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Development of geology in Spain: a case study of a marginal science.

Concerning "Una historia de la Geología en España" by M. Julivert

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ABSTRACT

Geology in Spain developed outside the mainstream of major geological ideas. Geology was introduced into the country when it had already grown mature. The history of geology in Spain is series of initiatives aimed at aligning the country with the innovative currents taking place in the rest of Europe. This was accomplished by different protagonists: state and private institutions during the Enlightenment, mining engineers in the 19th century, church and regional authorities in Catalonia in the last quarter of the 19th century and in the early years of the 20th century, and the university in the 20th century. The importance of the links with foreign geologists should not be underestimated. Not until the 20th century did improvement in living standards and university expansion allow Spanish geology to attain the critical number of scientists needed to undertake quality research and achieve full integration into the international community.

KEYWORDS | History of geology. Spain.

INTRODUCTION

"A history of geology in Spain" by Julivert (2014) is the first book on this subject. The author focuses on the pivotal figures who cultivated this discipline and on the institutions in which it was taught and in which research was undertaken. He does not concern himself with the history of the geological knowledge of Spain. He traces the history of geology in Spain against the socio-economic background of the country and against the background of the evolving geological ideas. Julivert, who belongs to the generation for whom the works of the second half of the 19th century and early 20th century are still alive, enriches his narrative with personal anecdotes during the difficult years following the Spanish Civil War (1936–39).

Given that Spanish scientists did not take part in the debates that would shape geological ideas, geology in Spain remained on the sidelines. Not until the second half of the 20th century did geology in Spain attain the critical number of researchers to gain permanent scientific status. The history of geology in Spain is then the history of this initiative to participate in the innovative currents of geology. This difficult task was carried out by a small number of scientists often against a hostile socio-political background.

Although these initiatives with their achievements and failures represented significant steps forward for geology in Spain, they ultimately ended in failure. Julivert explains how these efforts were thwarted by the political instability and the underdevelopment of the country and of Spanish geology. Nevertheless, all these endeavours left some threads of continuity that would be picked up to facilitate subsequent development.

INITIATIVES DURING THE ENLIGHTENMENT

The first initiative took place in the second half of the 18th century. This was the moment when initiatives provided new impetus to science, bringing Spanish scholars closer to the world of the nascent science of geology. A department of Natural History (Gabinete de Historia Natural), the forerunner of the present National Museum of Natural Sciences, was set up in Madrid in 1771 and a School of Mining (Seminario de Almadén) was established at Almadén in 1777 (Fig. 1). Moreover, in contrast to the indifference displayed by the universities to science, private scientific societies to promote science and its teaching flourished. Among these, the following institutions are noteworthy: the Seminary at Vergara (Seminario de Vergara) in the Basque country, the Conferencia Físico-Matemática Experimental, which would give rise to the the Royal Academy of Sciences and Arts in Barcelona (Real Academia de Ciencias y Artes de Barcelona), the Board of Commerce (Junta de Comercio) of Barcelona and the Royal Asturian Institute (Real Instituto Asturiano). Grants to study abroad were awarded to young engineers by both the state and by the private societies. Thus, the Elhuyar brothers and Del Río studied at the Mining Academy at Freiberg (Saxony). Moreover, foreign specialists were contracted to set up new institutions in which geologists who had trained abroad imparted classes.

FIGURE 1. The Casa Academia de Minas at Almadén, the building where the first School of Mining in Spain was housed from 1785 until 1835, when it moved to Madrid. Image by L. Mansilla.

After the end of the 18th century, Peninsular War (1808-1814) and the rapid loss of the colonies marked the onset of a period of political and economic stagnation during which some of the initiatives were interrupted, resulting in the closure of some institutions. Other institutions, however, survived, *e.g.* the Seminary at Almadén, which would become the School of Mining Engineers and would also give rise to the Comission of the geological map (Comisión del Mapa geológico). The School of Mining Engineers moved from Almadén to Madrid in 1835 (Fernández and Mansilla Plaza, 2004), and in 1910 the Comission of the geological map became the Geological Institute of Spain.

