas technical advances and artistic styles mainly produced Catalan cartography (Figures 3 and 4).

From the last years of the seventeenth century until the beginning of the nineteenth century, the wars against France were the main reason for Catalonian map production. Military engineers in the employ of the Spanish, French, English, or Austrian armies produced maps of cities, routes, and strategic regions (Figures 5, 6, 7, and 8).

The Instituto Geográfico y Estadístico (IGE), the predecessor of the present Instituto Geográfico Nacional (IGN), was created in Madrid in 1870. Its flagship 1:50,000-scale series, *Mapa Topográfico Nacional (MTN) de España*, was initiated in 1875 and completed in 1970. The first sheet of Catalonia was published in 1918. During the same period, the Army and the Navy developed their own maps for military use and also collaborated in the publication of the MTN 1:50,000 series (Figure 9).

In Catalonia during the nineteenth century and the beginning of the twentieth century – a time of tight finances for the Spanish government – most new cartographic projects were undertaken to support industrial development. Private and local public initiatives, such as the building of the railway network, hydrological pro-

jects, and the improvement of the road network, typify these cartographic products.

The last years of the nineteenth century witnessed the growth of hiking as an outdoor activity. The Club alpin français, created in 1874, published a significant number of maps of the Pyrenees and other mountainous areas in Catalonia. The Associació Catalanista d'Excursions Científiques, founded in 1876 and predecessor of the present Centre Excursionista de Catalunya (CEC), introduced the need for a public institution to produce a topographic map of Catalonia using the latest technical methods.

At the beginning of the twentieth century, the high demand for energy for industrial purposes forced the development of hydroelectric energy in mountain areas. Maps to support the building of hydroelectric power stations were the first need of these huge projects. Cartographers from Switzerland, France, and Canada introduced new technologies, such as photography and photogrammetry, for the generation of this precise cartography. Most of this cartography depicted prime hiking areas and was very often used as basic information in publishing hiking maps at smaller scales. Examples include the *Mapa del Cadí* at 1:50,000 scale (1922) edited by Kümmerly & Frey in Bern, the *Mapa de Cabdella* at 1:10,000 scale (1923) edited by Estudios y Construcciones Locher S.A. from Switzerland, the *Mapa de Tavascan* at 1:10,000 scale (1923) edited by Société française de stéréotopographie from France, the *Mapa del Montseny* at 1:50,000 scale (1924) edited by Kümmerly & Frey from Bern, and the Pyrenees maps edited by Franz Schrader (Figure 10).

At the same time, local municipal and provincial governments started to publish maps at several scales centred in their geographic areas. One of these organizations was the Servei del Mapa Geogràfic. Created in 1914 by the Diputació de Barcelona, with support from the Spanish government, they produced the *Mapa Geogràfic de Catalunya* at a scale of 1:100,000 (Figure 11). Although not published yet, the IGE allowed cartographic information compiled for the MTN 1:50,000 to be used. The series was to include 43 sheets, but production was stopped in 1939 after the publication of only 11 sheets because of the Spanish Civil War.

During the short period from 1931 to 1939, the Generalitat de Catalunya (Catalan autonomous government) assumed the responsibilities of the Servei del Mapa Geogràfic, which was transferred again to the Diputació de Barcelona after the Civil War. A map of Catalonia at 1:200,000 scale was one of its main products (Figure 12).

After transfers between Spanish and Catalan governments, the Servei del Mapa Geogràfic was finally assigned in 1983 to the Institut Cartogràfic de Catalunya (ICC). It was created one year earlier as an autonomous commercial, industrial, and financial organ of the Generalitat de Catalunya. From the beginning, while carrying on the work started by its predecessors, its overarching goal was to modernize cartographic studies and production in Catalonia. Innovation was encouraged. In



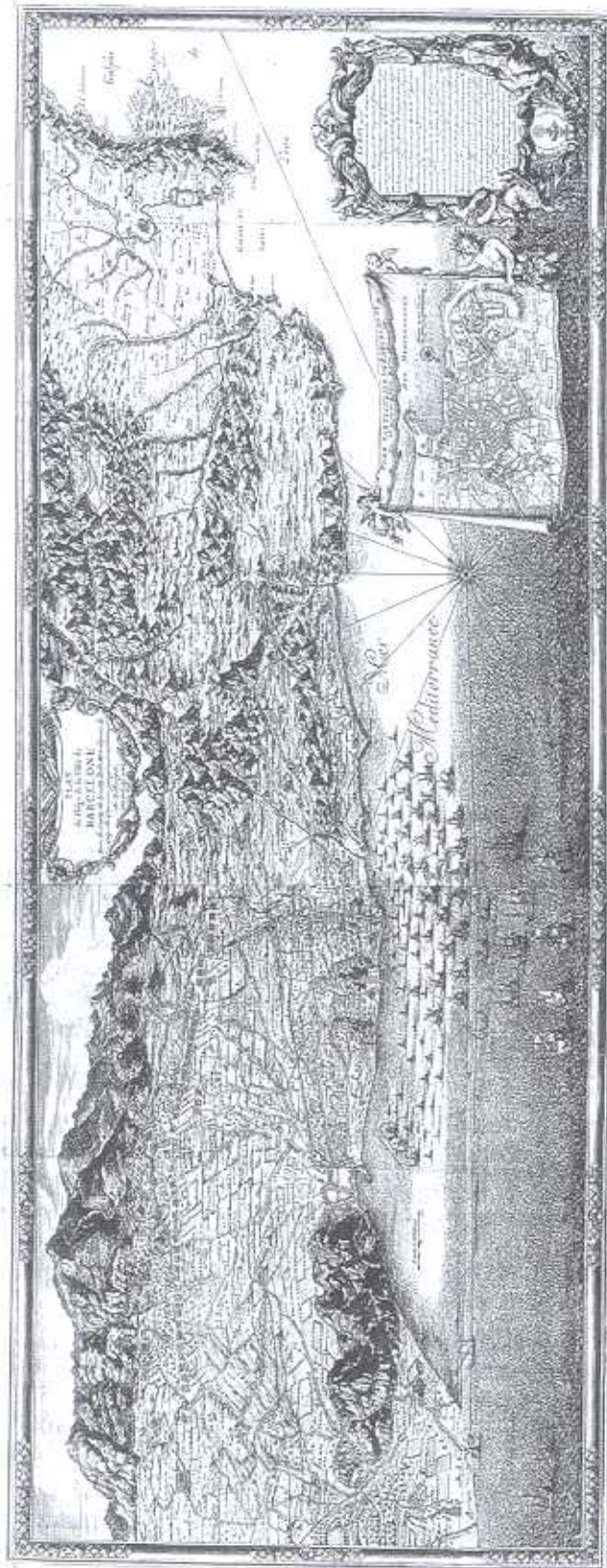


Figure 5. Plan du siège de la ville de Barcelone avec la carte de la cote de la mar depuis le cap de Cervere jusqu'aux environs de Llobregat. Published in *Les Glorieuses Conquestes de Louis le Grand, roy de France et de Navarre*, Paris, 1698. *Cartoteca de Catalunya, Institut Cartogràfic de Catalunya*.





