Plant and Vegetation 12

Javier Loidi *Editor*

The Vegetation of the Iberian Peninsula

Volume 1

Springer

Plant and Vegetation

Volume 12

Series editor
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ISSN 1875-1318 ISSN 1875-1326 (electronic)
Plant and Vegetation
ISBN 978-3-319-54782-4 ISBN 978-3-319-54784-8 (eBook)
DOI 10.1007/978-3-319-54784-8

Library of Congress Control Number: 2017941283

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The Introduction of Geobotany in the Iberian Countries

A book about the vegetation of the Iberian Peninsula is of great interest and importance to all of Europe, due to the importance of this territory in terms of its plants and habitat diversity. When the opportunity of writing such a book presented itself, instead of writing it alone, using the abundant bibliographic sources at hand and my own experience, I decided to make it a collaborative project in which a large number of skilled and experienced colleagues from Spain and Portugal, representing the majority of the vegetation scientists currently active in these countries, could participate. This book tries to summarise the knowledge and experience that a complete generation of Spanish and Portuguese geobotanists have accumulated during their lives in their research done during the last quarter of the twentieth century and the dawn of the twenty-first. The book is divided into three main parts: the first deals with general issues which influence vegetation distribution, such as the relief and the geology of the area, as well as its climate. This part includes one chapter about the Iberian flora and another on the biogeographical division of the Iberian Peninsula. In another chapter, the conceptual framework, supported by the general theory of vegetation dynamics and by the theory of dynamic-catenal phytosociology which has been developed under the basic concept of potential natural vegetation (i.e. vegetation series, geoseries and geopermaseries), is commented upon in order to better interpret the landscape from an ecological and dynamic point of view. The second part of the book consists of the systematic description of the vegetation of Iberia and the Balearic Islands. For that the territory has been divided into 14 regions following geographic-biogeographic criteria (Fig. 1). Each of these regions is described by authors having extensive experience in the area; the phytosociological system (or Braun-Blanquet approach) is applied to give structure to the description. The third part is formed by a number of chapters dealing with specific aspects of Iberian vegetation which deserve in-depth treatment, because some of them deal with particular habitat

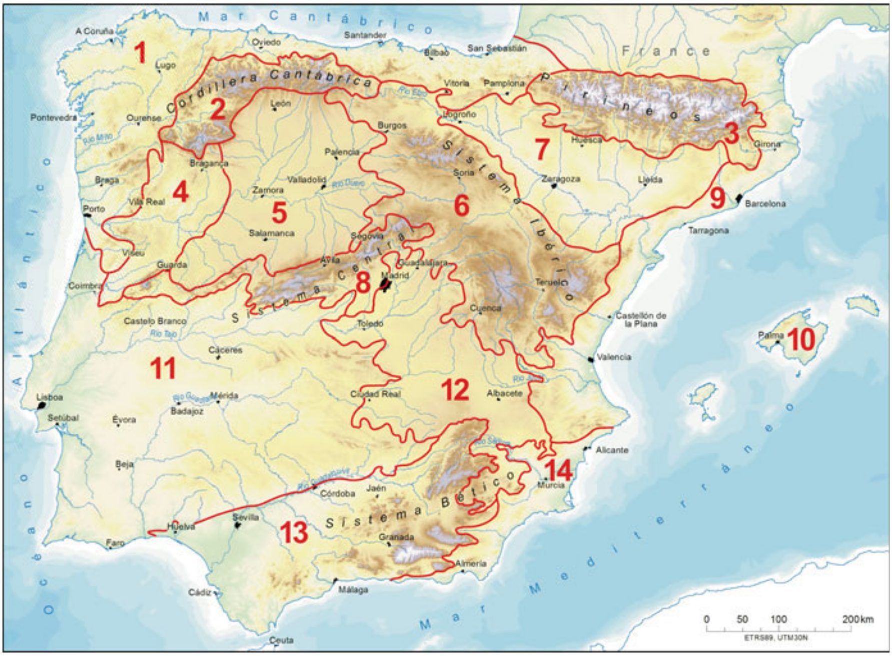

Fig. 1 The Iberian Peninsula and Balearic Islands divided into 14 regions described in the chapters of this book: (*1*) the lowlands and midlands of northwestern Atlantic Iberia; (*2*) the high mountain area of northwestern Spain, the Cantabrian range, the Galician-Leonese mountains and the Bierzo trench; (*3*) the Pyrenees; (*4*) Trás-os-Montes and Beira Alta; (*5*) the Duero Basin; (*6*) the Iberian ranges and highlands; (*7*) the Ebro Basin; (*8*) the Sistema Central (Central Range); (*9*) the Coastal Levantine area; (*10*) the Balearic Islands; (*11*) Lusitania; (*12*) La Mancha; (*13*) Bética and Southwest Andalusia; and (*14*) the arid southeast

groups (coasts, wetlands, high mountains or gypsum and dolomite vegetation) or with particular issues related to management (forests) or to biodiversity (alien flora). The final chapter about vegetation-plot databanks might be useful for completing the information provided.

