Sharing common ground: Nery Delgado (1835–1908) in Spain in 1878

A. CARNEIRO

Centre for the History and Philosophy of Science and Technology, Faculty of Science and Technology, New University of Lisbon, 2825-114 Monte de Caparica, Portugal (e-mail: amoc@netcabo.pt)

Abstract: The Geological Survey of Portugal (Comissão dos Serviços Geológicos), was created in 1857, as a section of the Geodesic Division of the Ministry of Public Works, Trade and Industry. It benefited greatly from the workings of the ministry, which in trying to modernize the country was concerned to keep up with the latest technical and scientific developments occurring elsewhere in Europe. Since its foundation, the Geological Survey of Portugal showed a clear drive towards its participation in an international scientific dialogue and cooperation. This strategy encompassed subscription to specialized foreign books and journals; intense correspondence with foreign specialists; the regular publication of monographs and memoirs in French; occasional or permanent collaboration with foreign experts; and travelling. The main outcome of the 'travel of negotiation' undertaken in 1878 to Spain by the Portuguese geologist J. F. Nery Delgado, then adjunct to the Director of the Portuguese Geological Survey, in addition to improving relationships with the geologists of the neighbouring country, was the collection of field data that was useful for the geological characterization of the southern Portuguese regions. He was also able to negotiate and look for data which could persuade his Spanish colleagues to subscribe to interpretations consistent with the Portuguese geological map, published in 1876.

Geology is a science to which political and administrative borders are irrelevant, because the boundaries of geological units do not comply with territorial conventions or national prejudices. In addition to being intrinsically historical, geology has a spatial dimension, which makes it a transnational science (Carneiro *et al.* 2003).

The transnational character of geology led many nineteenth-century geologists to cross borders and spend considerable periods of time studying geological formations in foreign countries. At the same time, they exchanged correspondence and publications with colleagues working in distant regions, that had similar geological features. Perhaps in geology more than in other sciences, communication was vital. As early as 1878, a specialized international forum, promoting regular meetings was created—the International Geological Congress (Ellenberger 1978). This organization formally institutionalized an international dimension by standardizing geology's verbal and visual language, and promoting initiatives such as the European geological map.

The transnational and international features of geology are all the more interesting as they coexisted with the rise of nationalism in Europe, often associated with the emergence of new nations through the territorial unification of countries like Italy and Germany, or the effective occupation of overseas possessions. As Oldroyd (1996) pointed out, in the nineteenth century territory was envisaged as a resource to be conquered, dominated and exploited, since territorial expansion would bring wealth and power. Geology was thus at the heart of the governmental apparatus, as it tried to rationalize and consolidate its control over territory.

A first organization devoted to mineralogical and geological surveying was founded, in 1848, as part of the Academy of Sciences of Lisbon. However, it was officially suspended in 1855 due to structural problems, difficulties in communicating with the government, lack of staff and funds.

Meanwhile, in 1852, within the Ministry of Public Works, Trade and Industry (Ministério das Obras Públicas, Comércio e Indústria, MOPCI), an essential structure of the Liberal Regime, a Geodesic Directorate was created, with the main purpose of making geographical, chorographical, hydrological and cadastral maps (Branco 1999). The MOPCI was a large 'centre of calculation'[1] composed of a myriad of specialized 'centres of calculation' with the additional task of providing the country with an infrastructure, ranging from the construction of railways, ports, bridges and the telegraph to the establishment of the metric system, the application of statistics nationwide, and the geographical, geological and cadastral survey of the country, the latter indispensable to tax collecting.

It was in this context that, in 1857, the Geological Survey of Portugal was established as a section of the Geodesic Directorate of the MOPCI. The Survey was led by Carlos Ribeiro (1813–1882), a military engineer,[2] and by the former physician

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Pereira da Costa (1809–1888), then Professor of Mineralogy and Palaeontology at the Lisbon Polytechnic. Nery Delgado (1835–1908; Fig. 1), also a military engineer, was then appointed adjunct to the directors of the Survey. From 1869 onwards he became co-director with Carlos Ribeiro, and in 1882, when the latter died he succeeded him, and led the Survey until 1908.

During the directorships of Ribeiro and Nery Delgado, stratigraphy merged with palaeontology, consolidating the practice of fieldwork and of geological mapping, thereby giving rise to a geological tradition.[3]

In the context of the Portuguese Survey travelling was inscribed in a more general strategy of internationalization of the activities of the MOPCI in its effort to modernize the state. The many technical and scientific activities of the ministry were characterized by an unusual concern in keeping its enterprises in accordance with international standards. This translated into the import of technology and regular stays abroad of engineers working under its jurisdiction with the purpose of improving techniques and methods. These were regularly applied and reported in the Ministry's journal, the *Boletim de Obras Públicas e Minas* (*Bulletin of Public Works and Mining*).

Fig. 1. Joaquim Filippe Nery da Encarnação Nery Delgado (1835–1908). (Courtesy of the Historical Archive of the Institute of Geology and Mining).

Needless to say, as part of the MOPCI, the Geological Survey profited from the dynamics of this governmental institution. By 1857, there was a clear drive towards the internationalization of the geological research carried out under its aegis through various strategies such as: the publication of monographs in French, especially after the 1860s; extensive correspondence with foreign experts;[4] and travelling.[5] Undoubtedly, travel played a major role in shaping the standards of research practices (Carneiro *et al.* 2003, pp. 249–297); in negotiating interpretations of geological data with foreign experts; in consolidating abroad the reputation of the work carried out locally, notably with the participation of Survey geologists in the meetings of the International Geological Congress; and finally in attempting to systematize geological data from missions obtained in the Portuguese African colonies, either by isolated individuals or in the context of the Geographical Society of Lisbon (Carneiro *et al.* 2003, pp. 272–281).

Following Nery Delgado's appointment in 1857, he soon became one of the leading Portuguese geologists involved in a scientific international dialogue, both through his vast correspondence and his travels. His main scientific interest became the study of the Palaeozoic, and his contributions in this field earned him an international reputation. His mission in Spain in 1878 falls into the category of 'travels of negotiation', for several reasons: the Portuguese Survey was more consolidated; Nery Delgado was by then an experienced geologist thereby able to discuss as an equal his interpretations; the activities of the Spanish Survey (Comisión del Mapa Geológico) (Ayala-Carcedo 1999; Blázquez Diaz 1992), and the studies so far carried out were certainly helpful to neighbouring countries; the Portuguese geological map (in the scale 1 : 500 000) had already been published in 1876, and it was important to get the Spaniards to agree with it as much as possible, and to set the standards of future cooperation.

The context of Nery Delgado's mission in Spain

Good scientific relations between Portugal and Spain were rare in the history of science of both countries. Historically, Portugal and Spain were at odds in both wars and mutual contempt. However, by the second half of the nineteenth-century some geologists of both countries engaged voluntarily in a regular scientific exchange, the leitmotiv being the ground shared by the Iberian peoples, but on which they have indelibly marked their national and regional divisions. The relationships established between

Portuguese and Spanish geologists working in their respective national Geological Surveys call for a detailed study. They transcended strictly scientific issues to encompass a dialogue on political and economic ones, the Iberian unification being a topic of friendly discussion, though not consensual among the geologists of both countries.