Figure 6. Fragment of *La Catalogne*, by P. Placide, Paris, 1792. *Cartoteca de Catalunya, Institut Cartogràfic de Catalunya*.  
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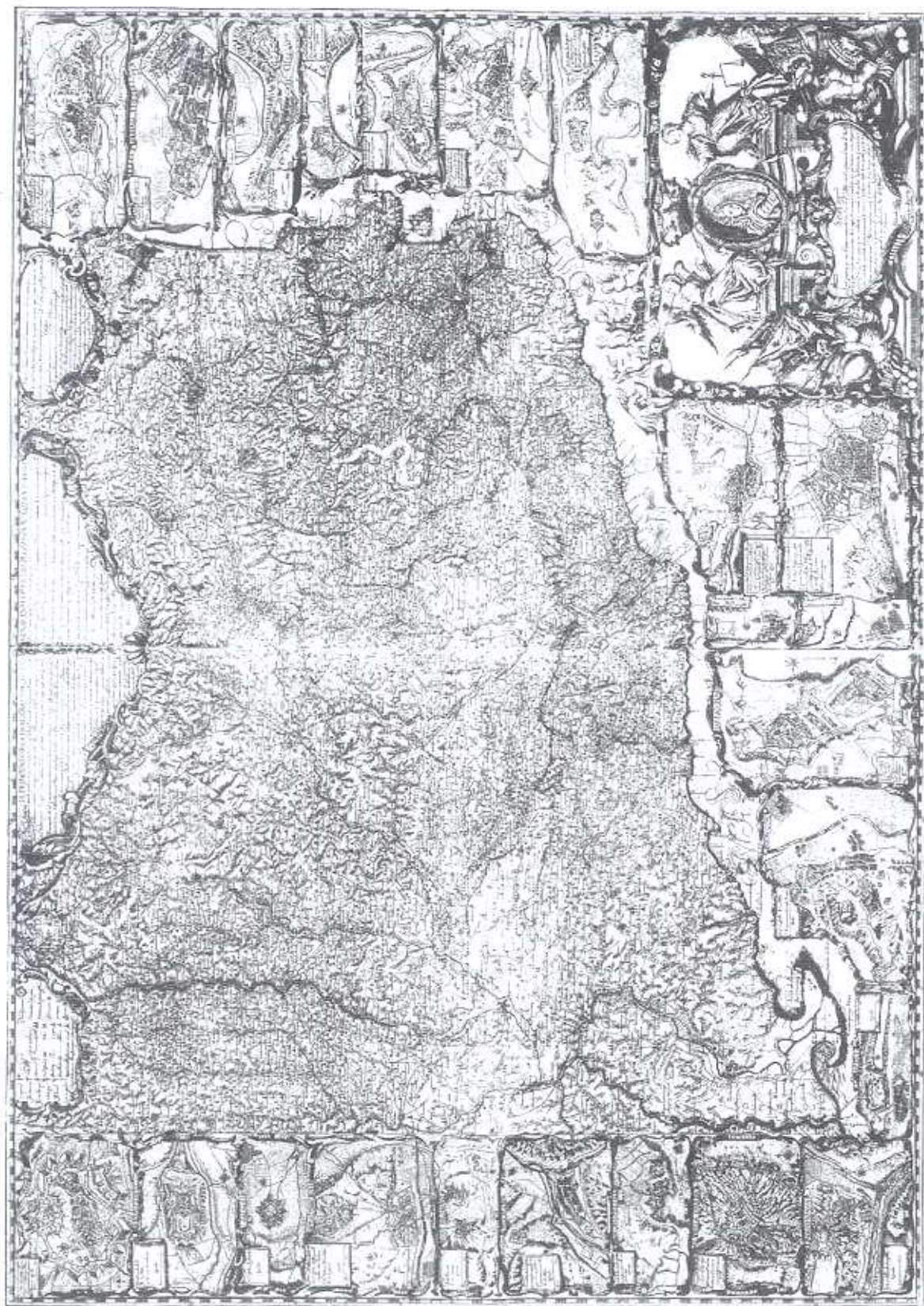


Figure 7. Facsimile of *Nuevo mapa del Principado de Cataluña y sus confines*, by *Oleguer de Taverner i d'Ardena*, *Comte de Darnius*, Barcelona, 1726. *Cartoteca de Catalunya*, *Institut Cartogràfic de Catalunya*.



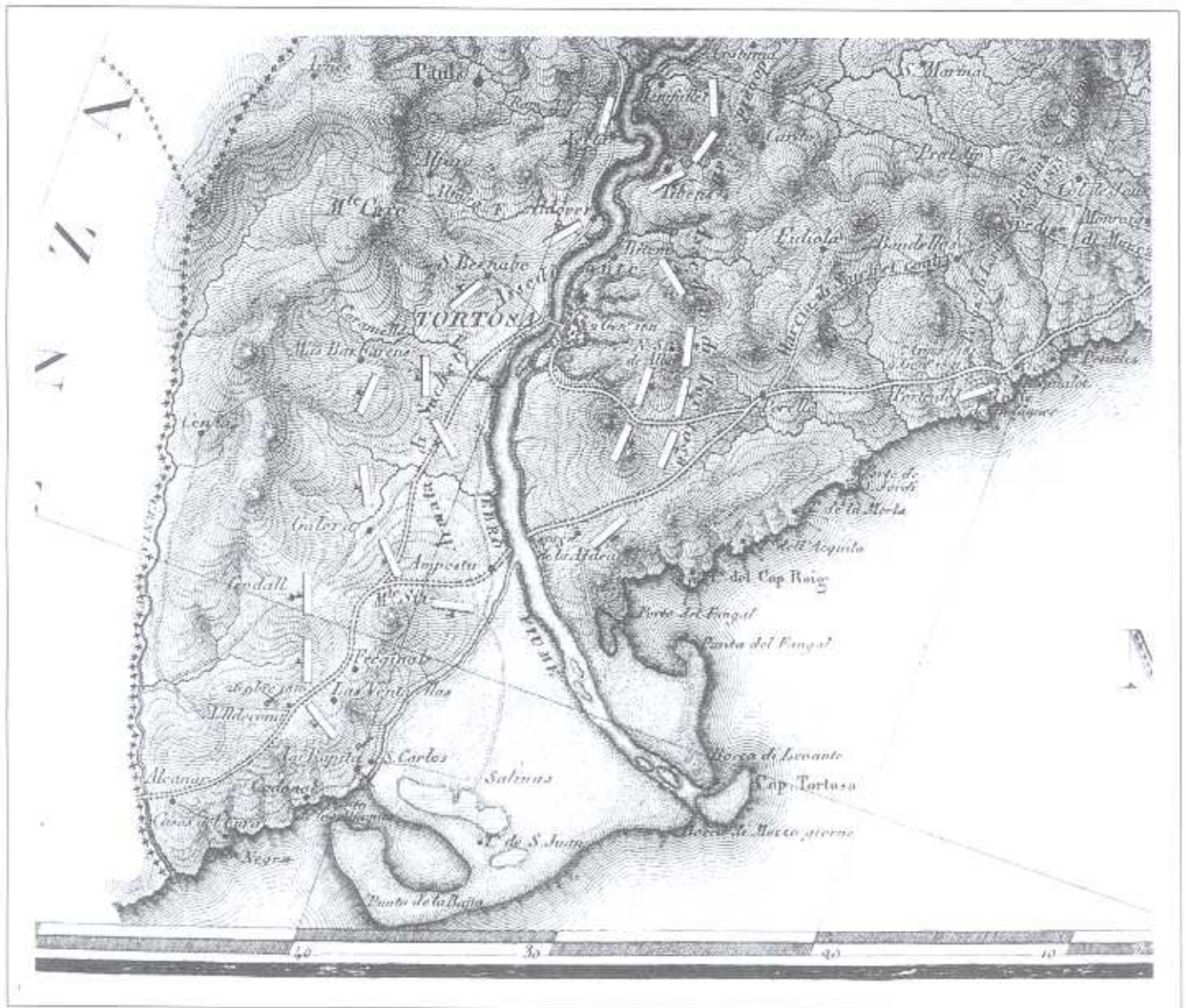


Figure 8. Detail of Carta militare della Catalogna: per servire alla Storia delle truppe italiane nelle diverse posizioni e spedizioni di più eserciti dal 1808 al 1813. Published in the atlas Storia delle campagne e degli assedi degli italiani in Spagna, by Camilo Bacani, Milan, 1823. Cartoteca de Catalunya, Institut Cartogràfic de Catalunya.

1995, the ICC assumed the management of the Geological Survey of Catalonia.

The purpose of the Institut Cartogràfic de Catalunya is the development of cartographic and geologic information, specifically:

- Producing, reproducing, and disseminating the basic cartographic work of various programs underway throughout Catalonia
- Densifying and surveying the lower-order geodetic network
- Providing the cartographic products necessary to support road construction and public works projects throughout Catalonia
- Executing programs for the development of thematic cartography, and using remote-sensing techniques to

monitor and evaluate natural resources, such as estimating areas affected by fires, land use, and geology

- Creating, structuring, and organizing the Cartoteca de Catalunya ("The Catalan map library"), which coordinates the compilation and study of the available cartographic and geographical documentation
- Creating cartographic databases that are used with automated systems for cartographic design and production. Besides basic cartography, this process also facilitates the immediate application of services such as public works and official land registry.
- Coordinating the cartographic work done by public or private institutions and, in some instances, cooperating with public and private organizations with similar purposes