In many of the chapters, and particularly in the descriptive part of the book, the phytosociological classification has been taken as the common system to formalise the information concerning plant communities. This is due to the common usage of the Braun-Blanquet approach in the Iberian countries and the fact that most of the authors have been trained in this approach. Hence, by using the same units for communities, as well as for bioclimatic and for biogeographic terms, the highest degree of coherence within the different chapters and parts of the book has been achieved. This hopefully will bestow a high consistency to the book as it will make the different chapters and parts easy to understand, making it also easily applicable to the adopted habitat typology of the EU for conservation policy. The typology and authorship adopted is that of Rivas-Martínez et al. (2011) for the Iberian Peninsula, enabling to refer authorship citation to that work and avoiding the explicit mentioning of authorship.

The information contained in this book is meant to be useful for vegetation scientists and ecologists throughout the world who want to have a source of updated and accurate information on Iberian ecosystems. Travellers and visitors of the country will find useful information for interpretation of the landscapes and the vegetation formations they find on their trips.

The Initial Steps of Geobotany in the Iberian Peninsula

Surveys on the vegetation and landscape of Iberia have been continuous throughout the twentieth century, but they were initiated by important earlier contributions, some by foreign researchers, that set the cornerstones of the subsequent development in this field in the Iberian Peninsula.

The first clear geobotanical observations done in the area date from the nineteenth century and originate from the Swiss botanist Pierre Edmond Boissier in his famous *Voyage Botanique dans le Midi de l'Espagne pendant l'année 1837* (1839–1845). He included a chapter describing the landscape (*géographie botanique*) and a famous diagram with the altitudinal belts of the Sierra Nevada and surrounding mountains (Fig. 2). Another remarkable attempt to improve the geobotanical

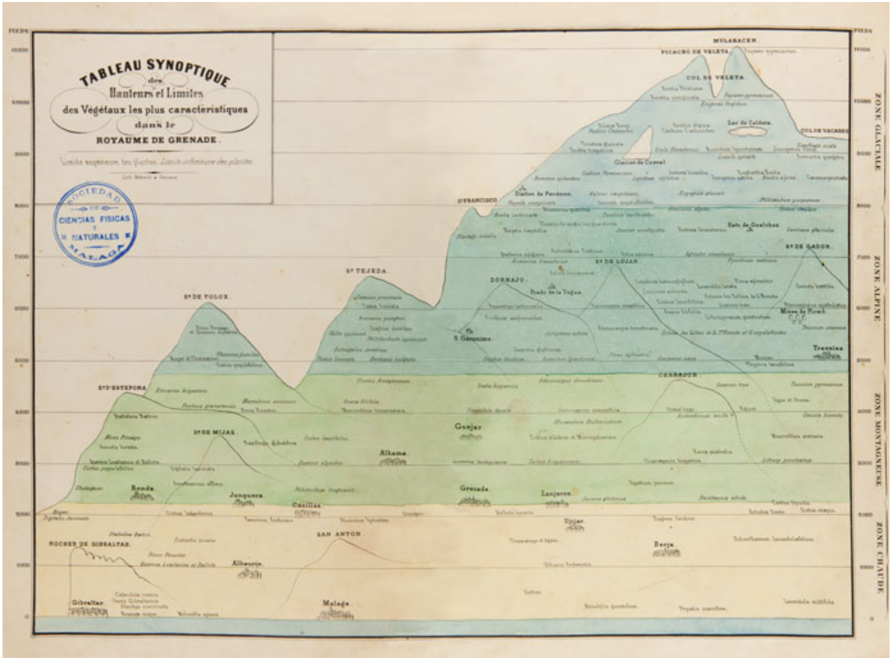

Fig. 2 Diagram by E. Boissier (1839) of the altitudinal belts of the Sierra Nevada and surrounding mountains

Fig. 3 Map by M. Willkomm (1852) of the steppe areas of the Iberian Peninsula

knowledge on the Andalusian mountains was done by Simón de Rojas Clemente (1864) describing the species composition of lichens in the vegetation belts of the Baetic mountains. These initial contributions were focused in the Sierra Nevada area of southern Spain, which is a very attractive territory for botanists due to its singularity and high concentration of endemic taxa, but these studies had limited influence on the development of geobotany in Spain.

A much more influential author in the subsequent development of the basic geobotanical conceptual framework for Iberia was the German botanist Mauritius Willkomm, who wrote two works on this topic, one (1852) about the supposed Iberian steppes (Fig. 3) and another with a more general treatment of the peninsular vegetation, which was published 1 year after his death (1896). In both works, an extensive description of the vegetation of the Iberian Peninsula is provided, and they can be considered the starting point of the development of geobotany at the scale of the entire peninsula. For a considerable period of time, Willkomm's description and ideas were entirely accepted by the local scientists and his influence endured for a long time after these publications. Nonetheless, in the early twentieth century, a remarkable author appeared: Emilio Huguet del Villar, a geographer and naturalist who was deeply influenced by Clements, was critical of the Willkommian

Fig. 4 The SIGMA excursion in Catalonia, Easter 1934. Among other participants, there are J. Susplugas, R. Tüxen, W. Koch, M. Klika, J. Cuatrecasas, R. Molinier, J. Braun-Blanquet, P. Font Quer and W. Rothmaler

tradition and denied the existence of true steppes in Iberia, an idea that had rooted deeply in the thinking of many naturalists in Spain as well as in the Germanic tradition until recently (Jäger 1971). Huguet worked extensively in edaphology and wrote a noteworthy textbook entitled *Geobotánica* (1929).