During the Enlightenment in central Europe the study of the earth underwent a change of focus, shifting from the study of minerals and rocks considered as non-temporal physico-chemical entities to units of rocks, terrains (Gebirge) and formations that were of a temporal significance in accordance with the neptunist viewpoint. In other words, this change of focus represented the leap from mineralogy to geology (Laudan, 1987). Lithostratigraphic successions began to be established, maps of lithological units were produced and the first regional descriptions were made, *e.g.* Lehmann (1756) and Füchsel (1761) in Thuringia, Arduino in Venetia and De Sauvages (1751–52) in France (Ellenberger, 1994). With the incorporation of geognosy (geology) into his teaching programme, Werner, the eminent professor of mineralogy at Freiberg, institutionalised the neptunist vision and the geognostic method. This method was disseminated by his students on their return to their respective countries, and as a result the first international geological community using a unified method was set up. It was during this time that the Elhuyar brothers (1778–1782) and Del Río (1786–1789) arrived in Freiberg. Subsequently, in the early years of the 19th century, Playfair promoted Hutton's plutonist ideas, triggering debates between the neptunists and the plutonists.

The initiatives during the Enlightenment therefore bore little fruit in Spain. Foreign specialists were contracted, albeit not the best ones. Needless to say, their work was counter-productive largely because of their lack of

commitment and because of the poor organisation and the backwardness of the country. Nor was the policy of awarding grants more successful because of the inadequate preparation of the grant holders and the unfavourable prospects that awaited them on their return. However, mineralogy and mineralurgy constituted an exception as shown by the careers of the Elhuyar brothers. The controversies between the neptunists and plutonists had little impact in Spain despite the fact that they were mentioned in some textbooks (Yáñez, 1820; Luxán, 1841). Geology was not practised in Spain and the graduates from the mining schools focused their attention on mineralogy as an activity subsidiary to mining, an attitude that would prevail throughout the 18th and 19th centuries. Only during the hiatus of the Liberal Triennial (1821–1823) was a chair of geology held by Yáñez at the University of Barcelona.

Despite the return of the young engineers from the Mining Academy at Freiberg, which was the cradle of geognosy, Spanish scientists were not able to make the leap from mineralogy to the new science and to adopt the geognostic method to study the land. Towards the end of the 18th century and in the early years of the 19th century, geology sensu stricto barely showed signs of existence in Spain.

INTRODUCTION OF GEOLOGY INTO SPAIN BY MINING ENGINEERS

In the early part of the 19th century, the different types of rocks and the processes that gave rise to them as well as the value of fossils as stratigraphic markers were already well known. The definition of stratigraphic systems had improved and geological maps with biostratigraphical units had been introduced. Between 1830 and 1833, Lyell published his "Principles of Geology", the aim of which is described in the subtitle as "an attempt to explain the former changes of the earth's surface, by reference to causes now in operation"–uniformitarianism–. Simultaneously, Cuvier wrote on Revolutions of the Earth and substitution of faunas, and Élie de Beaumont related Cuvier's Revolutions to the episodic formation of mountain ranges–catastrophism-. In geological practice, the survey of the earth and its representation on maps were of paramount importance. The 19th century would be the century during which the institutions entrusted with this task would be created and consolidated (Oldroyd, 1996).

The second initiative was undertaken by mining engineers within this framework of established geology. This initiative commenced in the 1830s and occurred simultaneously with the introduction of the practice of geology into Spain and culminated in the publication of the geological map of Spain at 1:400,000. This stage coincided with the arrival in Spain in 1831 of Schulz, who had trained at Göttingen and who had taken up residence in Spain and had held a number of administrative posts, *e.g.* director of the Special School of Mining, president of the Commission entrusted with the geological mapping of the province of Madrid and the Kingdom of Spain, minister of state education, etc. Of significance too, was the return from Freiberg in the early 1830s of Sainz de Baranda, Gómez Pardo, Ezquerra del Bayo, Amar de la Torre and Bauzá, who had been awarded grants to study abroad by Fausto de Elhuyar, the managing director of Mines. Another outstanding geologist was De Prado. These geologists published regional studies in the form of provincial reports accompanied by geological maps. Especially noteworthy were the ones of Galicia and Asturias by Schulz (1835, 1858), the ones of Aragón and Catalonia by De Maestre (1845) and the report of the province of Madrid by De Prado (1864). The first sketches of the geological map of Spain were published, and Ezquerra del Bayo produced the first account of the geology of Spain in 1850. De Prado discovered, in the mountains of Toledo and León, the "primordial fauna" which was studied by Verneuil and Barrande (1855, 1860). The "Elements of Geology" by Lyell, which was translated by Ezquerra del Bayo in 1847, was recommended by Amar de la Torre, professor of mineralogy and geognosy, as a book of reference at the School of Mining. In this period, a small group of mining engineers carried out much valuable work in the country, thus paving the way for the development of geology in Spain, which would take off when the Commission of the Geological Map was set up.