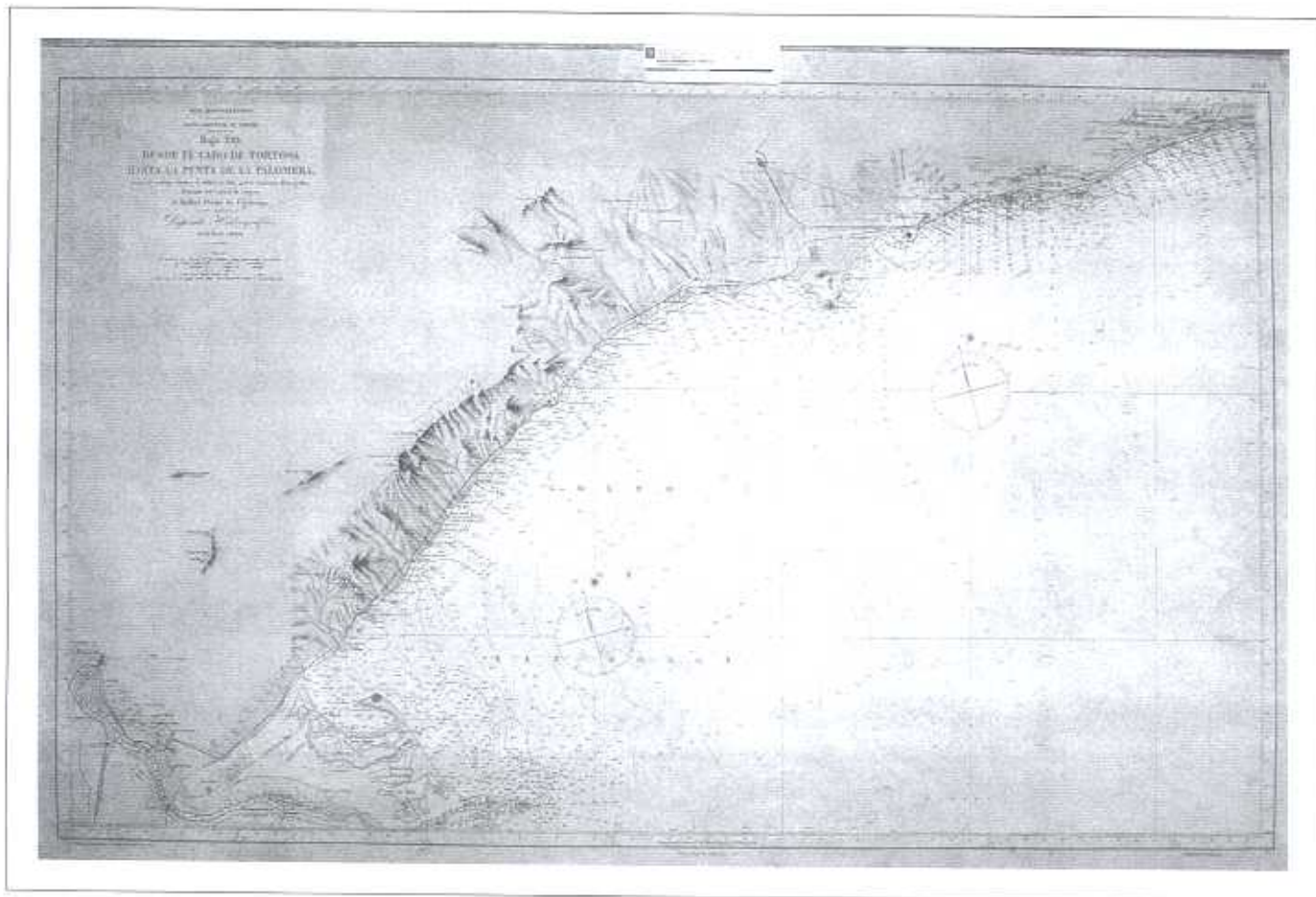


Figure 9. Costa oriental de España: Hoja XIII: Desde el cabo de Tortosa hasta la punta de La Palomera. Published by Dirección de Hidrografía, D. Rafael Pardo de Figueroa, Madrid, 1890. Cartoteca de Catalunya, Institut Cartogràfic de Catalunya.

#### Mountain Cartography Produced by the Institut Cartogràfic de Catalunya

The production of the Institut Cartogràfic de Catalunya is based on the generation of digital topographic and thematic databases and orthoimages between 1:5000 and 1:250,000 scales. Paper and raster maps are derived using these digital databases. The ICC cartographic production related to mountain cartography can be classified into two generic types according to the contents: thematic mountain products and topographic and image products. Examples of thematic products are the snow avalanche database, its derived maps, and hiking maps. Some topographic and image series include a large number of sheets of mountainous areas and also provide good examples of mountain cartography.

#### TOPOGRAPHIC DATABASE OF CATALONIA AT 1:5000 SCALE

The 1:5000-scale Topographic Base of Catalonia – a topographic database in vector format – covers the entire region at the largest scale. The project was started in 1985. The digital vector data were digitized using analogical and analytical photogrammetric systems, but the information was never structured to create a geographical

database for GIS purposes, so it is only "spaghetti" data. With the collected topographic information, a digital terrain model (DTM) was produced in grid format with one elevation point every 15 metres. This DTM was subsequently used in the orthophoto rectification and in the generation of shaded relief for maps at smaller scales. This first version was completed in 1995.

In 1996, updating was started using digital photogrammetric systems, which allow superimposition of stereo images and vector data. Some changes were introduced in the data structure in order to obtain a GIS-oriented database and to facilitate further generalization at smaller scales. New database features include polygons, hydrographic and communication networks, blocks in urban areas that help to define the street network, and classification of map names.

The use of a digital terrain model (DTM) instead of a digital surface model (DSM) in the orthophoto rectification can generate distortions in bridges and high buildings, as is shown in Figure 13. To solve this problem, the new data model was designed to store both the DTM and the DSM. Figure 14 shows the same orthophoto rectified using a DSM. Both models are available in triangulation and grid formats.



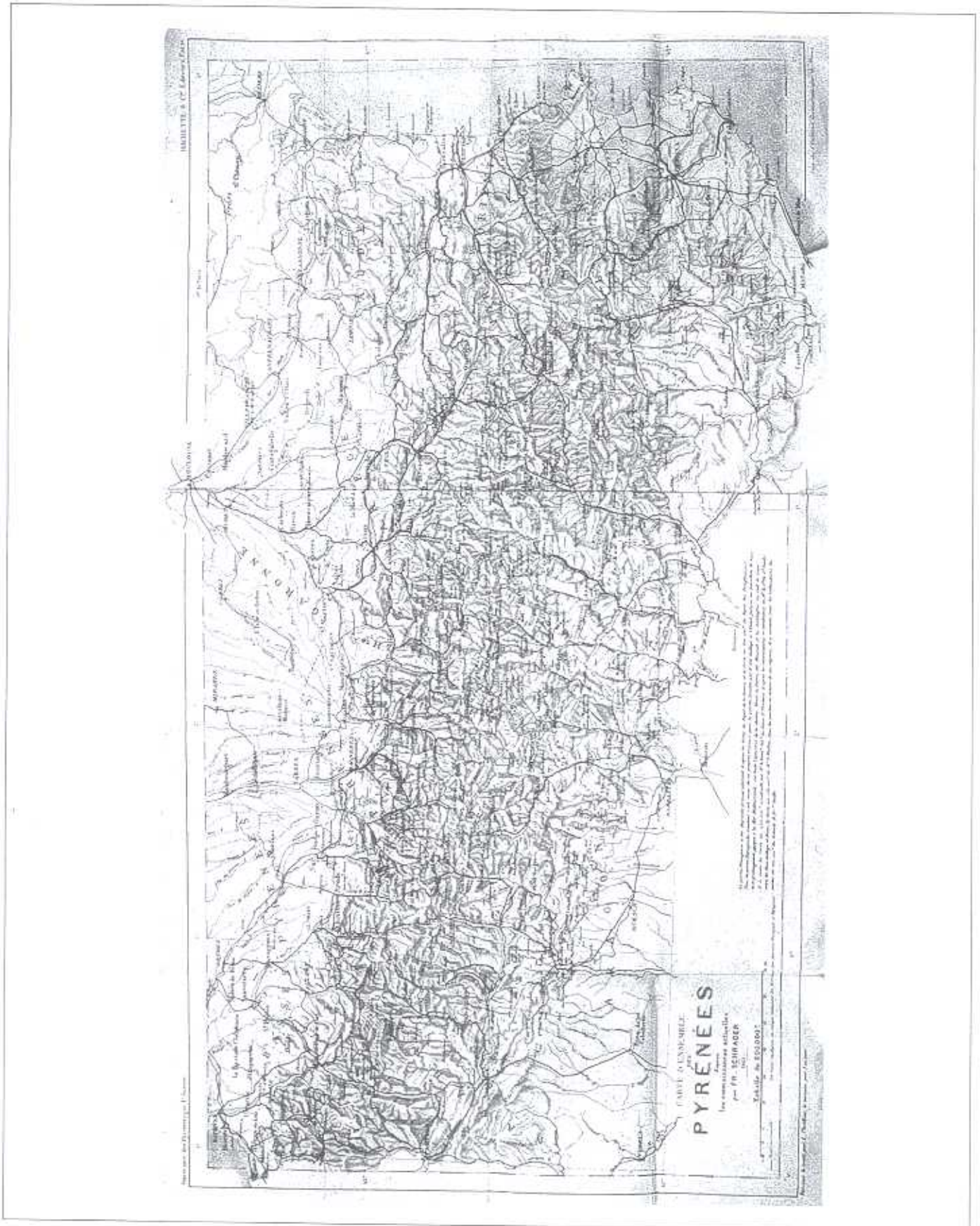


Figure 10. Carte d'ensemble des Pyrénées d'après les connaissances actuelles. Published by Franz Schrader, Paris, 1923. Cartoteca de Catalunya, Institut Cartogràfic de Catalunya.