A turning point in the Iberian geobotanical history was the excursion of the SIGMA (Station Internationale de Géobotanique Méditerranéenne-Alpine) led by Braun-Blanquet at Easter of 1934 through Catalonia (Díaz González 2004). It was organised by a prominent Catalan botanist, Pius Font Quer, who had earlier contacted Braun-Blanquet and was interested in the new discipline of phytosociology. The excursion was attended by many Spanish and European colleagues and was the first important demonstration in the field of the methods and procedures of this school in the Iberian Peninsula (Fig. 4). As a result of those contacts, a Spanish student, J González-Albo, was sent to the SIGMA in Montpellier to be trained by Braun-Blanquet and soon started his research in the area of Madrid. Unfortunately, he was prevented from completing his research as a consequence of the Spanish Civil War, but still wrote two meritorious works (1934, 1940).

After the war, contacts were re-established in two ways. One was by means of Braun-Blanquet himself, who had been working intensively in the eastern Pyrenees and published an extraordinary monograph about its vegetation in 1948. Shortly after that, Font Quer recruited a young botanist in Barcelona, Oriol de Bolòs, who was committed to be trained by him by making a survey of a substantial area. The selected territory was the Ebro Valley and several field campaigns took place in the early 1950s (Fig. 5). The monograph appeared in 1958, and it is one of the most important contributions ever done on the Iberian vegetation, being still constantly

Fig. 5 Seeing the Ebro steppe: J. Braun-Blanquet, Prof. P. Font Quer, Mrs. Braun-Blanquet and P. Montserrat

consulted and cited. This is the starting point of the Catalan school of vegetation science which has been working mainly in the eastern Iberian Peninsula and the Balearic Islands and currently is mostly located in Barcelona.

Another important event that happened in the 1950s was the contact established at the International Botanical Congress in Stockholm by Salvador Rivas Goday, a professor of the University of Madrid, who attended that meeting and attracted the attention of Braun-Blanquet and Tüxen. As a result of this, the 10th IPE (Internationale Pflanzengeographische Exkursion) excursion in the summer of 1953 across a large part of Spain (Fig. 6) was organised, with the participation of several prominent scientists from the Germanic area, particularly Tüxen, Oberdorfer, Lüdi, Gams, Kubiena, etc., and local organisers Rivas Goday, Bolós and Fernández Galiano. The results of this excursion were published in two volumes at the Institute Stiftung Rübel in Zürich in 1956 and 1958, and they are, as the aforesaid monographs by Braun-Blanquet, milestones in the subsequent development of research on vegetation. These presented some of the first synthetic summaries for the Iberian vegetation with a vegetation map by Rivas Goday (1956) (Fig. 7) and the large monograph by Tüxen and Oberdorfer (1958) establishing the basic units and patterns of the temperate Iberian vegetation.

In Portugal the beginnings were also led by Braun-Blanquet, who made contact with a skilled and enthusiastic engineer, António Rodrigo Pinto da Silva, who, together with Arnaldo Rozeira, established a working group which explored the entire country in three long excursions in the 1950s (Fig. 8). The results were published in four papers over several years (Braun-Blanquet et al. 1952, 1956, 1965 and 1972). This dedication of Braun-Blanquet to Iberia was completed with a later monograph on the Basque Country (1967) and reveals his commitment and devotion to the introduction of his method in the Iberian countries.

Fig. 6 Map of the itinerary of the IPE excursion through Spain in 1953 (This figure is largely commented in the text and is from the report: Rivas Goday 1956)

Undoubtedly, such efforts bore fruit. From the original centres of Barcelona, Madrid and Lisbon, the exploration of Iberia has grown intensively from the 1960s until the beginning of this century, resulting in a huge amount of published data (over 145,000 relevés in SIVIM, Font et al. 2009) in a countless number of publications. Two persons have been particularly relevant in this development, as they have guided most of the scientists who have done the fieldwork and analyses: Salvador Rivas-Martínez and Oriol de Bolòs. Rivas-Martínez was intensively trained in learning the Iberian flora by his father during his early childhood and youth and later, when he was a student, spent up to three summer stays with Tüxen in Stolzenau (Zentralstelle für Vegetationskartierung), but without having also direct contact with Braun-Blanquet (Loidi 1996). For that reason Rivas-Martínez was intensely influenced by Tüxen, while Bolòs was purely a Braun-Blanquet pupil. We safely can say that the current state of knowledge of the Iberian vegetation is due to their influence and constant supervision. In the following generation, the development was explosive, initially in Spain but somewhat later also in Portugal. Led by these authorities, a group of people, such as Manuel Costa, Jesús Izco,