After some initial setbacks, the Commission of the Geological Map, which was exclusively composed of mining engineers, was formed in 1870. The Commission produced the geological map of Spain in 1889 using a grid at 1:400,000, a synthesis of which was subsequently published at 1:1,500,000 in 1893 (Fig. 2). This survey was accompanied by the publication of a series of provincial reports which included maps. The explanatory notes of the geological map of Spain were entrusted to Mallada and were published between 1895 and 1911. This map was by far the biggest contribution to the geology of Spain in the second half of the 19th century. It was a testimony to the patience and dedication of a very small number of geologists born in the middle part of the century, who despite poor communications, precarious topographical maps, and a rudimentary grasp of the geology of the country, accomplished a remarkable feat.

However, while geologists were engaged in carrying out geological surveys of Spain, outside the country new ideas such as subsidence, geosyncline, isostasy, the models of Pratt and Airy, orogenesis and epirogenesis were being forged. Attention was being focused on tectonic structures,

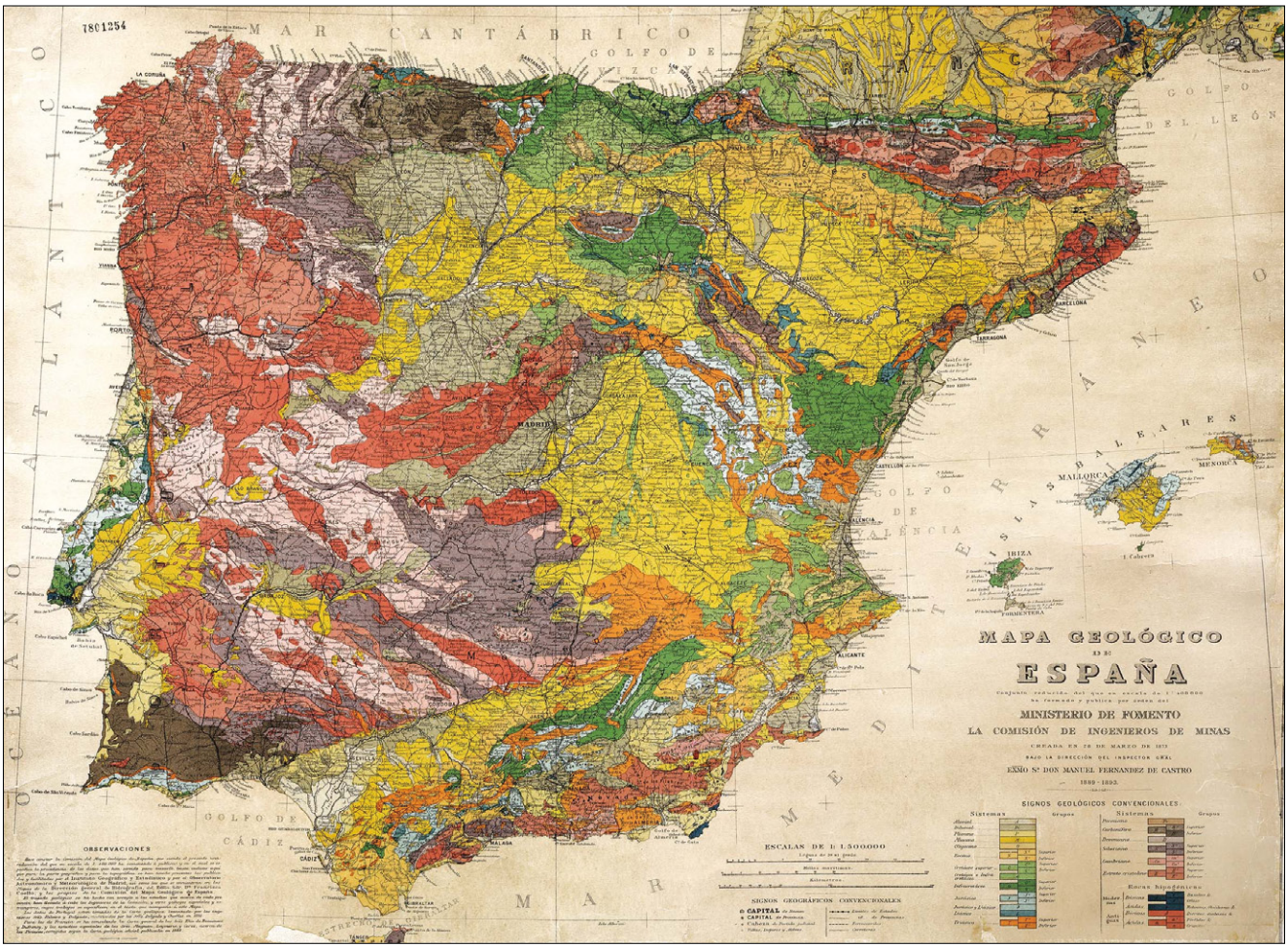

FIGURE 2. Geological map of Spain at 1:1,500,000, synthesis of the 1:400,000 map, published in 1893. Image by I. Rábano.

especially on shortening in mountain ranges and on the need for tangential forces to explain them. The idea of terrestrial contraction put forward by Élie de Beaumont in 1829 was accepted (Greene, 1982). Nevertheless, no reference to geosyncline, isostasy or contraction appeared in Spanish papers. Since its introduction into Spain, geology, throughout the 19th century, was focused on specific aspects of the country, and viewed exclusively from the mining perspective.

"Das Antlitz der Erde" by Suess (1883–1904) provides the synthesis of 19th century geology. According to Suess, uniformtarianism and catastrophism were theories that resulted from the two groups of phenomena that were superimposed. Phenomena such as erosion/sedimentation –uniformitarianist– were superimposed on orogenic phenomena –catastrophist–. In his "Das Antlitz der Erde", Suess proposed an integrated theory of the dynamics of the earth's crust within a contractionist framework (Greene, 1982).