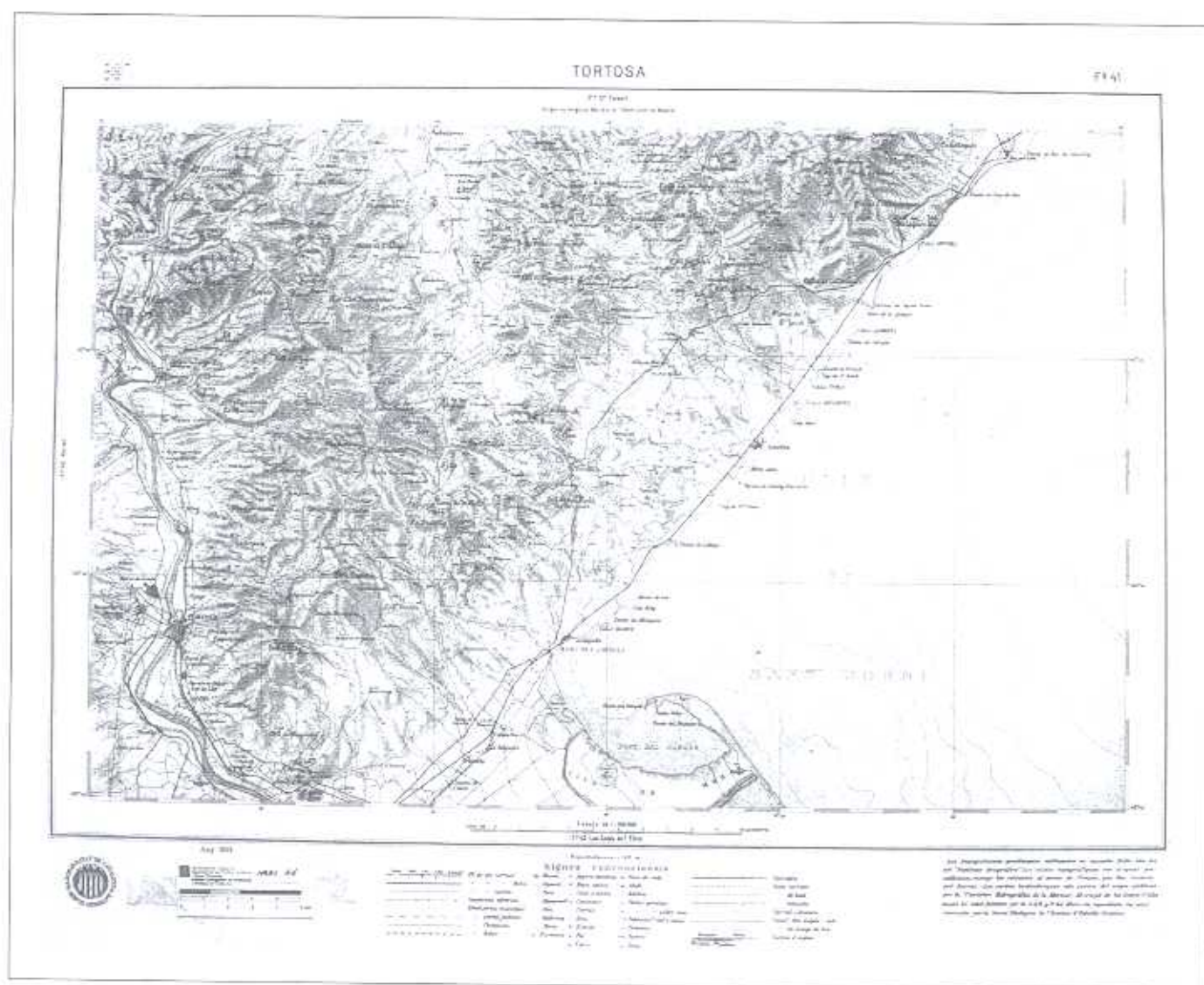


Figure 11. Mapa geogràfic de Catalunya 1:100,000. Sheet of Tortosa. Published by the Mancomunitat de Catalunya, Barcelona, 1923. Cartoteca de Catalunya, Institut Cartogràfic de Catalunya.

Stereoplotted features for the DTM generation include profiles, breaklines, spot heights, and flat areas such as ponds or lakes. Only in a few areas with complex terrain are contour lines directly compiled to infer breaklines during generation of the triangulation model. Moreover, all planimetric features captured on the ground are used as breaklines. In DSM generation, the elevation of areas covered by buildings or bridges substitutes for the terrain.

In mountainous areas the main problem is accurately modelling cliff areas. Minimizing crossing errors requires digitization of one breakline on top of the cliff and another at the bottom. Sometimes the bottom of the cliff is not clearly visible in the photogrammetric stereopair, and it is difficult for the cartographer to make a correct interpretation.

DTM data are verified during the data-capture stage by applying different techniques to detect and correct

errors. Crossing tests between altimetric features allows queuing and assigning the correct high value to the erroneous crossing points. Automatic generation of contour lines allows the results of interpolation to be analysed in relation to these elements. Finally, the generation of shaded relief gives an idea of the quality of the DTM grid and helps in detection of small errors. All these verification processes can be repeated until the digitized data are of acceptable quality. In data processing, special applications are required during triangulation to avoid vertical triangles, which are not supported by most commercial software. In some areas, the poor results in the generation of automatic contour lines show the need to improve the algorithms used to derive contours from elevation databases. Although the result is accurate, it is difficult to obtain the same aesthetical quality as that achieved from manual compilation.