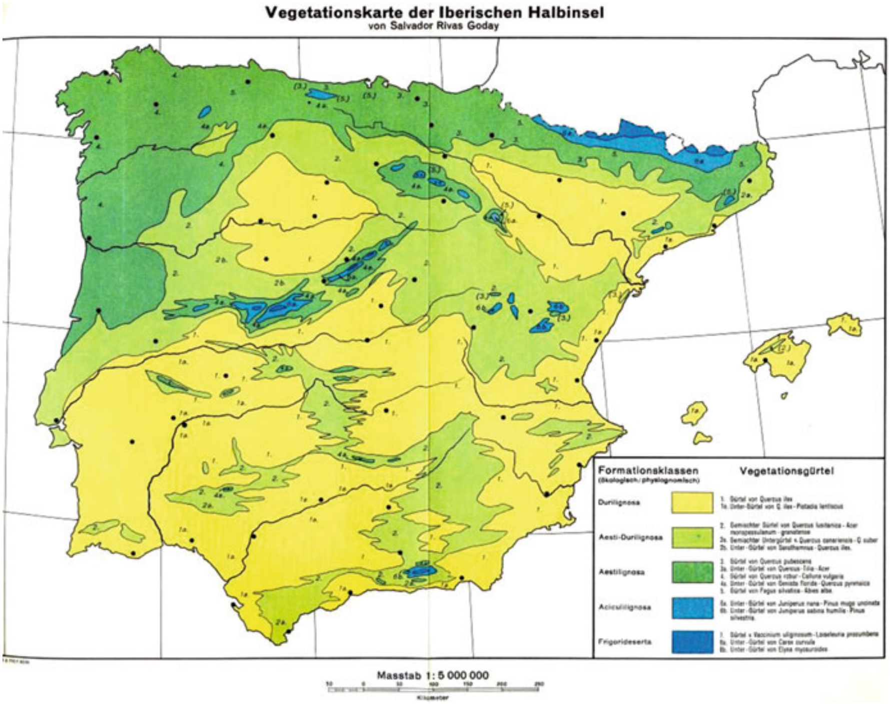

Fig. 7 Rivas Goday's map of the Iberian vegetation of 1956 (This figure is also commented in the text and is from Rivas Goday 1956)

Photo 23. De droite à gauche: Mme et M. A. R. Pinto da Silva, Prof. A. Rozeira, Br.-Bl., chauffeur, assistant M. Fontes, Mme Br.-Bl., J. Malato-Beliz dans la pineraie près de Tomar.

Fig. 8 Braun-Blanquet in Portugal. In a pine woodland near Tomar, from *right to left*: M. A. R. Pinto da Silva, Prof. A. Rozeira, J. Braun-Blanquet, M. Fontes, Mrs. Braun-Blanquet and J. Malato Beliz, among other persons

Miguel Ladero and Wolfredo Wildpret, started to work intensely in phytosociology under the leadership of the Rivas family in Madrid, while Josep Vigo was trained in Barcelona. In Portugal, the flame was temporarily put out as the original masters got many duties in the forest and agronomic service of their country, but a new and enthusiastic researcher, Mario Fernandes Lousã, restarted the Lusitanian tradition and developed the current flourishing Portuguese vegetation scientist group.

The development during the last decades has been documented sufficiently by other authors (Rivas-Martínez 1996) and it is unnecessary to repeat it in detail. In any case, it can be said that after the intensive, descriptive activity of the period between the 1970s and the 2010s, many researchers have tended to diverge into different fields in which their expertise has been advantageously used, particularly in the field of conservation biology, with the inventory and management of terrestrial habitats, endangered populations and species as well as community ecology.

Bilbao, Spain Javier Loidi

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Part I
General Conditions

Chapter 1
Introduction to the Iberian Peninsula, General Features: Geography, Geology, Name, Brief History, Land Use and Conservation

Javier Loidi

Abstract A brief description of the physical structure of the Iberian Peninsula is given: its position, size and main structural and lithologic entities. Also some general explanations about the main relief units ordered around the central core of the Peninsula, or *Meseta*, are offered. The etymology of the names of Iberia and Hispania is commented upon and a concise report of the human history in Antiquity is given. Traditional land-use by humans is considered important to correctly interpret the current landscape in adaptation to the conditions of the different parts of the territory. A special comment about irrigation and exploitation of the freshwater resources is made as regards its importance in the Mediterranean part of the Peninsula. Finally, some issues influencing conservation of terrestrial ecosystems are treated: the impact of the protected areas resulting from the policy of the administrations in the last decades, the landscape changes as a result of the rural abandonment (the "ecology of abandonment"), the urban development with the entailed artificialization of the land and the impact of the modern technicized forestry.

1.1 Physical Structure

1.1.1 Position and Size

The Iberian Peninsula or Iberia (Fig. 1.1) has a total extent of 583,832 km^2 encompassing continental Spain and Portugal, the Principality of Andorra, the British colony of Gibraltar and some areas of France in the Pyrenees. To this area, we add the 4992 km^2 of the Balearic Islands, which are related to the Iberian Peninsula as they form part of the same continental platform, entirely belonging to one of its structural units, and have been several times connected to the Peninsula

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J. Loidi (ed.), *The Vegetation of the Iberian Peninsula*, Plant and Vegetation 12,
DOI 10.1007/978-3-319-54784-8_1