Nery Delgado's visit to Spain in 1878 was preceded by an intense exchange of correspondence, which continued until his death in 1908. This correspondence shows that the relations between geologists of the Portuguese Survey and their Spanish counterparts developed in a friendly climate with views grounded in nineteenth-century Liberal ideology. They were framed in a kind of chivalric ideal of an international brotherhood of engineers, which seems to have replaced the eighteenth-century 'Republic of Letters' as an ideal realm gathering men of science and good will, regardless their nationalities or beliefs. The letter of introduction to Nery Delgado of the Spanish geologist Joaquim Gonzalo y Tarin (1838–1910), whom he was to meet during this mission, shows this spirit eloquently: 'As an engineer of the Mining Corps (. . .) I have the honour of addressing you with no other merit or link than that which unites the engineers of all countries'.[6]

From his mission in Spain, Nery Delgado left a written report (Nery Delgado 1879). At first, this report was meant to remain private, but Carlos Ribeiro, then the Portuguese Survey's director, decided otherwise, as Nery Delgado confided to his Spanish colleague José Macpherson (1839–1902) (Alastrué 1968; Barrera 2002*a*, *b*):

> Last year on my return from Spain, I submitted to my director an official report of what I had done, which has not really a scientific character, nor was it written to go around the world. My director thought otherwise and the report was printed. As you will probably find something that might interest you I will ask him permission to send you some copies. If you feel that I deserve that honour please send a copy to your brother Don Guillermo Macpherson and another to Don Antonio Machado [y Núñez (1812–1896)], because I do not dare to do it myself given its insignificant value.[7]

The normal procedure would have been to address a manuscript to Ribeiro, who in turn would have handed it on to the Head of the Geodesic Directorate and the MOPCI. However, he required the publication of Nery Delgado's report,[8] in this way setting a precedent, which can be seen as an important strategic move. By going public, Ribeiro was justifying the need to travel as part of the normal work of a geologist, but more importantly he was legitimizing the research carried out by him and by the geologists working under his supervision. Therefore, those in power could not ignore their role, especially as their work was being acknowledged in other countries, and similar research was being carried out and valued.

From then onwards, whenever Nery Delgado travelled abroad his reports were published (Nery Delgado 1882). Generally they are concise and accurate accounts, rich in details not only relevant to the history of Portuguese science but also to the history of European geology.

Fieldwork and theory

Nery Delgado's mission in Spain took two and a half months, that is from 28 May to 12 August 1878 and encompassed three fieldwork excursions, respectively in the provinces of Huelva (excursion 1) followed by a short stay in Madrid, then Asturias, Léon and Cantabria (excursion 2), and finally in the neighbourhood of Almadén in the province of Ciudad-Real (excursion 3).

Nery Delgado regretted the time spent travelling from one place to another and complained that storms and heavy rain prevented him from obtaining the kind of results he might otherwise have obtained. As compensation, he mentioned the cordiality which marked his personal encounters with Spanish colleagues, which he considered highly beneficial to the development of geological studies in both countries.

He then proceeded with the description of the objectives of his mission, the negotiations involved and the respective outcomes. Thus, the purpose of his visit to Huelva was to establish an agreement regarding the classification of the Palaeozoic formations located in the southern borders of the two Peninsular kingdoms; in particular, to compare the results of the research carried out in the Alentejo (southern Portugal) with those obtained previously by the Spanish mining engineer and member of the Spanish Geological Survey, Gonzalo y Tarin. The visits to Léon and Asturias were to understand the relationships between some shale formations, which were supposed to contain the 'primordial fauna' (Cambrian graptolitic shale) with contiguous Palaeozoic formations. Nery Delgado wanted to acquire practical knowledge in order to renew research on this topic carried out in Portugal, which until that point had been fruitless. At the same time, he examined sites at Colle and Almadén in the provinces of Léon and Ciudad-Real, which he considered particularly interesting for the study of both the Silurian and the Devonian. Nery Delgado wanted to collect data that would clarify the investigations on the same systems in Portugal, in particular in Buçaco (central Portugal) and Portalegre (southern Portugal). In this way, new references and means of comparison were gathered in order to describe the Palaeozoic as thoroughly

as possible, which for some time—as he rightly claimed—'have deserved special attention from geologists of all countries' (Nery Delgado 1879, p. 5).

From a theoretical point of view, Nery Delgado's work at the time he visited Spain was very much based on the palaeontological interpretations of Joachim Barrande (1799–1883), a geological traveller who dedicated the last half of his life to the study of the Silurian in Bohemia. Barrande started his palaeontological career in mid-life. He had been a civil engineer and then tutor to Count Chambord, with whom he emigrated from France to Bohemia (Kriz & Pojeta 1974). According to Goulven Laurent (1987), Barrande was one of the mid-nineteenth-century palaeontologists who resisted transformism. He was a Cuvierian, because he valued precise data, based on careful observation and comparison, but he rejected a generalized catastrophism, that is the idea that there was a sudden and total extinction of a particular fauna before a younger one appeared.

Despite recognizing the existence of three faunas in Palaeozoic fossils—'primordial fauna' (Cambrian), 'second fauna' (Ordovician [which was formalized later by Charles Lapworth]) and 'third fauna' (Silurian)—Barrande formulated a theory known as the theory of colonies, which undermined the basis of Georges Cuvier's (1769–1832) and Alcide d'Orbigny's (1802–1857) catastrophism. In his studies of the Palaeozoic fossils, Barrande had observed that in some places in Bohemia assemblages of younger fossils appeared during the existence of the preceding fauna. He explained this phenomenon as being the result of migrations of organisms from one region to another, and he called such organisms 'colonies'. For him, this was a purely palaeontological phenomenon, therefore independent from stratigraphic considerations,[9] an argument which called into question the well established principle of William Smith (1769–1839) for whom the identification of strata of a particular age was associated with fossils of a specific kind (Oldroyd 1990).

Barrande's theory generated a lively controversy, that lasted for about 20 years. Among Barrande's opponents were Jan Krejci (1825–1887) of Prague, and the British geologists Charles Lapworth (1842–1920) and John E. Marr (1857–1933).[10] An alternative interpretation to Barrande's was that of Krejci who claimed that the Bohemian strata had been dislocated by earth movements, or Marr's more elaborate interpretation, arguing that these palaeontological/stratigraphic discrepancies were explained by faulting. For both, tectonic movements resulted in a confused stratigraphic sequence, whose cause was a disturbed physical structure rather than an abnormal reaction of organisms that had set out to colonize existing fauna (Oldroyd 1990, p. 224, 2000).

It is hard to ascertain Nery Delgado's position regarding the implications of Barrande's theory of colonies, particularly in relation to catastrophism, fixism, and evolution. However, when he travelled in Europe in 1881, following the meeting of the International Geological Congress in Bologna, he went to Prague and visited Barrande, just after John E. Marr had published his article opposing the 'theory of colonies' (Marr 1880). Nery Delgado's comments on these debates seem particularly interesting because he expressed the view that the theory of colonies was a strong argument in favour of Darwinian evolution, although he was well aware[11] of Barrande's rejection of evolution, which was increasingly acquiring the status of a doctrine.[12]

However, during his visit to Spain, Nery Delgado's theoretical framework was very much Barrandian, which does not necessarily mean that he endorsed creationism and fixism.

Excursion 1: Diplomacy and negotiation in Huelva

Of the various fieldtrips that Nery Delgado made while visiting Spain, the excursion to Huelva in June 1878 was the longest, lasting more than three weeks. He was accompanied by Tarin, who had a comprehensive knowledge of the province since he had produced a mining-geographic map of that region. In addition to geological fieldwork, Nery Delgado visited mines, in particular the pyrites mines of Rio Tinto and Tharsis, which were considered the most valuable of this Spanish province, and in his opinion, for their type they were probably unrivalled by any other in the world. However, mining was not a subject that interested him much personally. Although recognizing the importance of these mines, he does not provide any description or comment about their organization.[13]

The first scientific issue he discussed with Tarin was the age of the formation on which the city of Huelva was built. Huelva sits on a group of hills composed of clay and fine yellow-grey sandstone with characteristics similar to those of the shell marls of Cacela, Adiça and Mutela (Portugal). The Spanish formations were abundant in fossils, most being molluscs similar to those found in Portugal. The fossils of Huelva had been studied by Justo Egozcue y Cia (1833–1900), then Professor of Geology and Palaeontology at the Mining School of Madrid and attached to the Spanish Geological Survey, and Lucas Mallada y Pueyo (1841–1921) (Alastrué 1983), a palaeontologist serving in the same institution. Given the

abundance of certain species, and the existence of others which Egozcue and Mallada thought to be characteristic of the Pliocene, they had classified the fossils of Huelva accordingly, a classification which Tarin accepted (Nery Delgado 1879, p. 7). However, Nery Delgado disagreed and contended that the fauna that inhabited Huelva during the Cenozoic was the same as had existed in Cacela and in the mouth of the Tagus River (Lisbon). The only difference, he said, was that some extra species had been found and others had vanished, which only amounted to a modification or local variation; he concludes that 'our fauna (. . .) corresponds perfectly to that of the Vienna basin classified as belonging to the upper part of the middle stage of the cenozoic (Upper Miocene)' (Nery Delgado 1879, p. 8).