From the 1:5000-scale Topographic Base of Catalonia,



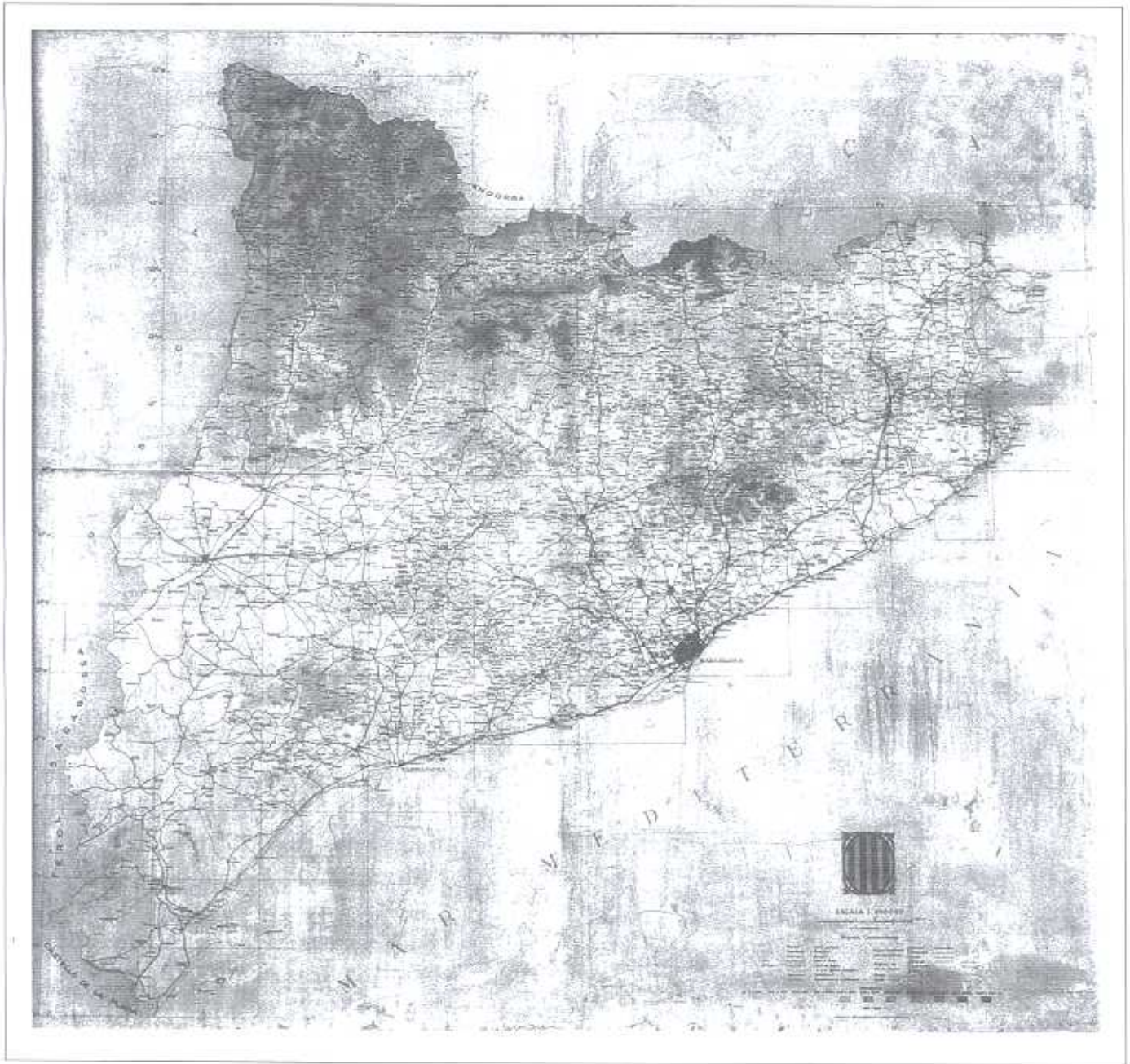


Figure 12. Mapa de Catalunya. Published by the Generalitat de Catalunya, Barcelona, 1936. Cartoteca de Catalunya, Institut Cartogràfic de Catalunya.

the map is generated by applying automatic selection and symbolization of features during plotting (Figure 15). Representation of cliffs is the main problem for mountainous areas, where the high density of contour lines can compromise legibility of the map. The paper map is plotted on demand at ICC using ink-jet plotters. A digital raster version is also distributed.

From this database, the topographic map at 1:10,000 scale is generated by applying cartographic generalization. After analysing public demand for the 1:5000-scale *Topographic Map of Catalonia*, it was determined that an intermediate scale between the 1:5000 and 1:25,000

would satisfy the requirements of users who wanted to cover areas with fewer sheets. Two main factors guided the choice of 1:10,000 scale: the availability of existing data and the potential for low cost if these data were to be generalized. Using the 1:5000-scale Topographic Database for generating the 1:10,000 series, the factor between the input and the output scales is low enough to avoid large costs in the overall generalization. The final product is a map, not a database. In this case, the generation of a database at 1:10,000 scale is not justified because it would be too close to the original at 1:5000 scale. The new map doesn't contain more information than





Figure 13. The image shows an orthophoto rectified using a digital terrain model.



Figure 14. The image shows the same orthophoto rectified using a digital surface model.



Figure 15. Detail of the Mapa topogràfic de Catalunya 1:5,000, Monestir de Montserrat, 1999, Institut Cartogràfic de Catalunya.



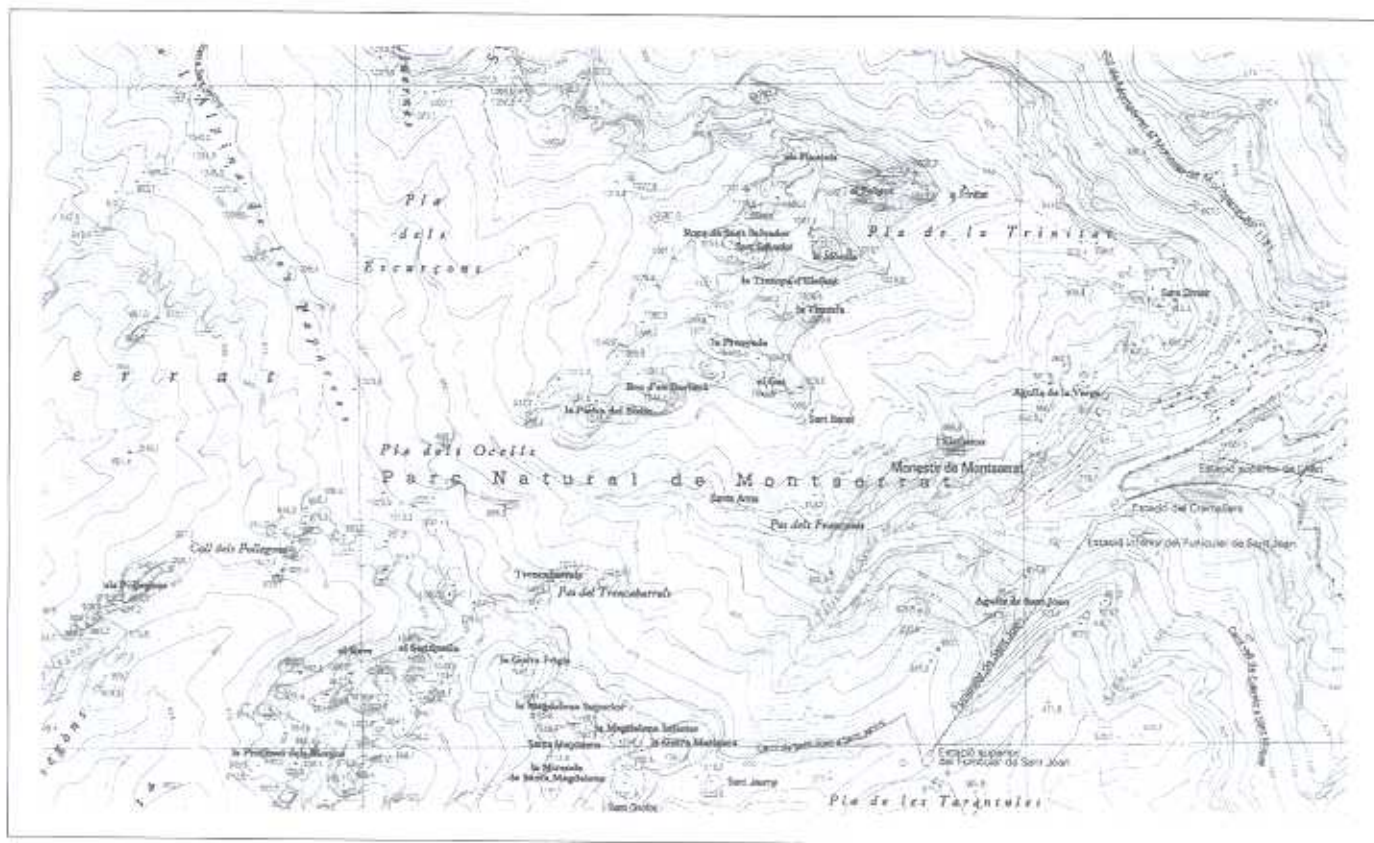


Figure 16. Detail of the Mapa topogràfic de Catalunya 1:10,000, Monistrol de Montserrat, 2000. Institut Cartogràfic de Catalunya.

the original from which it was derived. It is distributed on paper and as a digital raster map, but not as a vector database (Figure 16).

Another product to be derived from the 1:5000 Topographic Base of Catalonia will be the Topographic Base of Catalonia at a scale of 1:25,000. This product also will be created by applying automatic generalization. The project has just started and is focused mainly on obtaining a database.

#### TOPOGRAPHIC DATABASE OF CATALUNYA AT 1:50,000 SCALE

The 1:50,000-scale Topographic Database of Catalonia series was initiated in 1990. The planimetric information was compiled by digitizing 2-D vector data from 1:25,000-scale colour orthophoto images, using digital systems for the image display and data capture. These basic data were supplemented with fieldwork and other information, mainly the road network and national parks, obtained from several departments of the Generalitat de Catalunya. The contour lines and spot heights were obtained from the 1:5000 Topographic Database, the contour lines, from the DTM, and the spot heights, from manually generalizing the topographic data. The original DTM was collected at 1:5000, and at this moment there are no intelligent tools for its generalization to obtain representations at small scales. Simple tools on the

grid data, such as sampling or smoothing, are used with conservative parameters, to avoid elimination of main characteristics of the terrain together with the details. Automatic contour lines derived from the generalized DTM requires, in most cases, manual editing to achieve aesthetically satisfying results.

The digital database was created to provide topographical base information for GIS projects of several public and private companies and to publish the series *Mapa Comarcal de Catalunya* at 1:50,000 scale (Figure 17). Forty-one maps – covering all of Catalonia – were published between 1990 and 1995. Formatted to show a *comarca*, a Catalan administrative unit, the map sheets vary in size, depending on the area and shape of the *comarca* being represented. The digital shaded relief used on these maps was generated automatically from the DTM. The algorithm was developed at the ICC and uses the contrast as minimum and maximum percentage of colour, the vertical exaggeration, and the light direction as parameters. There are plans to also take into account new parameters, such as the slope. The interaction between parameters makes it difficult to predict results, especially in mountainous areas, and many proofs are required to obtain the final product. Desktop-publishing software was sometimes used to improve the appearance of automatically generated shaded relief.