Fig. 1.1 The Iberian Peninsula with its main structural units

during the ice ages of the Pleistocene. Iberia is a prominent large sized peninsula in the southwestern end of Europe, reaching the westernmost (9° 29′ W in Cape Rocha, Portugal) and southernmost (36° 00′ N in Tarifa) points of Europe, as only small areas in western Ireland and southern Kriti are beyond these coordinates in the European context. This peninsula has a massive pentagonal shape with large areas of medium to high elevation in its centre, viz. the huge central plateau or *Meseta*; the average elevation of Iberia is ca. 600 m asl. The straight line distance between peripheral opposite points of the peninsula oscillates between the extreme values of 1170 and 860 km. This bulky and prominent appendix of the European continent is welded to it by means of a wide isthmus of 435 km length, along the Pyrenees, one of the most prominent mountain ranges of the region. This type of connection, unifying but also separating, reveals the intense relationships of Iberia with Europe but also its independence and isolation from the rest of the continent, which is clearly translated into its history and culture, economy and biological content. It is an almost-island located between Europe and Africa and between the Atlantic and the Mediterranean, and its idiosyncrasy is determined by this double dualism of its geographical surroundings.

1.1.2 Geological Outline of the Iberian Peninsula

Iberia is a highly diverse territory from the geological point of view, in terms of rock types and relief models, with materials of a long array of ages. Essentially, Iberia was constructed around a primary old core to which successive portions were added in the course of time. This evolution can be divided into several periods, some of them corresponding to the build up of reliefs due to tectonic efforts (orogenesis), and others to the destruction of such reliefs due to erosion (erosive and sedimentary periods). This geological history is basically conditioned by its position between the African and the Eurasian plates in the middle of the western Tethys Sea and there are two momentous events: The Hercynian Orogeny, at the end of the Palaeozoic, and the Alpine Orogeny during the Tertiary. As a consequence, we can divide the Peninsula into two main sectors: One belonging to the old or Hercynian cycle, the old core of Iberia, and a second one related with the modern Alpine and post alpine stages. According to this, in the scheme by Terán and Solé Sabarís (1978), three main units have been recognized for the Iberian Peninsula.

1.1.2.1 The Hercynian Basement or Hesperian Shield

The Hercynian orogenic period took place at the end of the Paleozoic as a result of the collision between Laurasia and Gondwana that created the large supercontinent of Pangea. With this folding large amounts of the deposited materials in the seas which covered the area of the Peninsula so far were raised and emerged, forming the basis of the primitive Iberia. This primitive basement has been traditionally called the Hesperian Shield. These materials are the oldest of Iberia (pre-Cambrian and Paleozoic) and, depending on the conditions in which they were formed, are plutonic rocks, such as granites, formed after solidification of previously melted rocks, together with a wide variation of metamorphic rocks, including gneiss, quartzite, slate and schist. Most of these materials are siliceous and they constitute the old structural basement of Iberia, around which the other structural elements were later added. This Hesperian Shield underlies the basement of the central areas of Iberia, partially buried below more recent materials, but also emerging extensively in the western half of the Peninsula and in the core of several of the main mountain ranges, such as the Pyrenees, the Sierra de Demanda, the Central Range and the Sierra Nevada. These old siliceous materials, folded and wrapped during the Hercynian orogeny into mountain systems, eroded during the Mesozoic and were transformed into peneplains. The erosion material was deposited in the surrounding seas, such as the Thetys Sea, and mixed with biogenic lime. This process constituted the rocks which built the subsequent set of structures resulting from the Alpine Orogeny. This orogeny resulted in the current existence of an area of high elevation, or plateau, in the central section of the Iberian Peninsula, called the *Meseta*. It constitutes the basic structural element of modern Iberia, around which the rest of the structures are attached.

1.1.2.2 The Alpine Relief

After the dismantling by erosion of the Hercynian relief during the long Secondary era and its deposition into the sedimentary basins surrounding the Hesperian Shield, different phases of the Alpine Orogeny affected Iberia in the Tertiary, being responsible of the uplift of the main mountain reliefs that are currently found. This orogeny was generated by the African plate approaching the Eurasian plate and lifting most of the Iberian ranges. After the compressive phases, a generalized distension happened in the last part of the Tertiary and some tectonic fosses opened. They, as well as the peripheral basins such as those of the Ebro and Guadalquivir, were filled by the materials eroded from the high new reliefs formed in the Alpine orogeny. Among the mountains lifted in this orogeny there are three main groups: those resulting from the deformations of the previously existing Hesperian Shield, the so-called Mesetan Massifs; those formed in the borders of the Meseta; and those newly arisen from the bottom of the surrounding sedimentary basins, the true Alpine Massifs. The latter are basically formed from sedimentary materials, mostly limestone, sandstone or marl, such as the Pyrenees, the Iberian Ranges, the Catalonian Coastal Ranges and the Baetic Ranges. These Alpine massifs often show an emerging old Hercynian core too. The Mesetan Massifs resulted from a renewing of ancient Hercynian faults and the uplift of parts of the primitive Hesperian Shield, as e.g., the Central Range and the Montes de Toledo. They are formed mostly from siliceous rocks, such as granite, slate, gneiss, quartzite and schist, although there are areas with sandstone and limestone. Along the borders of the Meseta there are other groups of massifs, such as the Cantabrian Range, the Sierra Morena and the Iberian System.