To support his view, Nery Delgado reported that he found different types of Foraminifera in the sandstone of Huelva that were also present in the Vienna basin. This was material proof, which for the moment settled the issue and confirmed his interpretations. The outcome of this negotiation could not have pleased Nery Delgado more: the final conclusion was consistent with the classification that he and Carlos Ribeiro had made on the Portuguese geological map published in 1876 (Ribeiro & Nery Delgado 1876). Portugal, being a much smaller country, already had a geological map, whereas Spain was still struggling to produce a precise national geographic map to replace its regional maps. As in a game of chess, it was only natural that the Portuguese Survey should want to make the Spanish geological interpretations conform to its own.

Nery Delgado reported that together with Gonzalo y Tarin he had drawn an initial cross-section in Huelva, NW via Villanueva de los Castillejos and Puebla de Guzman towards Paymogo, that aimed at differentiating the relationships between the fossiliferous formations of São Domingos (Portugal), which he had classified as Silurian, the Culm[14] topping them, and with the underlying shale running northwards. However, this cross-section did not provide the expected answers (Nery Delgado 1879, p. 7).

Nery Delgado then explained that a strip running east–west in the central part of the Province of Huelva showed intense metamorphic activity, that had so deeply altered the characteristics of the original layers that it was almost impossible to differentiate them from the Azoic formation. In addition, Nery Delgado noticed that there had also been intense 'geyserian activity' (hydrothermal activity),[15] accompanied by metalliferous emissions, from which huge masses of minerals and limestone, and probably quartzite, had originated but in such an abnormal way that they did not exhibit the continuity typical of regularly formed layers (Nery Delgado 1879, p. 7). From Nery Delgado's description, he seems to have been referring to the presence of carbonatite, although he does not name it as such, as the term was only coined in 1921 by the Norwegian geologist and igneous petrologist W. C. Brögger (1851–1940).[16] Carbonatite is considered an unusual igneous rock, rich in calcite and other carbonate minerals, metals and rare earth elements. Since 1965, the magmatic origin of carbonatite has been reinforced by fieldwork and laboratory studies; however, the other hypotheses—intrusive limestone, alkaline metasomatism and recrystallization of sedimentary or metamorphic limestone, as well as hydrothermalism—remained as particular cases or complementary mechanisms (Brito de Carvalho 1978, p. 27). Nery Delgado's description seems to match the theory of a hydrothermal mechanism underlying the genesis of the then nameless carbonatite.

Nery Delgado explained that the features he had described made the study of this region so difficult that Tarin, despite his detailed investigations, was forced to paint all these layers in the geological map of this province with the colour representing the Culm. However, Nery Delgado contended, it was unlikely that this Palaeozoic formation covered such an area.

Nery Delgado was more fortunate with a second cross-section running northwards, beyond the borders of the province, and reaching the Province of Badajoz until Higuera de Fregenal. He recognized that there was a perfect replication of the strata observed in southern Alentejo (Portugal), and concluded that two seas, one Silurian and one Carboniferous had existed, either side of a barrier on both sides of which the same sediments had deposited. This explained the replication of strata, north and south of the strip of Azoic rocks, as already indicated in the Portuguese geological map, between Aldeia Nova and Corte do Pinto (Portugal), and extended into the Spanish territory.[17] He said that these ancient rocks formed a large promontory in the Silurian and the Cambrian, against which fine greywackes and greenish mudstone were deposited, covering vast areas of Portugal and Spain. He argued that later on, the formations of São Domingos (Portugal) emerged as a result of tectonic movements. They contained various specimens of Silurian fauna, which could not be found anywhere else in the Iberian Peninsula, and occasionally some graptolites, which seemed to impart a 'colonial' character to this fauna (Nery Delgado 1879, p. 8).

The same succession of fine greywackes and greenish mudstone that he had observed from São Domingos (Portugal) northwards were observed in Spain, near Molinos de San Bartolomé, five legs ESE of Barrancos (Portugal), though obscure and

barely distinguishable. Nery Delgado then established some correlations between his observations carried out in Spain: the 'ampelite'[18] of the Sierra de los Cotos, which he did not examine, probably corresponded to that observed in Ensinasola; the limestone of La Serrana and Sierra de Alamo corresponded to that of Hinojales and Arroio de Molinos in the southern border of the province.

The analogies of the slate formation of the Baixo-Alentejo (Portugal) and Huelva with the Taconic of North America, that Nery Delgado had mentioned in his memoir on the Silurian of Alentejo published in 1876 (Nery Delgado 1876), were also confirmed by his Spanish friend of many years, José Macpherson, when he identified a form of *Arhaeocyathus* (*Archaeociatid*), a coral, in the limestone occurring in northern Seville. Until then, *Archaeocyathus* had only been found in the sandstone of Potsdam (Canada), but Macpherson's discovery proved the existence of Cambrian strata in the south of the Iberian Peninsula.

Macpherson's confirmation of Nery Delgado's views had a special meaning for the Portuguese geologist. Carl-Ferdinand von Roemer (1818–1891), then Professor of Geology at Breslau, who had contested Nery Delgado's classification of the strata of São Domingos (Alentejo) as being Silurian (Nery Delgado 1879, p. 9), was thus led to revise his own arguments supporting his classification of São Domingos strata as belonging to a lower division of the Culm.[19] However, Nery Delgado recognized that further studies were required in Portugal, notably in the surroundings of Barrancos, a region until that point only barely studied and difficult to explore (Nery Delgado 1879, p. 9). Nery Delgado summed up his expedition in this Spanish province:

> If my visit to Huelva did not make completely clear to me the Silurian stretch of São Domingos, and if in the research carried out by Tarin I could see no good reasons to change the results obtained in Portugal, the discoveries made near Ensinasola shed an intense light which will greatly help me in pursuing my future investigations (Nery Delgado 1879, p. 9).

He then made a short trip to Seville to meet José Macpherson, and clarify some points regarding *Archoeocyathus*. He visited the museum of the local university whose director was Antonio Machado y Núñez (1812–1896), Professor of Natural History. Nery Delgado remarked that the collections were small, but possessed invaluable samples especially molars and the maxillary bones of an elephant collected in the sandstones of the river Guadalquivir, which Machado and the brothers Macpherson (José and Guillermo) had classified as belonging to the Quaternary. Nery Delgado believed that these deposits were contemporaneous with the sandstones of the Portuguese rivers Tagus and Mondego. He also considered himself prepared to introduce corrections to the Portuguese geological map, if further studies confirmed this hypothesis:

> If that species of proboscides belongs to the Pleistocene (post-Cenozoic) and if it was effectively extracted from the sandstone deposit with quartzite pebbles there is probably a reason to correct the classification of our modern sandstone deposits, indicated in the geological map by (n^3), which will have to be divided into Pliocene and Pleistocene, when more and fruitful observations unveil the fauna which inhabited our country at the time these deposits were formed (Nery Delgado 1879, p. 10).

Nery Delgado concluded that this large sandstone deposit existing in the Iberian Peninsula should be considered a general phenomenon. He then hypothesized about its formation: it could have been formed either during the time span separating the two glaciations, or by strong currents following the thawing of the great ice cap, should the existence of these two distinct periods in the Peninsula be demonstrated.