In 1996, the updating was started, using new digital





Figure 17. Mapa comarcal de Catalunya 1:50,000. Alta Ribagorça. 1995. Institut Cartogràfic de Catalunya.

orthophoto images. The pressure to publish the updated maps quickly did not allow concurrent updating of the database, forcing the creation of two related but different product lines: the database and the map. The second edition of the map was completed in 1998 and the third edition was completed in 2001. Updates to the first version of the database were started in 2000, and the second version (related to the third edition of the maps) was also completed in 2001.

Limited numbers of 1:100,000-scale topographic maps of Catalonia have also been derived from the database. The first one, the *Mapa Topogràfic de les Comarques de l'Ebre*, published in 1996, is noteworthy for being the first map produced using automatic generalization tools at the ICC.

#### THEMATIC MAPS OF CATALONIA AT 1:25,000 SCALE

The thematic series at 1:25,000 scale mostly comprises avalanche and geological maps. Other maps are centred on national parks and areas of special socio-economic interest. Producing topographical base information is the main problem plaguing thematic maps at this scale, which will be solved with the creation of the Topographic Base of Catalonia at a scale of 1:25,000 derived by generalization of the Topographic Base at 1:50,000 scale.

The design of most of these maps includes shaded relief, cliff drawing, and rock depiction in mountainous ar-

eas, which is still produced manually. Testing has demonstrated that digital techniques lack sufficient quality to be considered for final production. In the case of *Mapa topogràfic de Catalunya 1:25,000 Parc Nacional d'Aigüestortes i Estany de Sant Maurici*, cliffs were drawn on film by hand. To begin this process, cliff areas were delineated from orthophoto images as polygons. Next, within the polygons, the rock artist drew six different patterns to depict rocks, depending on their geologic type. Finally, the drawing was scanned and incorporated into the layout of the map (Figure 18).

The series *Mapes de Zones d'Allaus* at 1:25,000 scale comprises 14 avalanche path maps representing the areas affected by avalanches in the Catalan Pyrenees. Recorded avalanche events are outlined on these maps. The mapping of avalanches is based on DTM analysis, the interpretation of aerial photography or orthophoto maps without snow, and, finally, fieldwork to compile more detailed information, particularly to determine avalanche dates. Additional information about avalanches – their boundaries, characteristics (typology), frequency, period, victims, and destructive effects, as well as meteorological and snow conditions – is obtained by interviewing local people. Each avalanche path represented on the map has a related database containing its most relevant features. In order to acquire, store, and manipulate these data, a GIS is used. Each season's avalanche releases produce new information, requiring polygons on the maps to be updated when new events extend beyond the boundaries of previous avalanches.

The published avalanche sheets include *Val d'Aran Nord* (1997), *Val d'Aran Sud* (1997) (Figure 19), *Pallaresa Nord-Marimanya* (1998), and *Núria-Freser* (2000). In addition to avalanche data, the maps contain altimetric information, including shaded relief, and planimetric information.

Since the published maps do not depict avalanche risk, a daily bulletin including a forecast of avalanche danger for the Catalan Pyrenees is published during the winter on the ICC Web page (<http://www.icc.es>). It also gives short- and medium-term weather forecasts, snow distribution, up-to-date snow-layer conditions, and predictions for 24, 48, and 72 hours.

#### HIKING MAPS

In 1946, the Editorial Alpina initiated the publication of hiking maps in Catalonia, mainly at 1:25,000 and 1:40,000 scales, which were included in hiking guides. The model was the French hiking maps available for the northern side of the Pyrenees. Topographic mapping was the main objective, although additional thematic information was included for mountainous areas. These maps were a milestone in Catalan cartography during the second half of the twentieth century. The topographic information came from the MTN 1:50,000, the thematic information was provided by hikers, and names were always in Catalan. Absence of competitors, low prices,



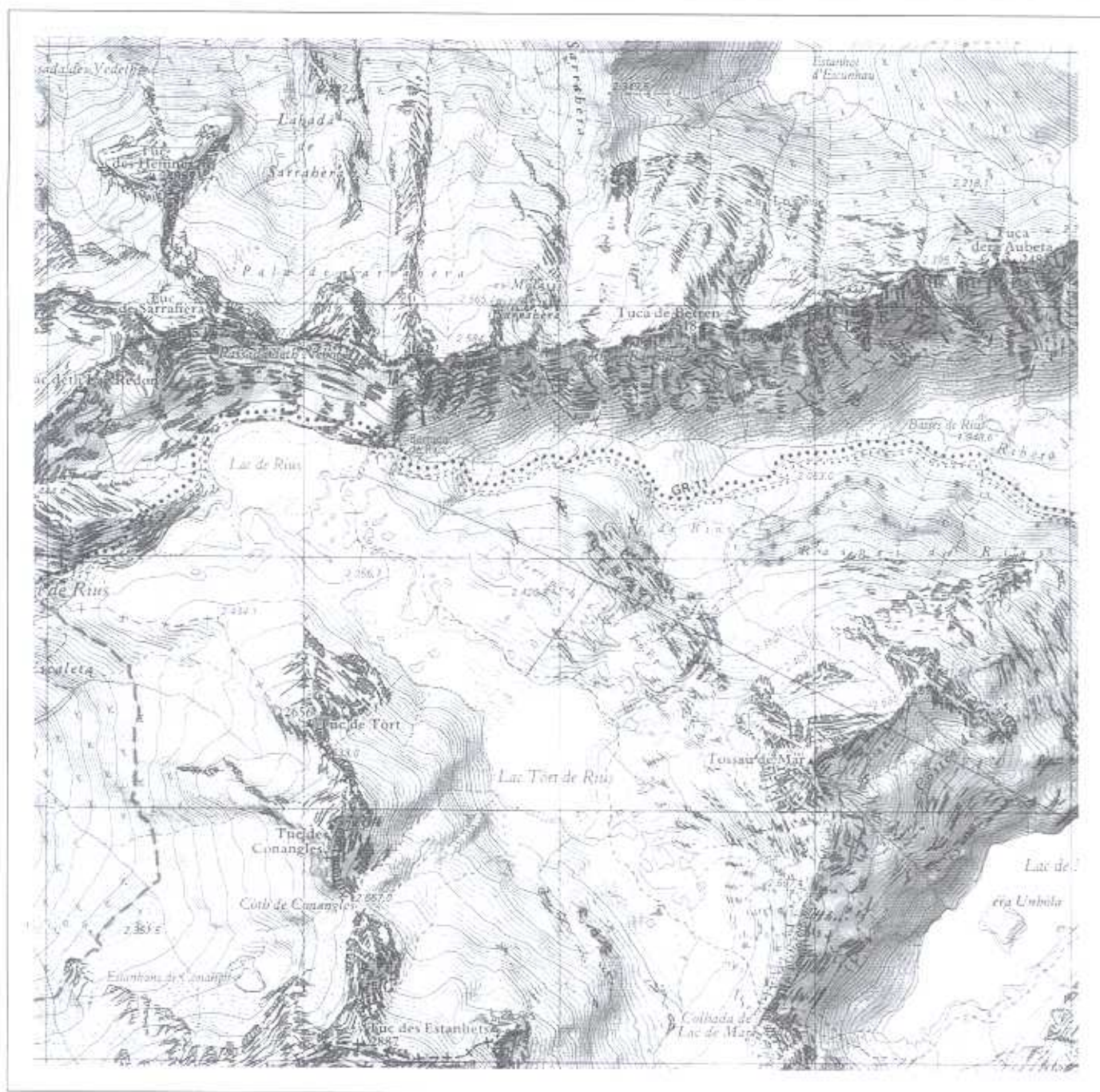


Figure 18. Mapa topogràfic de Catalunya 1:25.000. Parc Nacional d'Aigüestortes i Estany de Sant Maurici. 1997. Institut Cartogràfic de Catalunya.

and pent-up demand for high-quality hiking maps made them overwhelmingly popular. Two generations of Catalonians learned map-reading skills from these maps.

From 1946 until 1991, 69 maps were published covering all of the Pyrenees as well as other mountain areas in Spain, including Picos de Europa, Sierra de Gredos, and Sierra de Guadarrama. Today, the company continues its map-publishing tradition under the name Edicions Cartogràfiques Salvador Llobet, S.A.