However, the role of mining engineers in the development of geology in Spain declined in importance once mapping at 1:400,000 was completed. In 1927, the Geological Institute of Spain was transformed into the Geological and Mining Institute of Spain. The five first sheets of the Geological Map of Spain at 1:50,000 were published in 1928 by this Institute, the activities of which are ongoing.

DETAILED GEOLOGICAL MAPPING IN CATALONIA

The third initiative led to the introduction of detailed mapping. This occurred in Catalonia, where an autochthonous geology had developed outside the state institutions in the last quarter of the 19th century and in the early years of the 20th century. This initiative stemmed from a combination of two concerns. First, the desire of the Bishop of Barcelona to Christianise science in Catalonia (1874), the result of which was the geological orientation of Almera, a priest PhD. in natural sciences who taught geology at the Conciliar Seminary in Barcelona and

who set up the Museum of Geognosy and Paleontology at this institution. This subsequently became a centre of biostratigraphy run by ordained geologists and continues its activities today. Secondly, the interest of the Diputación Provincial of Barcelona (Provincial council), who aware of the potential economic advantages, were interested in a geological map of the province. Thus, in 1885, Almera was given the task of mapping the province. Five sheets at 1:40,000 were published between 1891 and 1914 though publication was interrupted when Almera retired. In 1914 the Mancomunitat of Catalonia (regional government that grouped the four Catalan provinces) created the Geological Survey of Catalonia in order to map the whole region at 1:100,000 under the supervision of Faura. Six sheets were published before the dictator, Primo de Rivera, suppressed the Mancomunitat and the Survey in 1923 (Aragonès, 1992, 2005, 2006; Gómez-Alba, 1995).

The maps of the province of Barcelona by Almera were extremely accurate despite lacking structural data which at that time began to be taken into consideration. They were the only detailed maps that were available in Spain, and they continued to be used until the early 1950s since they were of much higher quality than the few maps of Catalonia at 1:50,000 issued by the Geological and Mining Institute of Spain. The map at 1:100,000 was a significant achievement that responded to a realistic vision as regards scale. However, the Survey was not able to fulfil all its objectives because of its short life, the lack of personnel and the incapacity of the university to supply geologists.