Afterwards Nery Delgado left for Madrid, where he devoted himself to the study of the palaeontological collections of the Spanish Survey. He concentrated on those pertaining to the Silurian and the Devonian of Ciudad-Real, Asturias and Léon as a preparation for the field excursions he planned to make in the latter two provinces.

Excursion 2: Léon, Asturias and the Cantabrian mountain range

The second field excursion was to Léon, Asturias and the Cantabrian mountain range. Its purpose was to investigate the lithological characteristics and the stratigraphic relationships of the shale containing the 'primordial fauna' (Cambrian), which had not been found in Portugal at that time. However, the 'primordial fauna' had been observed in various Spanish regions, particularly in these two provinces thanks to the work of Casiano de Prado (1797–1866) (Ayala-Carcedo 1997). On this field-trip, Nery Delgado was accompanied by Lucas Mallada and Jesus Buitrago both of whom were working for the Spanish Survey and were heading to Asturias to decide on a question raised by Charles Barrois (1851–1939), who had recently contested Prado's claim of the existence and location of a Cambrian formation between Grado and Belmonte.

Prado and Edouard Verneuil (1805–1873) had discovered the 'primordial fauna' (Cambrian) in Léon and also in the centre of Asturias, between Grado and Belmonte (Prado 1850). Barrois was interested in studying this fauna, which as he argued:

> The primordial fauna is highly interesting to a great number of geologists of both worlds who attended the Exhibition in Philadelphia, and which they feel should deserve full attention in the

meeting of the International Geological Congress to be held in Paris in the next year (Barrois 1877, p. 378).[20]

Barrois added that, in France, nobody had been able to identify the 'primordial fauna' and therefore the opportunities for studying it were scarce. But, on his trip to Spain, he was also unable to find this fauna between Grado and Belmonte where Prado claimed to have found it. At first, Barrois was persuaded that the whole region was constituted by Devonian layers, but he finally located strata containing the 'primordial fauna'. However, these strata formed a regular strip in the western part of Asturias, not in central Asturias as Prado had claimed. For Barrois, the shale containing the 'primordial fauna' in western Asturias penetrated the limestone. It was overlying micaceous shale and gneiss, and covered by white sandstone and *Skolithos*, which in his view had the same stratigraphic position and the same lithological characteristics of the shale constituting the cliffs in Douarnenez Bay in Britanny. He concluded that the shale of Asturias and Britanny might be of the same age. The 'primordial fauna' of Asturias, which he hoped to be able to find in France, contained *Paradoxides*, *Conocephalites* and *Trochocystites* but differed from that of Léon because it lacked Brachiopoda (Barrois 1877, pp. 378–379).

The Spanish Survey published a translation of Barrois's paper resulting from this trip, which had been released in the *Bulletin de la Société Geólogique du Nord*, but added a note to Barrois's considerations in which it hints at a certain malaise. It reads:

> The Spanish Geological Survey received the news that an engineer of the Corps of Mines, who had long lived in the Mining district of Oviedo, visited and on frequent occasions carefully observed the locations mentioned by Verneuil and Prado. In the neighbourhood of Belmonte he recognized various fossils belonging to the 'primordial fauna' and among them a *Trochocystites bohemicus barr* and the glabella of an *Elipsocephalus*. It is plausible to think that if Barrois was not able to see them, it is because geologists are not always lucky enough to find everything they seek, when they decide to undertake a quick excursion to a particular site, which is undoubtedly the case of Barrois's. The Spanish Survey therefore believes that one should suspend judgment about a particular question, until it becomes totally clear.[21]

Despite the stormy weather, Nery Delgado reported that he was able to clarify the questions that troubled him at the same time he discovered the reasons underlying what he considered Barrois's mistake, thereby providing his Spanish colleagues with arguments against the interpretation of the French geologist.

Nery Delgado pointed out that there was a quartzite mountain range in western Asturias, which the German-born mining engineer Guillermo Schulz (1800–1877) (Puche Riart & Ayala-Carcedo 2001) had classified as Devonian in his geological map. Its features corresponded to the same formation that occurred in Portugal and constituted the base of the Silurian, and contained the 'second fauna' (now known to be Ordovician). Nery Delgado described this quartzite as being either finely grained or compact, containing some mica, and being white or whitish in colour as a result of superficial alteration. Underlying this massive and thick formation, at times interrupted by thin layers of clay and clayey-siliceous, dark-greyish micaceous shale, a thick formation of clay and clay-siliceous shale more or less micaceous developed. Upwards, it effected the transition between the micaceous clay and the quartzite. At the base, there was clayey shale where various forms characteristic of the 'primordial fauna' were found, namely trilobites, belonging to the genera of *Paradoxides*, *Conocephalites* and what Nery Delgado considered a remarkable cystidium (*Trochocystites bohemicus*? *barr*), being particularly abundant in one stratum (Nery Delgado 1879, p. 16).

Nery Delgado explains that the base of this fossiliferous shale formation was composed of a thick layer of dolomitic limestone, either with a sugar-like or compact texture with spar spots with a greyish, yellowish or rosy colour, probably due to superficial alteration. In his view, this layer represented the oldest group of rocks in the region and at the same time it established the connection between the fossiliferous strip and the limestone, which in the southern part of the Cantabrian mountain range contained the same fauna. Nery Delgado argued that limestone was the key rock to understand the question because it indicated the sites of a region where the 'primordial fauna' (Cambrian) could be found:

> Wherever limestone appears under the quartzite formation, there are good reasons to suppose the existence of that fauna in the intermediate shale layers (Nery Delgado 1879, p. 16).

By taking into consideration Schulz's geological sketch of the region where limestone was represented at the western end of Asturias, between Vega de Rivadeo and Santa Eulalia de Oscos, along a series of outcrops aligned with the astronomic meridian, Nery Delgado argued that one could presume the existence of the 'primordial fauna' (Cambrian) (Nery Delgado 1879, p. 16). However, that had not been Barrois's conclusion. He also said that according to Barrois's investigation, this fauna appeared instead in the borders of the province of Oviedo with Galicia.

Nery Delgado was led to conclude that similar considerations should be applied to different isolated outcrops of limestone, more or less extended but to some degree aligned and related to one another, that run parallel to the quartzite strip, crossing the province northwards in the chain separating rivers Narcea and Navia. That had been Prado's

conclusion in relation to the mountain range of El Crono de Peñarubia, running northwards until reaching the sea (Nery Delgado 1879, p. 17).

Paradoxides was observed in both the western and eastern parts of the high quartzite mountain range of El Pedrorio and Peñamanteca in the neighbourhood of Belmonte. The mountains were aligned with one another, which led Nery Delgado to conclude that they were a synclinal fold, in which he had found the Devonian system, represented by alternating limestone, clay and shale, the most abundant rocks of the region (Nery Delgado 1879, p. 17).

In the valley of Santa Maria de Villandar, west of Pedrorio, the Devonian layers formed, in Nery Delgado's view, another synclinal fold, whose axis corresponded roughly to the direction of the thalweg, because the different layers were replicated in each slope, giving the impression at a first glance that they intruded under the quartzite of Pedrorio and the shale with *Paradoxides* and limestone. Nery Delgado argued that the boundary of the Devonian system lopsidedly cut the direction of the strips of 'primordial fauna' (Cambrian) and the Silurian quartzite, which was probably determined by a fault running along the foot of the mountains of Pedrorio and Siaza, the position of these layers resulting from their dislocation (Nery Delgado 1879, p. 17).