The Institut Cartogràfic de Catalunya began collaborating with Edicions Cartogràfiques Salvador Llobet,

S.A., starting in 1996. To date, three maps at 1:40,000 scale have been produced: *Les Gavarres: Massís de Begur/Costa Brava* (1996), *Montserrat* (1997) (Figure 20), and *Lluçanès* (1999). The topographic information and map names are extracted from the ICC digital databases at scales of 1:5,000, 1:25,000, and 1:50,000. Edicions Cartogràfiques Salvador Llobet, S.A., provides the thematic information.

Since 1995, the ICC in collaboration with Randonnées Pyrénéennes from France has been producing the 1:50,000-scale map series *Mapa excursionista - Carte de*



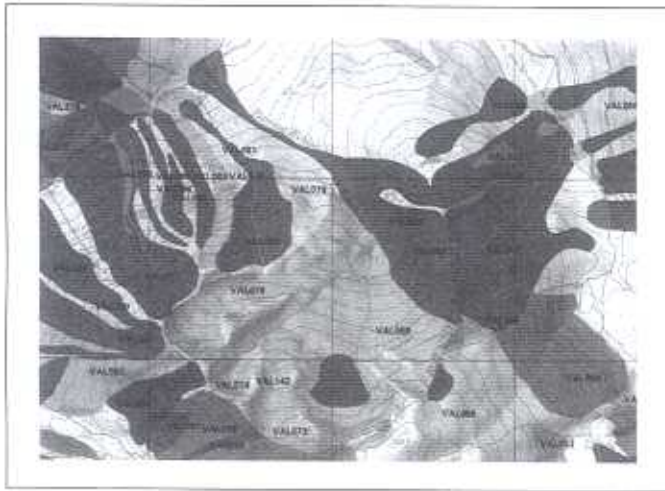


Figure 19. Mapa de zones d'allaus de Catalunya 1:25,000 Vall d'Aran sud, 1997. Institut Cartogràfic de Catalunya.

*randonnées* of the Pyrenees, which contain thematic information for hikers and tourists. The project is co-financed by the European Union. The series presently includes 25 maps, 6 of which have been published by the ICC. They are *Puigmal-Costabona* (1995), *Pica d'Estats-Aneto* (1999) (Figure 21), *Gavarnie-Ordessa* (2000), *Aneto-Posets* (2001), *Ansó-Hecho* (2001), and *Andorra-Cadi* (2001).

Contour lines, spot elevations, shaded relief, and rock depiction of cliffs and rocky areas provide altimetric information. The cliffs are generated as vector data using a combination of area patterns, composed of dots at different sizes and linear patterns. Interactive manual editing gives the rocks a random natural appearance (Figure 22).

#### IMAGE CARTOGRAPHY

Orthoimage mapping plays an important role in the ICC cartographic production. When the ICC was founded in the early 1980s, updated maps of Catalonia were unavailable. Maps based on aerial orthophotos and satellite orthoimages allowed quick coverage of the territory. Even today, orthoimages provide a method for fast updates.

Catalonian image maps produced by the ICC have scales ranging from 1:5000 to 1:250,000. Production is based on aerial photography for scales of 1:25,000 or larger, and satellite images are used for scales of 1:50,000 or smaller (Figure 23). In some cases, image maps have also been published as relief maps using the DTM (Figure 24). The ICC is also producing image cartography of other countries, including Argentina, Venezuela, Namibia, and select regions in Spain.

In the last two years, radar images have allowed maps to be generated despite poor visibility (typically caused by cloud cover) – a factor that limits the usefulness of aerial photography and satellite images for mapping. The ICC has used radar technology to map a rainforest area south of the Orinoco River in Venezuela: a 1:50,000-scale project that covers 270,000 square kilometres. By

using radar images, a detailed DSM of the area has been obtained by applying interferometry techniques (Figure 25).

#### Conclusion

The main problems in the ICC mountain cartography are derived from the limitations in relief modelling and representation. Although some processes are fully automatic, many must still be finished manually, of which cliff representation and shaded relief are clear examples. The enrichment in the ICC elevations data model and the improvements in the generalization and representation algorithms – in development now – will help to increase automation.

New data acquisition sources tested or used recently at the ICC, such as satellite imagery at high resolutions, radar images, or laser data, will facilitate the mapping of areas with poor visibility or limited access and also decrease the updating cycle of information. For example, in mountain areas, available updated data are essential for mapping snow avalanches.

Finally, in the near future, new tools will be developed to distribute the available mountain ICC information using the new communication technologies.

**Zusammenfassung** Die strategische Lage Kataloniens in der Mittelmeerregion – beidseits der Route zwischen Europa und Afrika – trieb die Entwicklung der Kartographie seit dem Mittelalter an. Wegen des unwegsamen Gebietscharakters sind detaillierte Gebirgskarten ein wichtiger Bestandteil des kartographischen Vermächtnis Kataloniens. Die Cartoteca von Katalonien, die Katalonische Kartenbibliothek, hat schöne Beispiele von alten Karten, die in den Gebirgsbereichen ihren Mittelpunkt haben. Heute werden neuere Technologien vom Institut für Kartographie von Katalonien eingesetzt, um eine große Auswahl von kartographischen Produkten, einschließlich Gebirgskarten, zu erzeugen. Diese alten Karten und die gegenwärtigen kartographischen Produkte, die am Institut für Kartographie von Katalonien bewahrt bzw. erzeugt werden, tragen dazu bei, dass interessante Beispiele der Gebirgskartographie in einer – auf dieses Thema konzentrierten – Publikation verbreitet werden.

Dieser Aufsatz wird in zwei Teile gegliedert. Der erste, nach einer kurzen Einführung in die Beschreibung des Katalonischen Reliefs, um die Gebirgsbereiche in diesem Gebiet zu lokalisieren, gibt einen historischen Überblick über Kartographie in Katalonien mit einigen Beispielen an alten Karten. Der historische Überblick ist in der Gebirgskartographie eingebettet, da eine große Anzahl der Karten, die während der letzten zwei Jahrhunderte produziert wurden, Katalonien in den Gebirgsbereichen darstellen. Dieser Überblick hilft, die Entwicklung einiger Gebirgskarten bis zur heutigen Produktion am Institut für Kartographie von Katalonien zu erklären, der den zweiten Teil dieses Aufsatzes bildet. Zudem stehen die thematischen Produkte in Zusam-