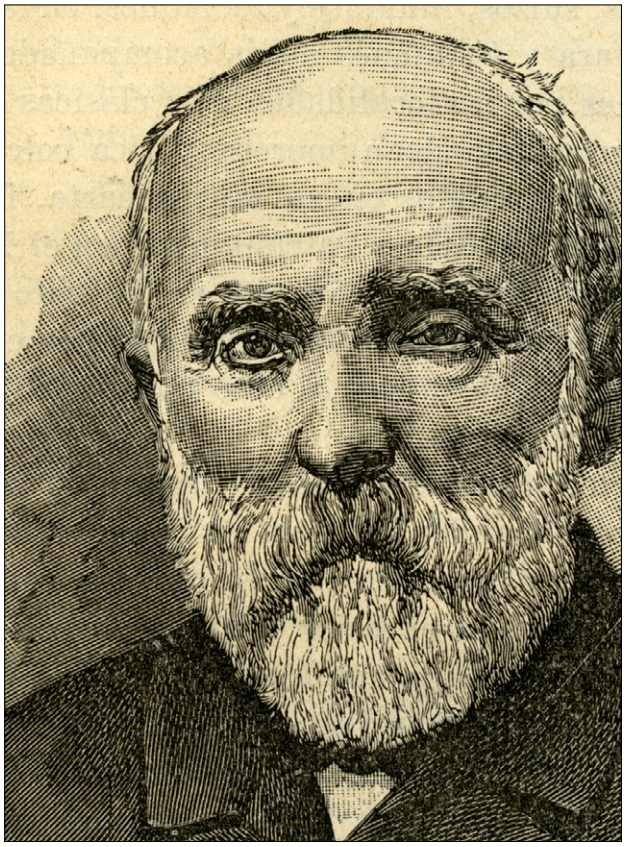

FIGURE 3. Juan Vilanova y Piera (1821–1893), the first professor of Geology and Paleontology in Spain. Part of an engraving from the Anales de la Sociedad Española de Historia Natural, 1893.

GEOLOGY AT THE UNIVERSITY

The fourth attempt to draw level with the advanced ideas of geology took place at the universities in the 20th century. Geology at Spanish universities was a late starter and progress was slow. The first chair of Geology in Spain was inaugurated at the University of Madrid (1854) and was occupied by Vilanova y Piera (Fig. 3) and subsequently by Calderón (1895), who was one of the most outstanding geology professors at this University. At the University of Barcelona, Odón de Buén held the chair of Mineralogy and Botany (1889) and, after his departure to Madrid, Pardillo occupied the chair of Crystallography and Mineralogy (1911) and San Miguel de la Cámara that of Physical Geography and Dynamic Geology (1912).

Thus the early decades of the 20th century witnessed the birth of geology at the universities of Madrid and Barcelona. Notwithstanding, these institutions suffered from severe shortages of funds and personnel. In Madrid, natural sciences were offered at the university in the first two decades of the 20th century during which some graduates turned towards geology. Despite the difficulties, scholars such as Parga and Royo managed to pursue successful university careers. However, the activities of this nascent school of Madrid were cut short by the outbreak of the Civil War. The post-war years were a difficult period during which the country was subjected to a system of economic autarchy, political repression and ideological control. Nevertheless, Solé i Sabarís at the University of Barcelona succeeded in directing a group, the school of Barcelona, which was strongly influenced by the ideas and methods of Stille. In 1953, degree courses in geology were offered in Madrid and Barcelona and five years later in Oviedo and Granada and subsequently at other universities. This led to the inauguration of chairs, many of which were occupied by geologists from the school of Barcelona. The improvement in living standards in the late 1960s and early 1970s led to a rapid expansion of the university, and to the creation of numerous posts that were filled by young contract teachers.

Until the late1960s geology was dominated by a fixist vision based on the theory of contraction despite the fact that this theory was inconsistent with the theory of isostasy. Nevertheless, it was not long before the theory of contraction was challenged by the acceptance of thrusts with large displacements and the first mobilistic ideas

were published: the deep currents of Ampferer (1906), the continental drift of Wegener (1912), the magma flow that would connect vulcanism and range formation of Schwinner (1920) and the energy needed to produce convection currents caused by radioactivity proposed by Holmes (1931). Despite containing notions that would be incorporated into plate tectonics, these ideas made no direct contribution to this theory. They were attempts to supersede the theory of contraction but proved unsuccessful owing to the prevailing fixism. In the 1960s, the theory of plate tectonics (Le Pichon, 1968) was advanced thanks largely to improvements in the geophysical techniques for exploring the interior of the earth and the ocean floor. This theory revolutionised geological ideas and continues to be the basis for developments in geology (Hölder, 1989; Oldroyd, 1996; Wagenbreth, 1999).