Based on these considerations, Nery Delgado claimed that he was forced to recognize that a synformal folding of the layers, running NNE along the mountain range of Pedrorio, Bejega and Peñamanteca, produced various anticlinal and synclinal folds. In his view, they explained why the Silurian quartzite of the base of the 'second fauna' (later regarded as Ordovician) came to occupy the highest points due to the greater resistance they offered to external agents and denudation. The layers of the Devonian, which by a discordant or transgressive stratification originally rested on the layers of quartzite, shale and underlying limestone, underwent the same dislocation movements as the older formations, thereby producing faults. Nery Delgado argued that these faults corresponded to the deep ravines in whose walls the lower layers were observed, showing the contact with the Devonian. He concluded that this apparent inversion had troubled Prado so much, and had mistaken the 'no less skilful geologist Barrois, 18 years later' (Nery Delgado 1879, p. 17).

From the orientation of the quartzite strips indicated on Schulz's map, Nery Delgado was in no doubt that the layers of the 'primordial fauna' (Cambrian), after inflection from NNE to SSW, inflected again southwards, southwestwards and then eastwards, penetrating the province of Léon and proceeding to Boñar and Sabero via the southern slope of the Cantabrian mountain range (Nery Delgado 1879, p. 18).

Nery Delgado and Barrois continued to exchange letters on this subject between 1879 and 1883, following the publication of Nery Delgado's report of his mission in Spain. In particular, they discussed the correlations Barrois had established between the Palaeozoic of Britanny and Alentejo (southern Portugal) by taking into account Nery Delgado's investigations in this Portuguese province.[22] Barrois, then working in the Geological Laboratory of the Science Faculty of Lille, had engaged in the study of the geology of Asturias, Galicia (Spain)[23] and Brittany published various works that he discussed with Nery Delgado.

The Cantabrian mountain range

Nery Delgado then went from Estacas to Ferredal, a place located in the parish of Quintana, where he observed the transition from the quartzite layers to the underlying fossiliferous shale, and then to the lower limestone and marbles. Ferredal is built on limestone and it was in the shale layers immediately overlying the limestone that fossils were found. Nery Delgado remarked that the transition from marble to shale was through a coarse reddish limestone similar to that of Sabero where he had found fossils. But what Nery Delgado found most striking was that the fossiliferous shale, slightly greenish and slightly chloritic, showed in some parts a similar character to the shale or slate clay of the 'colonial' horizon of Buçaco (central Portugal), especially going from Portela de Sazes to Sazes. Nery Delgado argued that this coincidence could lead one to conclude that the limestone is but a lithological accident of the shale layers, its origin being 'geyserian'. In his view, the 'geyserian activity' began to manifest before the water transported the muddy sediments, but he argued that like in Buçaco (central Portugal) it probably continued long after the sediments were deposited (Nery Delgado 1879, p. 18). Again, he seemed to be hinting at the presence of volcanic activity and the possible presence of carbonatite this time in Buçaco, which is all the more interesting as in the twentieth century its existence on mainland Portugal was absent from geological literature, mainly because calcium carbonate based rocks are invariably assumed to be sedimentary rocks.[24]

Nery Delgado contended that the study of the wide Silurian part of Asturias—a task that in his view would take a long time because the country was rough and the members of the Spanish Survey had to investigate other regions first that they barely knew—would provide invaluable data to aid the knowledge of other Palaeozoic formations. But what seemed indisputable to Nery Delgado was that when the Silurian of the Iberian

Peninsula was taken as a whole, this lower formation had undoubtedly greater thickness in the north than in the south, where it finally died out (Nery Delgado 1879, p. 18).

On the southern slope of the Cantabrian mountain range, Nery Delgado confirmed what Prado had pointed out: the 'primordial fauna' (Cambrian) appeared in narrow strips (10–40 m), essentially composed of coarse and ferruginous clayey limestone, whose red/yellowish colour could be observed especially in the upper layers. These strips were intercalated with the Devonian and the Carboniferous, and Nery Delgado remarked that their features were such that it was difficult to distinguish them from the contiguous layers containing the 'primordial fauna' (Cambrian). In his view, that was why the 'primordial fauna' of the Peninsula had not been discovered in Spain, but in Paris in the cabinets of Barrande and Verneuil, to whom Prado had sent the fossils he had collected in his field missions in the Cantabrian mountain range. Yet, Nery Delgado praised Prado's work because he had persistently followed the vestiges of these strips for more than 100 km in a very rough and so far unexplored region, thereby providing the first positive data on the existence of the 'primordial fauna' in the Iberian Peninsula. Prior to Prado's work, only the fossil fragments that he had collected in the Guadiana basin, north of Ciudad Real, had merely hinted at its existence (Nery Delgado 1879, p. 19).

Nery Delgado then observed the relationships between the 'primordial' strips of Léon and Asturias. He remarked that limestone and shale occur in both places, but in Oviedo the fossils occurred exclusively in the shale, whereas in Léon they were more abundant in the limestone. What he found most striking was that in the borders of these two Spanish provinces, or in the passage of the Cantabrian mountain range, fossils appeared both in the limestone and in the shale, which in his view proved both a petrographic and palaeontological connection between the 'primordial' strips located on both sides of that important orographic line (Nery Delgado 1879, p. 19).

However, he noted that there was a difference regarding the richness of these faunas, which resulted from more favourable conditions on the southern slope of the chain compared with the region to the north. Despite being less abundant, a greater variety of species had been discovered in the deposits of Léon than in Asturias, the absolute absence of Brachiopoda in this province being the most relevant feature. In Léon, they amounted to one third of the total of species collected. According to Nery Delgado, the composition of this fauna and the existence of certain genera linked it with the Menevian of St Davis, or associated the first stage of the 'primordial fauna of Barrande' with the fauna of northern Spain (Nery Delgado 1879, p. 19).

One of the geological cross-sections that Nery Delgado drew and found most interesting was that from Colle towards Collada de Llama, near Sabero. He drew it to observe the bedding and features of the *Posidonomya pargai* that had been discovered there. Nery Delgado had supposed that this species would be similar to the *Posidonomya becheri* of the Culm, which he had assumed to be present in Spain. He concluded instead that there was nothing common between the formation containing the first species and the particular *facies* of the Lower Carbonic, which contained the *Posidonomya becheri* in Huelva, and in the southern provinces of Portugal. He thus recognized that these species were quite different, and made sure that the conditions in which the deposits (of different age too) had been formed were also distinct. In effect, Nery Delgado did not find any Carbonic species or those of the Culm in the layers of black slate clay with many clayey-siliceous nodules, containing *Posidonomya pargai* and other Devonian species. He contended that this species was characteristic of a lower horizon than that of *Posidonomya becheri*, which until then had not been found either in the Cantabrian mountain range, or in the Peninsula (Nery Delgado 1879, pp. 19–20).

In the Spanish province of Léon, as Nery Delgado observed, the Devonian was immediately followed by the Cretaceous, with petrological features similar to those found in Portugal, namely in the Mondego valley (central Portugal), and he found this correlation in such distant places as these. In the Mondego valley, the Cretaceous was composed of a lower stage of light coloured clay, containing pebbles and small quartz rock fragments, more or less angular, of varied appearance showing either big white or yellow, purple or reddish spots of kaolin. This clay derived from the decomposition of granite rocks and led Nery Delgado to conclude that it was contemporaneous with the Cretaceous clay of Portugal. Upwards, Nery Delgado observed that there was a limestone layer, fairly clayey and coarse, with some fine and barely coherent clay layers, or marls, containing a particular fauna with species peculiar to this Spanish locality. He then correlated this limestone horizon with the limestone of Figueira da Foz (central Portugal), which, as in Léon, marked a significant change in the stratigraphic phenomena (Nery Delgado 1879, p. 20).

In Nery Delgado's view, a series of parallel faults, a common feature in Cantabria, had repeated these layers in the Middle Devonian strip where they were intercalated, placing these older rocks in a similar role to the one they played in relation to the limestone containing the 'primordial fauna' (Cambrian) (Nery Delgado 1879, p. 20).