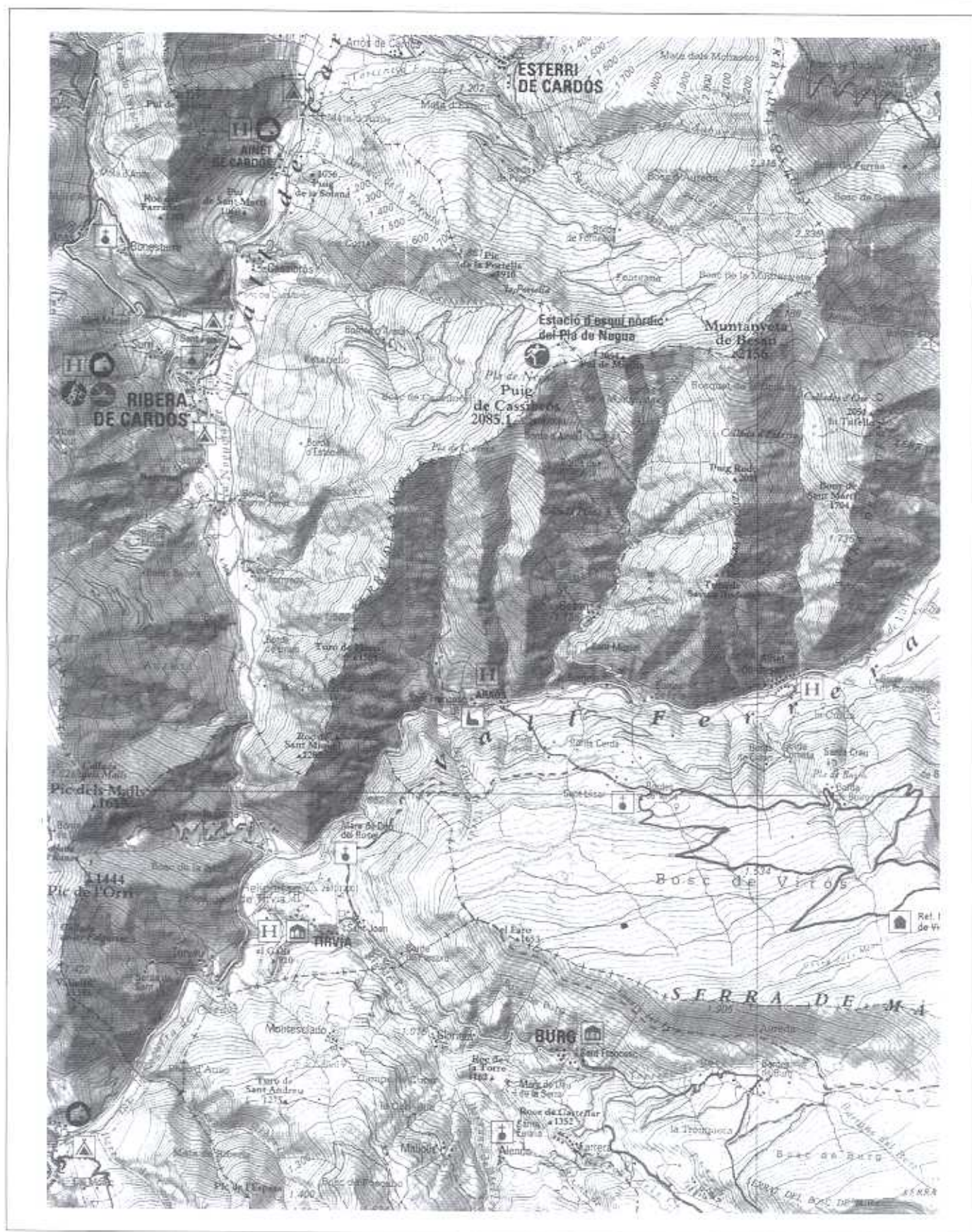


Figure 21. Mapa excursionista-carte de randonnées Pica d'Estats-Aneto. 1999. Institut Cartogràfic de Catalunya and Randonnées Pyrénéennes.



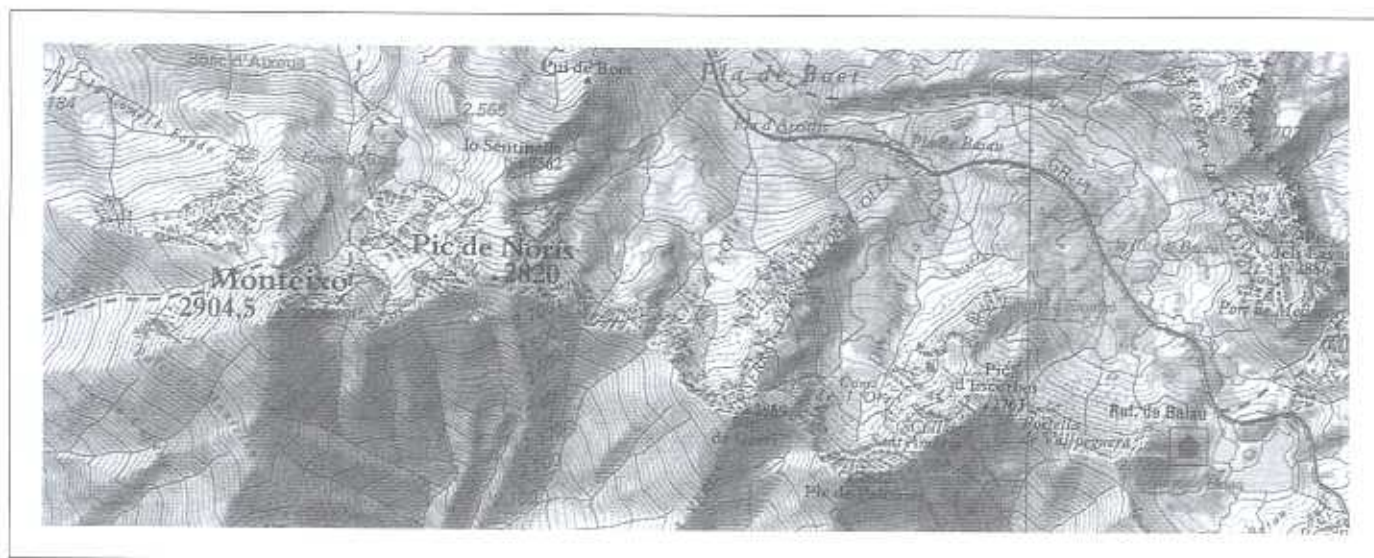


Figure 22. Example of cliff and rocky area.

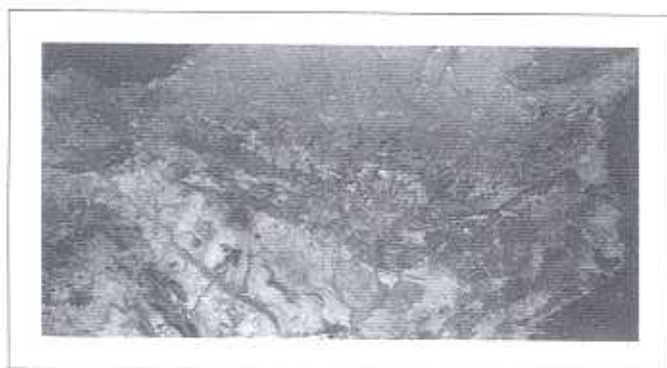


Figure 23. Mapa d'imatge satèl·lit dels Pirineus 1:400,000, 1990. Institut Cartogràfic de Catalunya.

lèe de montagne fait partie intégrante de l'héritage cartographique catalan. La « Cartoteca de Catalunya », la cartothèque catalane, possède quelques exemples intéressants de cartes de montagne. De plus, l'avancée technologique actuelle de l'Institut de Cartographie de Catalogne lui permet la création d'une large gamme de produits cartographiques, y compris des cartes de montagne. Ces vieilles cartes et ces produits cartographiques actuels, créés ou conservés à l'Institut de Cartographie de Catalogne, constituent un fond intéressant pour la diffusion d'une publication concernant ce sujet.

Cet article est divisé en deux parties. La première, après une brève introduction décrivant les reliefs catalans afin de repérer les zones montagneuses au sein du territoire, propose un aperçu historique de la cartographie en Catalogne à l'aide de quelques exemples de cartes historiques. L'aperçu historique est inclus au sein de la cartographie de montagne car un grand nombre de cartes produites en Catalogne durant ces deux derniers siècles représentaient des zones montagneuses. Cet aperçu permettra notamment d'expliquer l'évolution de



Figure 24. Detail of Mapa en relleu d'imatge satèl·lit de Catalunya 1:100,000, 1991. Institut Cartogràfic de Catalunya.

quelques cartes de montagne, vers les productions actuelles de l'Institut de Cartographie de Catalogne qui constituent la seconde partie de cet article. En plus des productions thématiques relatives à la cartographie de montagne, un ensemble de cartes de régions montagneuses sera également proposé. Ce papier est plus centré sur la présentation de produits de cartographie de montagne, que sur une description détaillée des processus et problèmes concernant la production de ces produits. De plus amples informations concernant ces





Figure 25. Radar orthoimage. Institut Cartogràfic de Catalunya.

produits peuvent être trouvées sur les pages web suivantes : [www.icc.es](http://www.icc.es)

**Resumen** La posición estratégica de Cataluña en el área mediterránea, en la ruta entre Europa Central y África, favoreció la producción de cartografía ya desde la Edad Media. Debido al carácter montañoso de su orografía, los mapas de montaña constituyen una parte muy significativa del legado cartográfico de Cataluña. La Cartoteca de Cataluña guarda bellos ejemplares de mapas antiguos

representando zonas de montaña. En la actualidad, el Institut Cartogràfic de Catalunya (ICC) implementa algunas de las más avanzadas tecnologías para obtener una amplia gama de productos cartográficos, incluyendo cartografía de montaña. Tanto los mapas antiguos como los productos cartográficos actuales, conservados o elaborados en el ICC, aportan ejemplos interesantes para una publicación monográfica de cartografía de montaña.

El artículo está dividido en dos partes. En la primera, después de una breve descripción del relieve de Cataluña que permite localizar las áreas montañosas en su territorio, se presenta una breve visión histórica de su cartografía, mostrando algunos ejemplos de mapas antiguos. La visión histórica está incluida en el contexto de cartografía de montaña debido a que un gran número de mapas publicados durante los últimos doscientos años, están centrados en este tipo de regiones. Esta visión ayuda a explicar la evolución de algunos mapas de montaña hasta la producción actual realizada por el ICC, que se incluye en la segunda parte del artículo. Además de los productos temáticos relacionados con esta cartografía, también se describen algunas series que incluyen un gran número de hojas en áreas montañosas. El artículo está enfocado a la presentación de productos de cartografía de montaña, más que a la descripción detallada de los procesos o problemas para elaborarlos. En las páginas-web del ICC ([www.icc.es](http://www.icc.es)) se puede encontrar información más detallada sobre estos productos.