1.1.2.3 The Great Depressions

Embedded between these ranges, there are a number of wide depressions which are filled by Tertiary materials and drained by the main Iberian rivers. There are four depressions or main valleys: Ebro, Duero, Tagus-Guadiana and Guadalquivir, and they can be divided into two categories: those which lie over the Meseta (upper Duero and Tagus-Guadiana) and those which are enclosed at the periphery of the Meseta (Ebro, Guadalquivir and the lower Douro and Tagus-Sado). Another division can be made based on its recent geologic history: depressions which were disconnected from the open sea during the Tertiary and were filled with sediments of the surrounding land areas, with abundant evaporitic materials (Ebro, upper Duero and Tagus-Guadiana), or depressions which never lost their connection with the open sea (Guadalquivir, lower Tagus-Sado). Each of these big valleys is covered by recent deposits (marl, sand) which are favourable for agriculture. For that reason those areas comprise a major part of the agricultural wealth of the Peninsula as well as of its human population. Huge irrigation infrastructures have been developed in many of these territories since several centuries, transforming the agrarian economy of many districts.

1.1.3 Relief Units of the Iberian Peninsula

In this part some more details are given about the main structural units in which Iberia can be divided (Loidi 1999). They are ordered according to their relation to the Meseta or Hesperian Shield, the basement of the Iberian Peninsula (Figs. 1.1 and 1.2).

1.1.3.1 Units Within the Meseta

The Basins Atop the Meseta

This large high-elevation area (211.000 km^2) occupies the centre of the Iberian Peninsula and is divided by the Central Range into two halves called submesetas, the northern submeseta or Duero Basin, and the southern submeseta or upper

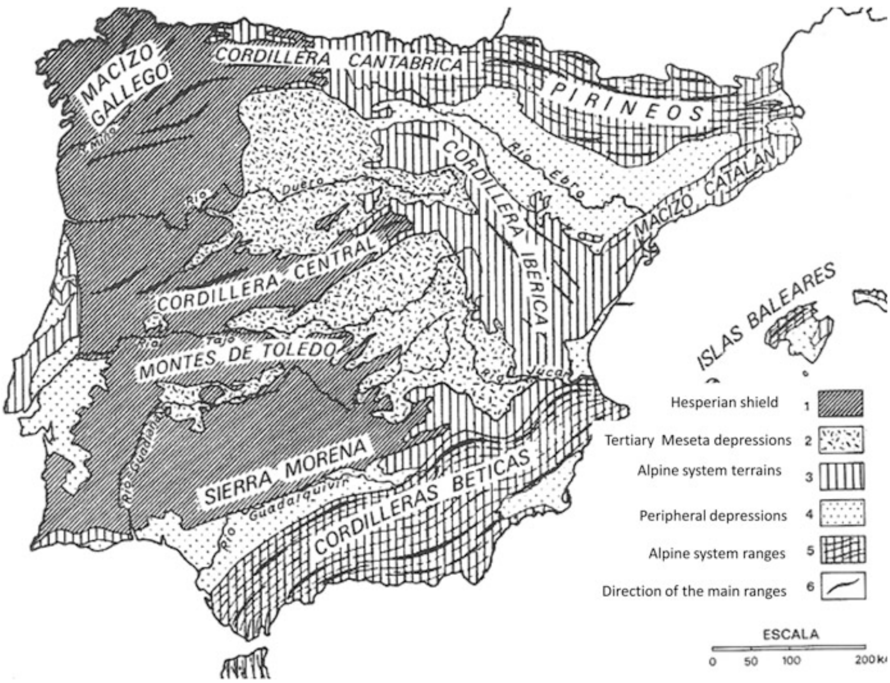

Fig. 1.2 Simplified geological structure of the Iberian Peninsula after Terán and Solé Sabarís (1978)

Tagus-Guadiana basin: La Mancha. Both basins fringe at their western border on the old siliceous terrains of the Hesperian Shield in the peneplains of Extremadura and Zamora, and these depressions are filled with sediments of Tertiary age, deposited in inland seas and subsequently not folded because they are of more recent age than the Alpine ontogeny. These materials often constitute evaporitic rocks, often gypsaceous, together with marl and limestone. As the Meseta is slightly tilted to the west, the drainage is basically towards the Atlantic, and is done by the big rivers flowing westwards, such as the Duero, Tagus and Guadiana; only the Júcar flows eastwards towards the Mediterranean Sea, draining the southeastern part of La Mancha.

The Upper Duero Basin

This is a perfectly tray-shaped basin concealed by the Mountains of León and the Cantabrian Range in the northwest and north, the northern Iberian System in the east, and the Central Range in the south. Its western limit is formed by the escarpments of the Meseta, with the lower Duero in its last stretch towards the Atlantic Ocean crossing northern Portugal (Douro). It covers about 55,000 km^2 occupying most of the northern Submeseta and an elevation ranging 700–800 m asl.

The Upper Tagus-Guadiana Basin: La Mancha

This basin extends over the southern Submeseta at an elevation between 600 and 700 m Its limits are defined by the Central range in the north, the Iberian System in the east and the Sierra Morena in the south. Its western limits are somewhat undefined as this basin grades into the Montes de Toledo and the Extremadurean peneplain. In the Guadiana headwaters the terrain is so flat that the streams possess little energy and speed and a large part of the water sinks into a huge aquifer system which, when it emerges at some points, forms lakes (ojos) or swamp areas (tablas).