This period also witnessed the controversy, which started in the 1930s, surrounding the origin of granite. The transformists such as Eskola argued that granite was the result of a transformation of other rocks whereas the magmatists such as Niggli and Bowen postulated that it had a magmatic origin. The question was resolved in the late 1950s thanks to advances in geochemistry and experimentation.

Although geologists in Spain were fully aware of these and other ideas concerning doctrine, they took no part in the debates. The country lacked the resources and the preparation to undertake studies of such scope. Nevertheless, the advent of democracy in 1976 and the improvement in living standards opened up Spanish society and facilitated the arrival of new ideas. This also created more opportunities for geologists and enabled geology in Spain to catch up with that of the international community (Julivert, 2014).

SOME CONSIDERATIONS

Geology in Spain for almost all its history remained outside the mainstream of geological development. This does not mean that the geology was isolated but that it lagged behind advanced geology. The following examples serve as an illustration: i) Non-involvement of Spanish geologists in the gestation of geognosy. Geology was introduced into Spain when it had already grown mature. ii) Late inclusion of geology in university studies. In his history of geology in Germany, Wagenbreth (1999) mentions a dozen centres of higher education where classes of geology were imparted in the 1830s when Schulz arrived in Spain. By contrast, geology began to be taught in Spain on a regular basis at the School of Mining in the 1840s. The first university chair of geology was not inaugurated until 1854 and geology at the university did not really begin to thrive until well into the 20th century. iii) The late publication of the first geological map of the whole country. The geological map of Spain at 1:400,000 was published in 1889 whereas the geological map of France at 1:500,000 had appeared in 1841.

This late development involved a one way process with respect to the advanced geologies of the day, a process that proved beneficial to geology in Spain because of the assimilation of new ideas and improved methodologies. This process was brought about in different ways: i) the arrival of foreign geologists such as Schulz; ii) the departure of young scholars to prestigious institutions *e.g.* the mining engineers to Freiberg, and Vilanova y Piera to Paris; iii) the return of political exiles such as Ezquerra del Bayo and De Prado who benefited from contacts with foreign specialists; iv) the collaborations between Spanish geologists and foreign experts to study samples or resolve problems arising from research as illustrated by the relationship of De Prado with Verneuil and Barrande and by the numerous collaborations of Almera with geologists from abroad; and v) the research carried out by foreign geologists in Spain, which is the case of the group of Stille in the 20th century.

The contribution of foreign geologists to the understanding of the geology of Spain especially after the publication of the map at 1:400,000 and of the provincial reports was noteworthy. Although Julivert's history does not deal with this topic, it is not without interest since it provides interesting insights into the aforementioned dependence on foreign geologists. Until well into the 20th century, Spanish geologists were only concerned with the collection of data and the publication of local reports without attempting any synthesis of the geological units (Solé Sabarís, 1956). A notable exception was the study of the Meseta by Calderón in 1885. Foreign geologists provided interpretations and regional studies, paving the way for the assimilation of new ideas and modes of understanding geological research. Thus, in his paper on the structure of the Iberian Peninsula, Staub in 1926 interpreted the Betic Cordillera introducing thrust tectonics. The papers of Stille's co-workers on the geology of Spain showed how to integrate different kinds of geological data into consistent geological histories (Julivert, 2014).

This one way process began to fall into abeyance once Spanish geologists started to provide regional interpretations that would constitute references for subsequent studies of both foreign and local geologists. One of the first examples of these interpretations was provided in 1965 by Julivert with his major study on the structure of the Cantabrian Cordillera, in which he described its décollement and thrust tectonics for the first time.

Today the number of geologists in Spain has already

exceeded the critical number needed for quality research. Spanish geologists are currently engaged in a variety of undertakings around the globe on land and sea and are able to count on state-of-the art technology, *e.g.* data processing, analyses of various kinds, geophysics, etc. They are today fully integrated into the international geological community. Although there is still some distance to go in terms of the degree of development, they are now in a position to carry out research with implications for geology in general.