Excursion 3: Almadén (Ciudad-Real)

Nery Delgado ended his report with his field excursion in the neighbourhood of Almadén. He emphasized that this region was famous due to its mercury mines, which supplied the world market with great quantities of this metal. However, his personal interest lay elsewhere, in the possibility they offered to geologists to study the Palaeozoic. In particular, he could observe the links of the Silurian to the system classified as Lower Devonian, which immediately followed in a seemingly concordant manner. Nery Delgado recognized that this investigation would take a long time, as the region was so difficult to explore; Casiano Prado as well as other geologists were only able to produce provisional conclusions (Nery Delgado 1879, p. 21).

One of the results that Nery Delgado obtained was that in the borders of Castella-a-Nova, as well as in Asturias and Portugal (corresponding to an area of more that 8000 square leagues) the base of the Silurian (formalized later as Ordovician) was composed of a thick quartzite formation, containing thick layers of 'bilobites' (*Cruziana*), which were strongly dislocated. They formed a mountain chain that correlated with each other in different parallel strips, thereby revealing the action of the ample movements and strong pressures they underwent (Nery Delgado 1879, p. 21).

One of these quartzite ridges ran southwards in front of Almadén and formed a slight curve opening to the village. According to Nery Delgado, a league southwards and related to the former, was a second one that represented another branch of the anticline on both sides of which were a repeat of the Ordovician and the Devonian layers. The axis of this undulation, or the valley between the two quartzite ridges, contained a thick formation of greywacke and greenish slate clay, which in the Portuguese provinces of Beira and Alentejo occurred at the same stratigraphic position, as Nery Delgado had observed (Nery Delgado 1879, p. 21).

A cross-section made in Almadén running north or northwestwards towards Chillon revealed to Nery Delgado the perfect correlation between the graptolitic shale ('colonies'), sometimes occurring in the middle stage of shale and quartzite in alternating thin layers, the trap reef contemporaneous with this shale, and the quartzite formation that constitutes the base of the Devonian (Nery Delgado 1879, p. 21). Following or contemporaneous with the genesis of quartzite, another emission of trap rocks, whose decomposition produced most of the debris found in some sedimentary layers, seemed to Nery Delgado to have coincided in time with the appearance of Brachiopoda and Bryozoa, characterizing the fauna of the Lower Devonian (Nery Delgado 1879, pp. 21–22).

In Almadén, Nery Delgado observed fossils in a quartzite layer containing many moulds of small *Nuculas*, with the same petrographical and palaeontological features of a stratum, which in Buçaco (central Portugal), were intercalated with the 'Lower Silurian' (now classified as Ordovician), corresponding to the culminating group of this division, the 'colonial' horizon. Nery Delgado contended that this observation proved that this formation and the abundance of Brachiopoda were closely associated. They had been referred to the base of the Devonian, 'to our Middle Silurian'. He argued that, perhaps, there was no reason to consider that formation to be the coeval representative of some of the upper stages of the Silurian of the Bohemia basin that are not so clearly defined outside that 'privileged region' (Nery Delgado 1879, p. 22).

Nery Delgado observed that the succession of rocks in Almadén was similar to that of Serra de Portalegre[25] (southern Portugal) with the single difference that the shale containing fossils of the 'second fauna' (now known to be Ordovician) was missing in that Portuguese region, whereas in Almadén, although poorly developed, it was clearly represented. For Nery Delgado this fact proved that the Silurian sea or gulf, where the species of the 'second fauna' would have lived, extended from Spain towards the Portuguese border, the Serra de Portalegre (southern Portugal) corresponding to the boundary of that sea. Nery Delgado argued that this reinforced his arguments in favour of the existence of an insurmountable barrier that prevented communication between the two Silurian seas of central and southern Portugal, whose deposits showed two totally distinct facies. The latter would have been closely linked to the Silurian deposits of America and northern Europe; the former showed strong analogies with those of France and central Europe. But Nery Delgado emphasized that one should not suppose that there had been a sudden transition from one of these deposits to the other. On the contrary, he believed that the Silurian strip of Serra de Portalegre (southern Portugal) somehow established the transition between the deposits of Buçaco (central Portugal) and Monfortinho (central eastern Portugal)—which have been clearly characterized—and the special facies he observed in Barrancos and São Domingos (southern Portugal) (Nery Delgado 1879, p. 22).

Nery Delgado added further hypotheses: the oscillation of the sea floor at the end of the Silurian—immediately related to the trap reef and with the appearance of hydrothermal springs—would have been responsible for the sharp discordances,

and possibly the simultaneous emergence of the fauna of *Nereites* in São. Domingos (Portugal), and the graptolites in northern Huelva (Spain), Barrancos and Portalegre (Portugal). He also assumed that the quartzite with *Cruziana* was probably formed during a period of subsidence, which was preceded by slow uplift, during which deposits of the 'primordial fauna' (Cambrian) accumulated. Thus, it did not surprise him that the limestone containing *Archaeocyathus* in northern Seville, on the southern slope of Sierra Morena, was contemporaneous with the quartzite formation of Asturias, corresponding in this way to the terminus of the 'primordial fauna' (Cambrian) whose first stage of existence he believed was absent in the Iberian Peninsula, with this single exception (Nery Delgado 1879, p. 23).

Nery Delgado first classified the fauna of São Domingos as belonging to the 'Lower Silurian' (now classified as Ordovician) in 1876 (Nery Delgado 1876), but in 1899 as being Devonian (Nery Delgado & Choffat 1899). In his last memoir published in 1908, he contended that it was part of the 'Upper Silurian' (now Silurian as against Ordovician) (Nery Delgado 1908).

Impressions and souvenirs from Spain

Travelling provides references with which more authoritative comparisons can be made. In his report, Nery Delgado made evaluations of Spanish scientific practices and used them as an opportunity to criticize current Portuguese procedures.

Whilst in Madrid, he was able to appreciate the efforts of the Spanish Geological Survey, in particular the role of Manuel Fernández de Castro (1825–1895), the General Inspector of Mines presided over this institution at that time (López de Azcona 1984–1990). Nery Delgado hinted at the existence of a geological culture in Spain (Knell 2000) that joined together individuals who carried out geological research either by their personal initiative or on an official basis, a phenomenon which he could not observe in his home country:

> It is really remarkable and of the highest scientific value some of the works published both by the Survey members and mining engineers working under its aegis, and by individuals devoted to geological studies, working either officially or freelance, or even by simple apostles of science (Nery Delgado 1879, p. 11).

As he well knew, in his native country, geology was only consistently practised in the context of the Geological Survey. Given the lack of 'apostles of science' (to use Nery Delgado's expression) working on a private basis, and of local scientific societies, geology emerged and was practised within a governmental framework thereby relying primarily on state economy and human resources (Carneiro 2005).

Nery Delgado recorded that the Spanish Geological Survey aimed to publish a more or less comprehensive description of a province annually, and produced two publications, the *Memorias* and the *Boletín*: the former published more detailed studies and the latter, notes, descriptions of partial and preliminary studies. At this time, the Portuguese Survey did not publish a journal, only monographs. In 1883, the Survey began to publish the first Portuguese specialized journal devoted to geology, the *Communicações da Commissão dos Trabalhos Geologicos*.[26]

The difficulties of his Spanish colleagues in carrying out their work was the object of Nery Delgado's considerations. The first difficulty was the size of the country: of 49 provinces, including the Balearics and the Canaries, eight had never been studied, for 15 the available data was very scarce, and of the remaining 26 there were some published descriptions that provided positive data to the geological description of the whole. Only upon completion of this enterprise, could a general geological map of Spain be started.[27] Nery Delgado also regretted that the petrographic study of rocks, which he considered highly useful, had not been taken up by the Spanish Survey due to lack of personnel.