The Central Range

This is the huge dividing range which crosses the Meseta in a southwest-northeast direction for 440 km, dividing it into two halves. It ranges from the Serra da Estrêla at its western end to the Sierra de Ayllón at the opposite end, encompassing a number of sierras such as Gata, Peña de Francia, Candelario, Gredos and Guadarrama. Many of these reach more than 2000 m, with the highest peak, the Pico Almanzor (Gredos) reaching 2592 m. This range is formed by blocks of the old Hesperian Massifs lifted by the Alpine Orogeny and separated by valleys corresponding to tectonic fosses. The bedrock is siliceous and old and includes granite, quartzite and slate. Glaciers have left their footprints in the main massifs of the Central Range.

The Montes de Toledo

These are a group of mountains of modest elevation (Corocho de Rocigalgo 1440 m; Sierra de Guadalupe, Las Villuercas 1603 m) dividing the southern submeseta into two watersheds, that of the Tagus and that of the Guadiana rivers. They have a similar origin as the Central Range and share many of its lithological and geomorphological characteristics, occupying an important area in western La Mancha and eastern Extremadura.

1.1.3.2 Units Bordering the Meseta

The Lower Douro Basin

This area has a sizeable extent in northern Portugal comprising the regions of Douro Litoral, Alto Douro and Tras os Montes. The lower stretch of the Duero river (Douro) crosses northern Portugal carving, together with its tributaries, deep and narrow valleys in the siliceous rocks of the Meseta basement.

Mountains of Galicia and León

In the northwestern part of the Iberian Peninsula, including Galicia and the neighbouring parts of León and Zamora, the Hesperian Shield folds and fragments due to the forces of the Alpine Orogeny and results in a series of reliefs of uneven elevation and morphology. Rocks are basically siliceous: quartzite, gneiss, slate, with outcrops of granite. The Sil depression (El Bierzo and Valdeorras) profoundly divides this unit, leaving its highest massifs on its southern side, with important mountains above 2000 m, such as the Teleno (2188 m). Glacial footprints are visible in the summital areas of the higher mountains.

The Cantabrian Range

The northen side of the Meseta is bordered by a high range of mountains of over 220 km long, parallel to the Atlantic coastal shoreline. This area is called Cantabria, a name that covers both the range and to the narrow fringe of low land between the mountain chain and the coast. The Cantabrian Range contains several massifs with numerous peaks over 2000 m, with its highest summit in Torre Cerredo (2648 m) in the Picos de Europa. The northern slope is very steep, the distance between the high summits (1800–2600 m) and the sea being only 40–60 km. This leaves the Cantabrian Fringe as a narrow stretch of land separating the Cantabrian Range and the sea (Gulf of Biscay) and being crossed by a high number of fast-running rivers coming from the high elevations towards the sea and excavating a steep relief with deep valleys. Rock materials are Paleozoic, as all the Hesperian ones, the siliceous ones (slate, quartzite, sandstone and conglomerates) being more abundant, but in the eastern sectors, as in the Picos de Europa or Peña Ubiña, Carboniferous limestone is also important (Caliza de Montaña). These calcareous massifs are often submitted to karstification and the water has excavated narrow gorges, such as that of the Cares. The southern slope is less steep because the northern Meseta plain lies at 800 m. Glacial activity has been important during ice ages in the high-altitude areas.

The Iberian System

This system limits the eastern side of the Meseta, spanning about 400 km from the Sierra de la Demanda, in its northwestern end, to the Maestrazgo reliefs, close to the Mediterranean shore in the Valencia region, where it contacts with the Catalan Coastal Range and the Baetic Ranges. It is a vast complex of mountain chains and high plateaus (páramos), separated by several internal depressions, which form an uneven system of elevated lands separating the Meseta from the Ebro Basin. Summits often reach over 2000 m, attaining their maximal height in the northern sector (Moncayo, 2315 m) and being more modest in the south (Javalambre, 2020 m). Regarding the origin and age of its rock types, the Iberian System can be considered as a mixed cordillera. It is built of a combination of emerged materials, some belonging to the old core (Hesperian Shield), as is the case for the Sierra de Demanda or Moncayo, with Pre-Cambrian and Paleozoic siliceous materials (quartzite, siliceous conglomerates or slate), and others belonging to the sedimentary cover (or burden), mostly of the Triassic, Jurassic and Cretaceous periods, such as limestone, abundantly represented in most of the mountains and páramos. Some tectonic depressions intermingle with the high ranges and were filled with eroded soft materials such as marls, and form important corridors as that of Calatayud-Teruel.

Sierra Morena

The Meseta ends at its southern border in a vast dissected area called Sierra Morena, which really is an aggregate of low elevation ranges occupying a space of almost 500 km long, from the Serra de Monchique (Algarve, Portugal) to the Sierra de Relumbrar at the eastern end, and a maximal width of 120 km along the north-south transect across western Andalusia and southern Extremadura. It is the southern border of the Hesperian Shield which was faulted during the Alpine Orogeny and that resulted in a sort of doorstep, clearly distinguishable, towards the Guadalquivir Depression. Rocks are mostly siliceous and of old age: quartzite, slate and sometimes limestone, alternating with granitic intrusions. Elevations are modest (highest elevation in the Sierra Madrona, Bañuela summit 1323 m) and the landscape is dominated by hills of rounded summits in which husbandry has been traditionally the most important land use, hosting a great part of the wooded pastures (or dehesa) landscapes existing today.