CONCLUSION

After several valiant attempts, geology in Spain managed to overcome its condition of marginality and to gain permanent scientific status within the international geological community. A review of its history, from the moment of its introduction and practice in the country in the first half of the 19th century, shows that geology in Spain during this period remained on the sidelines of the important doctrinal ideas and debates that took place outside the country. In this connection, the following factors in the development of geology in Spain should be borne in mind: i) the absence of geology in Spain at the time of the birth of geology in Europe; ii) the introduction of geology into the country when this discipline had already grown mature; iii) the non-involvement of Spain in doctrinal controversies, which accounted for the delay in embracing new ideas; iv) the late inclusion of this discipline in university studies and v) the enduring links with advanced foreign geologies.

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REFERENCES

Ampferer, O., 1906. Über das Bewegungsbild von Faltengebirgen. Jahrbuch der kaiserlich-königlichen geolologischen Reichanstalt, 56, 538-622.

Aragonès, E., 1992. La primera cartografia geològica subvencionada per una institució catalana (1869-1870). Treballs del Museu de Geologia de Barcelona, 2, 13-44.

Aragonès, E., 2005. El mapa geològic i topogràfic de la província de Barcelona: la sèrie 1:40.000 (1888-1914). Treballs del Museu de Geologia de Barcelona, 13, 115-280.

Aragonès, E., 2006. Marià Faura i Sans i el Servei del Mapa Geològic de Catalunya (1014-1924). Treballs del Museu de Geologia de Barcelona, 14, 81-264.

Arduino, 1760. Lettera Prima di Giovanni Arduino Veronese-Vicentino Sopra varie sue Osservazioni Naturali. Nuova Raccolta di Opusculi Scientifici e Filologici, Venezia, 6, 99-132; Lettera Seconda Ibid., 133-180.

De Prado, C., 1864. Descripción física y geológica de la provincia de Madrid. Madrid, Imprenta Nacional, XVI, 219pp.

De Sauvages (abbé P.A. Bossier de la Croix), 1751-1752. Mémoire Contenant des observations de Lithologie, pour servir à l'Histoire Naturelle du Languedoc, & à la théorie de la Terre. Mém. Acad. Roy. Des Sciences, Paris, année 1746 (1751), 713-718; année 1747 (1752), 619-743, pl. 21-24.

Élie de Beaumont, L., 1829-30. Recherches sur quelques-unes des revolutions de la surface du globe, présentant différents exemples de coïncidence entre le redressement des couches de certains systèmes de montagnes et les changements soudains qui ont établi les lignes de démarcation qu'on observe entre certains étages consécutifs de sédiment. Annales des Sciences naturelles, 18 (1929), 5-25, 284-416; 19 (1930), 5-99, 177-240.

Ellenberger, F., 1994. Histoire de la géologie, tome 2. La grande éclosion et ses prémices, 1660-1810. Paris, Tec & Doc Lavoisier, 383pp.

Ezquerra del Bayo, J., 1850. Ensayo de una descripción general de la estructura geológica del terreno de España en la península. Memorias de la Real Academia de las Ciencias de Madrid, 1(1), 35-65.

Ezquerra del Bayo, J., 1850. On the geology of Spain. Quarterly Journal of the Geological Society of London, 6, 406-413.

Fernández, M.F, Mansilla Plaza, L., 2004. La Academia de Minas de Almadén. Doscientos veinticinco años de historia. Actas del VIII Congreso de la Sociedad Española de Historia de las Ciencias y la Técnicas (2002), 859-869.

Füchsel, G.C., 1761. Historia terrae et maris, ex historia Thuringiae, per montium descriptionem eruta. Actorum academiae electoralis moguntinae scientiarum utilium quae Erfordiae est, 2, 44-209.

Gómez-Alba, J., 1995. Jaume Almera i Comas (Vilassar de Mar, Maresme, 1845–Barcelona, 1919). La geologia apologètica. In: Camarassa, J.M., Roca Rosell, A. (eds.). Ciència i Tècnica als Països Castalana: una aproximació biogràfica als darrers 150 anys. Barcelona, Fundació Catalana per a la Recerca, 1, 596-621.

Greene, M.T., 1982. Geology in the nineteenth century. Changing views of a changing world. Ithaca and London, Cornell University Press, 324pp.

Hölder, H., 1989. Kurze Geschichte der Geologie und Paläontologie. Ein Lesebuch. Berlin, Springer Verlag, 244pp.

Holmes, A. ,1931. Radioactivity and earth movements. Transactions of the Geological Society of Glasgow, 18, 559-606.