As to the collections, in addition to those of the Spanish Survey, Nery Delgado examined the mineralogical collection of the Museum of Natural History of Madrid, which possessed invaluable samples, but he regretted the fact that they were displayed on aesthetic rather than on scientific criteria. He also visited the mineralogical and palaeontological collections of the Mining School of Madrid, the former classified according to Georges Dufrénoy's (1792–1857) method and the latter according to d'Orbigny's.

He was then taken to the Geographic and Statistics Institute led by General Carlos Ibañez de Ibero (1825–1891). Despite recognizing that this visit was outside the scope of his mission in Spain, Nery Delgado claimed that he could not have missed this important institution whose purposes he found similar to those of the Portuguese Geodesic Directorate. On this visit, Nery Delgado was accompanied Eduardo Benot (1822–1907), a former Minister of Development, who, in 1873, succeeded in passing the law that removed the Spanish Geographic Institute from the control of the Government, a move that pleased Nery Delgado a great deal:

> Up to then the Institute had endured a difficult existence due to its dependence on the central government, which now cannot appoint or dismiss personnel arbitrarily. The hiring of staff is carried out through competition, dismissals are subject to strict rules, and the only reasons can be those directly linked to work (Nery Delgado 1879, p. 12).

Coming from a state geologist Nery Delgado's comment was all the more significant. It was a clear criticism of the imbroglio underlying the suspension of the Portuguese Geological Survey back in 1868.[28]

Nery Delgado was undoubtedly in favour of the autonomy of scientific institutions and claimed that the work of the Spanish Institute 'free from the ups and downs of politics, which in Spain like everywhere else sterilizes the most productive scientific activity, has developed rapidly and securely'. (Nery Delgado 1879, note on p. 12). On his return to Portugal, he even wrote to Eduardo Benot, asking him for details about the organization of that autonomous institution.[29]

The chromolithographic technique invented by Ibañez de Ibero to print maps at the Spanish Geographic Institute was also critically examined by the Portuguese geologist.[30] However, he did not seem enthusiastic about this method:

> I do not dare to express an opinion about the course of action taken by the wise director of the Geographic Institute. However, it seems to me that the efforts of General Ibañez—concentrating on the scientific and artistic improvement of these partial maps with the purpose of matching or even overcoming the best that has been published in more advanced countries—are not entirely profitable. It would be more advantageous if, as happens in Portugal, those efforts were directed towards a presentation of a general geographic map of Spain, precise enough to provide a basis for the work of the Spanish Geological Survey (Nery Delgado 1879, p. 15).

Nery Delgado pointed to the difficulties under which his Spanish colleagues worked, in particular the lack of an accurate general geographic map of Spain, which could have helped them to draw the boundaries of the different geological units. The fact that he sent his report to Macpherson, who most certainly publicized it, suggests that Nery Delgado seized this opportunity as an external observer to promote the needs of his Spanish colleagues, as much as he used the positive Spanish examples to express his and Ribeiro's views.

Conclusions

In the nineteenth century, travels in the context of the Geological Survey of Portugal were inscribed in the very dynamics of the Ministry of Public Works of which the Survey was part. The 'travel of negotiation' of Nery Delgado to Spain in 1878 occurred at a stage when the work and reputation of the Portuguese Geological Survey were already established. In addition to improving the relationships with the geologists of a neighbouring country, he was able to collect field data that enabled the geological characterization of the southern Portuguese regions. He was also able to negotiate and look for data with which to persuade his Spanish colleagues to subscribe to interpretations consistent with the Portuguese geological map, published in 1876.

On this account his field excursion in Huelva was significant because the fossils of Huelva had been classified by Spanish geologists as belonging to the Pliocene. Nery Delgado was able to persuade them that the fauna which had inhabited Huelva in the Cenozoic was the same found in Cacela, and in the mouth of the Tagus (Portugal). It corresponded to the fauna of the Vienna basin, and therefore belonged to the middle stage of the Cenozoic (Upper Miocene). In the sandstone of Huelva, Nery Delgado found Foraminifera, which proved his interpretations right and consistent with the Portuguese geological map. In addition, Nery Delgado contended that there had been hydrothermal activity in Huelva (central part), which he called 'geyserian activity', accompanied by metalliferous emissions, from which masses of minerals and limestone originated, thereby raising the possibility of the existence of what came to be known, in 1921 as carbonatite.

The discovery made by his Spanish friend, José Macpherson of *Archaocyathus*, a coral, in the limestone of northern Seville proved the existence of the Cambrian in the south of the Iberian Peninsula, and confirmed Nery Delgado's classification of the strata of São Domingos (Portugal), and led Roemer to revise his arguments supporting the classification of São Domingos strata as belonging to a lower division of the Culm.

In the borders of Huelva with the Province of Badajoz, Nery Delgado recognized that there was replication of the strata observed in southern Alentejo (Portugal), extending in the Spanish territory, which again was consistent with the Portuguese geological map.

Nery Delgado's field excursion in Asturias led him identify folding and faulting along the mountain range of Pedrorio, Bejega and Peñamateca, which had caused an apparent inversion of strata. Nery Delgado's conclusions about the location of the 'primordial fauna' (Cambrian) in Asturias were contradictory with those of Charles Barrois, but consistent with the observations of the Spanish geologist Prado, which certainly contributed to reinforce the position of the Iberian geologists. However, following his trip to Spain, Nery Delgado exchanged correspondence with Barrois regarding the geological correlations, which the latter established between Asturias, Brittany and Alentejo (Portugal).

In the Cantabrian mountain range, Nery Delgado compared the fossiliferous shale of that region with that of Buçaco (Portugal) and again referred to 'geyserian activity' when he claimed that the limestone in Buçaco was but a lithological accident of

the shale layers (carbonatite?). In his view, there was evidence of hydrothermal phenomena before the water transported the muddy sediments, but it probably continued after the sediments were deposited.

In Almadén, Nery Delgado searched for data to reinforce his views that an insurmountable barrier had prevented communication of the two Silurian seas of central and southern Portugal. The first showed analogies with those of France and central Europe, and the latter would have been linked to the Silurian deposits in America and northern Europe.

Nery Delgado also used his travels as a subtle means of comparing and criticizing Portuguese and Spanish practices. In the national context, the publication of a report of this mission to Spain set a standard, since from that time onwards whenever he travelled his reports were published. Thus, by demonstrating that travelling abroad was part of the normal work of a geologist, he enhanced his scientific authority, and legitimized the work of the Geological Survey. At the same time, by voicing the accomplishments and difficulties of his Spanish colleagues, Nery Delgado reinforced their position and gave expression to the brotherly links uniting geologists in both countries.

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Notes

[1]Expression coined by Bruno Latour to mean centres where specimens, maps, diagrams, logs, questionnaires and paper forms are accumulated and used by scientists and engineers (Latour 1987).

[2]Military engineers in science and technology in Portugal in the nineteenth century were trained by the Army School and/or the Lisbon Polytechnic. Given the structure of the Portuguese educational system of the time, they were the only people available in the country possessing the kind of scientific and technical training required by tasks ranging from statistical, geodesic, geographical and geological surveying to telegraphy and civil works. As far as geology was concerned, their knowledge of planning military campaigns, their acquaintance with mining and geology, their command of cartography and the practice of using explosives facilitated the organization and practice of geological fieldwork.

[3]Before the establishment of the Survey, geology was only practised in institutions for higher education—the University of Coimbra, the Lisbon Polytechnic and the Polytechnic Academy of Oporto. However, it consisted mainly of palaeontology and mineralogy still held to antiquarian practices typical of eighteenth century natural history. Students were taught geology through examples and collections of foreign countries. Despite the need for further historical research, geologists working in the context of Portuguese academia seem to have been cabinet scientists rather than field researchers, as were those working in the Geological Survey.

[4]Indeed, the Survey geologists discussed scientific questions with foreign geologists and palaeontologists rather than with their Portuguese colleagues working in higher education, whose outlook seemed to be embedded in a distinct scientific culture.