1.1.3.3 Relief Units Outside the Meseta

Basque-Cantabrian Mountains

They form a system of west-east oriented reliefs connecting the Cantabrian Range and the Pyrenees, parallel to the shores of the Gulf of Biscay. They are formed by three parallel mountain alignments of elevations of less than 2000 m, the northern one being the highest, with peaks such as Castro Valnera 1718, Aizkorri 1549 and Ortzainzurieta 1567 m. They occupy a wide fringe of land in the headwaters of the Ebro river and in those mountain ranges, mostly limestone or sandstone intermingle with marly valleys. Materials are overwhelmingly Cretaceous and were lifted during the Alpine Orogeny. The southernmost alignment confronts the Ebro Basin and the northernmost one marks the border of the Cantabrian Fringe in its eastern stretch.

Pyrenees

This important range stretches from northeastern Navarre, near to the Gulf of Biscay, to northeastern Catalonia, close to the Mediterranean shore, stretching 400 km long and 150 km wide in its central sector. East-west disposed along the connecting isthmus between Iberia and the rest of Europe, it forms a formidable wall with most of its summits over 2000 but with several peaks in the central part even over 3000 m (Aneto 3404 m). At the same time, this connecting element is also an isolating one. The Pyrenees have an axial range, which is mostly formed by the old Paleozoic core, with siliceous materials such as quartzite, slate, schist, greywacke and conglomerates combined with granite and granodiorite outcrops, and the burden of younger rocks (Mesozoic and Tertiary limestone and marl) surrounding it. Structurally, the Pyrenees are divided into an array of three parallel ranges: the Axial Range (basically corresponding to the core), the Inner Range and the Outer Range. Between the latter two ranges there is the Inner Depression (Canal de Berdún, Graus, Conca de Tremp). The Axial Pyrenees show footprints of intense glacial activity and are enveloped by the Pre-Pyrenees, a wide fringe of mountains and valleys basically formed by the Inner Depressions and the Outer Ranges.

Catalan Coastal Ranges

Two parallel range systems, uplifted during the Alpine Orogeny, stretch along the Mediterranean coast of Catalonia. They span 180 km from the Empordá area in the north, where they connect with the eastern Pyrenees, to the Ports de Beseit, where they connect with the eastern Iberian System. Elevations are relatively modest (Montseny 1712 m) and materials are diverse, being either siliceous (granite, slate) or limestone depending on localities. The mountain alignments are disposed in a southwest-northeast direction and are interrupted by the river Ebro, which carved narrow canyons in its last stretch towards the Mediterranean.

The Baetic Ranges

These are one of the most important structural units of Iberia as they stretch from the Gibraltar area (Campo de Gibraltar) at the southwestern end, to the island of Minorca, encompassing the numerous southeast-northeast oriented massifs of southern Andalusia to the southern part of the Valencian region (Dianic Ranges) and the entire Balearic Islands. In the Peninsula *sensu stricto* the Baetic Ranges are some 600 km long and in the Balearic archipelago they cover another 180 km. The width of this complex is also noteworthy as it attains 150 km at its widest stretch. Its peninsular area occupies about a half of the Andalusian region, the whole of Murcia and southern Alicante. It has numerous peaks over 2000 m and the Sierra Nevada holds the highest elevations of the Baetics and the highest peak of the Iberian Peninsula (Mulhacén 3481 m). In this highest massif the southernmost glacier footprints of Iberia are found. Rock types are very diverse, and are dominated by base-rich materials such as dolomite, limestone and marl. In some areas the old core of siliceous materials emerges, mostly in the Penibetic sector, being either metamorphic or mafic: slate, schists, marble and peridotites. Between some of these massifs, some depressions became filled with sediments of soft marly materials and formed corridors important for human communications such as the Vega de Antequera, the Vega de Granada, the Hoya de Guadix and Baza.

Great Sedimentary Basins External to the Meseta

Ebro Basin This basin is concealed in the triangle formed by the Pyrenees, the Iberian System and the Catalan Coastal Ranges, thus forming a closed-to-the-sea basin. It occupies a vast area in the northeastern part of the Peninsula and sediments are lacustrine continental largely due to the circumstance that this basin became endorrheic during a long time between the Oligocene and the Pliocene when the connection with the sea was interrupted and an inland sea developed in the basin. This explains the abundance of evaporitic rocks such as gypsum-rich marls and the salinity phenomena in its depressions.

Guadalquivir Basin Between the Sierra Morena and the Baetic Ranges there is this sedimentary basin that is open to the Atlantic; it has been filled with recent marine deposits, rich in clay, eroded from the surrounding massifs. Due to their high content of expansible clay, these terrains support an intensive and highly productive cereal agriculture.

Sado-Lower Tagus Basin At the western end of the Iberian Peninsula a particular sedimentary basin, open to the Atlantic, lies between the westernmost reliefs of both the Central Range and the Sierra Morena ensemble. The northern limits are the