Julivert, M., 1965. Sur la tectonique hercynienne à nappes de la Chaîne cantabrique (étude géologique de la région à l'Est du bassin central, Espagne). Bulletin de la Société géologique de France, 7(7), 644-651.

Julivert, M., 2014. Una historia de la geología en España. En su contexto socioeconómico, cultural y político, y en el marco de la geología internacional. Barcelona, Publicacions i edicions

de la Universitat de Barcelona, 295pp.

Laudan, R., 1987. From Mineralogy to Geology. The foundations of a science, 1650-1830. Chicago and London, The University of Chicago Press, 278pp.

Lehmann, J.G., 1756. Versuch einer Geschichte von Flötz-Gebürgen. Berlin, 248pp.

Le Pichon, X., 1968. Sea-floor spreading and Continental Drift. Journal of Geophysical Research, 73, 3661-3697.

Luxán, F., 1841. Lecciones de geologia aplicada, explicadas en la Sociedad de Instrucción Pública. Madrid, Imprenta de E. Aguado, 378pp.

Maestre, A., 1845. Descripción geogostica y minera del distrito de Cataluña y Aragón. Anales de Minas, 3, 193-278.

Mallada, L., 1895–1911. Explicación del mapa geológico de España (siete tomos). Memorias y comunicaciones del Mapa Geologico de España, 19 (1895), 558pp.; 20 (1896), 515 pp.; 21 (1898), 405 pp.; 22 (1902), 514 pp.; 23 (1904), 519 pp.; 24 (1907), 686 pp.; 25 (1911), 544 pp.

Oldroyd, D., 1996. Thinking about the Earth. A History of ideas in Geology. London, The Athlone Press, 410pp.

Schulz, G., 1835. Descripción geognòstica del reino de Galicia, acompañada de un mapa petrográfico de este país. Madrid, Imprenta de Herederos de Collado, 52pp.

Schulz, G., 1858. Atlas geológico y topográfico de Asturias. Madrid, G. Pfeiffer, reedited in 1989, Oviedo, Avizoras Libros.

Schulz, G., 1858. Descripción geológica de la provincia de Oviedo. Madrid, Imprenta de Don José González, 158 pp. Reeditado en 1989, Oviedo, prólogo de A. Marcos.

Schwinner, R., 1920. Vulkanismus und Gebirgsbildung. Ein Versuch. Zeitschrift für Vulkanologie, 5, 175-230.

Solé Sabarís, L., 1956. Aportación alemana a las ideas tectónicas modernas sobre la Península Ibérica. In: Lotze, F. (ed.). Geotektonisches Symposium zu Ehren von Hans Stille, als Festschrift zur volllendung seines 80 Lebensjahres; überreicht von der Deutschen Geologischen Gesellschaft, der Geologischen Vereinigung und der Paläontologischen Gesellschaft, 177-189, Stuttgart, F. Enke Verlag.

Staub, R., 1926. Gedanken zur Tektonik Spaniens. Vierteljahrschrift der Naturforschende Gesellschaft Zürich, 71. 196-260. Spanish transl.: Carbonell, A., 1927. Ideas sobre la tectónica de España. Real Academia Ciencias, Bellas Letras y Nobles Artes de Córdoba, 83pp.

Verneuil, A., Barrande, J., 1855. Description des fossiles trouvés dans les terrains silurien et dévonien d'Almadén, d'une partie de la Sierra Morena et des montagnes de Tolède. Bulletin de la Société géologique de France, 2(12), 964-1025.

Verneuil, E., Barrande, J., 1860. Description des fossiles de la faune primordiale de la chaîne Cantabrique. Bulletin de la Société géologique de France, 2(18), 526-542.

Wagenbreth, O., 1999. Geschichte der Geologie in Deutschland, 264 pp., Enke, Georg Thieme Verlag, Stuttgart.

Wegener, A., 1912. Die Entstehung der Kontinente. Dr. A. Petermanns geographische Mitteilungen aus Justus Perthes' geographischer, Anstalt, 58: 185-195, 253-256, 305-309.

Wegener A., 1912. Die Entstehung der Kontinente. Geologische Rdschau, 3, 276-292.

Yáñez, A., 1820. Lecciones de historia natural explicadas en el Colegio Nacional de Farmacia de San Victoriano de Barcelona. Barcelona, Viuda de Roca, 508pp.