[5]This effort was complemented by the arrival in Portugal of Paul Choffat (1849–1919) who worked under contract for the Survey between 1879 and 1919 on a permanent basis and the occasional resort to foreign experts, such as the Swiss palaeontologist Oswald Heer (1809–1883) who studied the flora of the Cenozoic between 1880–1881; the Frenchman Marquis of Saporta (1823–1895) who worked on the Mesozoic flora, in 1890; C.L.P. de Loriol Le Fort (known as Perceval de Loriol) (1828–1908), a Swiss expert who analysed the Cretaceous and Jurassic faunas, in 1888, 1890 and 1896. The Survey also subscribed to various specialist foreign journals, the regular acquisition of foreign books and maps and the creation, in the 1890s, of the Survey journal, the *Comunicações dos Serviços Geológicos de Portugal*.

[6]Letter from Gonzalo y Tarin to Nery Delgado, Huelva, 26 December 1876. Historical Archive of the Institute of Geology and Mining/Portugal (IGM), Bookcase 10, Shelf 2, Box 4.

[7]Letter to José Macpherson (1839–1902), Belas, 8th March 1879, IGM Historical Archive, Bookcase 10, Shelf 1, Box 5.

[8]The official letter of Carlos Ribeiro sent on 19 October 1878 to the Head of the Geodesic Office, General Filipe Folque, reads: ‘I have the honour to send to Your Excellency the report about the travel and the geological studies carried out in Spain by the Captain Engineer, adjunct to this Section, Joaquim Filippe Nery Delgado. This mission was accomplished with the intelligence and knowledge which characterize the scientific merit of this geologist. The depth and interest of this report to the geological knowledge of our Peninsula justifies, in my opinion, its publication in the format of the publications of this Section, because it

renders a good service to science and to our country'. File 'Relatórios Manuscritos', Archive of the Geographic Institute of Portugal.

[9]In Barrande's words: 'Les colonies, en général, étant des apparitions partielles et anticipées d'une faune, durant l'existence de la faune précédente, constituent un phénomène purement paléontologique, et qui, par conséquent, pourrait être complètement indépendant des phénomènes stratigraphiques, c. à d. de la nature et de la succession des roches'. (Barrande 1861). Furthermore, Barrande (1859–1860, 1881) published various memoirs defending the colonies from various opponents, notably the British.

[10]For Barrande's controversies that went on for about 20 years, see Perner 1937. A comparison of Barrande's interpretations with modern stratigraphy see Kriz & Pojeta 1974.

[11]Nery Delgado drew attention to what he perceived as a paradox in the dispute: 'It is highly remarkable that British geologists, being the most interested in supporting the theory of evolution formulated by Darwin—a theory which undoubtedly found a good basis in the theory of colonies—come now (without providing new evidence, one should say) fighting against this theory advocated by an expert who, on the contrary, does not subscribe to transformist ideas'. (Nery Delgado 1882, p. 36).

[12]Given the richness of the 'primordial fauna', and in order to be consistent with their theory, transformists suggested the existence of a series of more ancient faunas. However, as no trace of those faunas could be found in geological strata, they were led to admit that they had vanished owing to metamorphism. Barrande, in turn, responded that if geologists were unable to find fossils in the Azoic rocks, the reason was not that metamorphism had destroyed their remains but simply because they had never existed (Laurent 1987, p. 303).

[13]Also in his correspondence, his lack of enthusiasm about practical applications of geology was often expressed throughout his career. He often confided to his foreign colleagues that he could not devote the time he would like to fundamental geology owing to his official duties concerned with mining and hydrology. For example, in a letter to the Spanish geologist Lucas Mallada, Nery Delgado gave vent to his sorrows: 'As I said before, it is unfortunate that for more than one year I had to leave aside my geological work because I was assigned the mission of helping Mr Carlos Ribeiro in the exploitation of water to supply Lisbon. Now you can see my good friend that lately our geology has made little progress, not to say it has regressed. Only when our government becomes truly convinced that geological research is useful, and requires more and specialized personnel will these studies progress regularly.' After all, as a civil servant Nery Delgado was forced to comply with governmental orders, and the task of carving a place for fundamental geology in state bureaucracy proved to be a difficult one. Letter from Nery Delgado to Lucas Mallada, Lisbon, 12 June 1876. IGM Historical Archive, Bookcase 10, Shelf 2, Box 15.

[14]Continental facies of the Mississippian (Lower Carboniferous, Dinantian).

[15]Nery Delgado original expression is 'actividade geyseriana'. Nery Delgado 1879, p. 7.

[16]The reference to Waldemar Christofer Brögger's article on carbonatites usually given in scientific literature is Brögger 1921. His name is mentioned in Brito de Carvalho 1978, p. 1.

[17]Between Aldeia Nova and Corte do Pinto.

[18]Ampelite: an obsolete term for black carbonaceous or bituminous shale.

[19]Roemer wrote: 'For very good reasons you have advocated the classification of the Nereites of S. Domingos as belonging to the Silurian (. . .). It seems to me almost certain that the system of shale strata from which that fossil came, which is located immediately below the layers of *Posidonomya becheri*, in the province of Seville, belongs also to the Protozoic division of the Silurian'. Quoted by Nery Delgado 1879, p. 9.

[20]This is a translation in Spanish of Barrois's paper presented to the French Société Géologique du Nord.

[21]Note added by the Spanish Survey to Barrois 1877, pp. 378–379.

[22]Letter from Barrois to Nery Delgado, Lille, 19 May 1879, IGM Historical Archive, Bookcase 10, Shelf 2, Box not numbered.

[23]On the work of Barrois in Asturias see Truyols 1982.

[24]Research on carbonatites in Portugal was developed in the twentieth century, especially by geologists working in the Portuguese African colonies such as Brito de Carvalho, Matos Alves and Britaldo Rodrigues. Africa and Scandinavia are the regions where carbonatites are more abundant. Studies on the possible presence of carbonatites in mainland Portugal are to my knowledge absent (see Brito de Carvalho 1974; Matos Alves 1969, Rodrigues 1972).

[25]Serra: Portuguese word for mountain range.

[26]By then the Survey exchanged publications with 81 institutions, mainly foreign (Nery Delgado 1883–1887, Preface).

[27]The map was completed in 1889 at the scale 1:400 000.

[28]The suspension of the Survey occurred due to deep disagreements opposing Ribeiro to his co-director, Pereira da Costa (1809–1888). Costa, a former physician, Professor of Mineralogy and Palaeontology at the Lisbon Polytechnic, was in charge of the classification of fossils at the Survey. Still holding to an antiquarian technique, concentrating on cabinet tasks and resisting fieldwork due to his alleged vulnerable health, Costa was only interested in well preserved fossils, which he liked to classify and display on aesthetic rather than on scientific criteria. Costa's conceptions and susceptibility, the slow pace at carrying out his tasks, and the fact that he

appropriated Ribeiro's and Nery Delgado's work without their consent, led to deep disagreements between the two directors. However, Costa was well connected in the political sphere and friendly with Calheiros de Menezes, then Minister of Public Works. They joined forces and managed to get the Survey suspended, a situation that lasted from 1868 to 1869. As a result, the fossil and mineral collections were moved to the Lisbon Polytechnic, leaving Ribeiro and Nery Delgado with virtually nothing.

[29]Reply from Eduardo Benot, Madrid 8 August 1878, IGM Historical Archive, Bookcase 10, Shelf 1, Box 5.

[30]In Portugal, the use of lithography to print out maps was initiated in 1854 when the Portuguese Government contacted J. Lewicky, a Polish émigré living in France, who set up a lithographic workshop at the Geodesic Commission. This workshop together with that of the National Stationary Office (Imprensa Nacional), both inaugurated a tradition of lithography and chromolithography in Portuguese cartography. The first Portuguese geological map of 1876 published in the scale 1:500 000 was chromolithographed at the printing office of the Geodesic Commission (see Alegria & Garcia 1995, p. 121).

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