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EXPLORING FIELDWORK EDUCATION THROUGH A CONTEXT OF IBERIAN COOPERATION: ACTIVITIES WITH SEDIMENTARY ROCKS AND FOSSILS IN THE CENOMANIAN OF FIGUEIRA DA FOZ (PORTUGAL) AND TAMAJÓN (SPAIN)

EXPLORANDO LA EDUCACIÓN EN CAMPO A TRAVÉS DEL CONTEXTO DE COOPERACIÓN IBÉRICA: ACTIVIDADES CON ROCAS SEDIMENTARIAS Y FÓSILES EN EL CENOMANENSE DE FIGUEIRA DA FOZ (PORTUGAL) Y TAMAJÓN (ESPAÑA)

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ABSTRACT:
Fieldwork activities could be important strategies for the outdoor learning of Geology, as a complement of the practical hands-on of minerals, rocks, fossils and models. They have been increasingly used in the last years, by teachers and students of different grades, and planned in line with the formal teaching taught in the classroom and contextualized with themes adopted by the national curricula of Natural Science. Our purpose is to explore an Iberian context of cooperation, using examples of outcrop with analogous stratigraphic contexts of the same age, and closely related facies, fossils and palaeoenvironments. To develop these outdoor activities around concepts of stratigraphy, sedimentology and palaeontology. Two Cenomanian (Upper Cretaceous) sections with fossiliferous marine carbonate units (Figueria da Foz, in Portugal, and Tamajón, in Spain) have been chosen, due to the many stratigraphic and palaeontological characteristics they have in common, allowing students to understand that despite distance, both geographical areas can be compared, as they shared contemporaneous flora and faunas and a common overall palaeogeography, when the Iberian microplate was extensively flooded by shallow warm seas.

KEY WORDS: fieldwork, sedimentary geology, stratigraphy and palaeontology, didactic activities, Iberian cooperation.
RESUMEN:
Las actividades de trabajo de campo pueden ser importantes estrategias para el aprendizaje al aire libre de la Geología, como un complemento a las prácticas de seminario de minerales, rocas, fósiles y modelos. Cada vez más, en los últimos años, son utilizadas por profesores y estudiantes de diferentes grados, y planeificadas de acuerdo con la enseñanza formal de aula y contextualizada con los temas adoptados por el currículo nacional de Ciencias Naturales. Nuestro propósito es explorar un contexto Ibérico de cooperación, utilizando ejemplos de aforamientos con contextos estratigráficos análogos estrechamente relacionados por tener la misma edad, facies, fósiles y paleoambientes, para desarrollar actividades de campo en torno a conceptos de estratigrafía, sedimentología y paleontología. Se han elegido dos secciones Cenomaníneas (Cretácico Superior) con unidades fósileras de carbonato marino (Figueira da Foz, en Portugal, y Tamajón, en España). Debido a las grandes similitudes estratigráficas y paleontológicas, permite a los estudiantes comprender que a pesar de la distancia, ambas áreas geográficas son comparables, ya que compartieron flora y fauna contemporáneas en una paleogeografía general común, cuando la microplaca Iberica estaba extensamente inundada por cálidos mares poco profundos.

PALABRAS CLAVE: trabajo de campo, geología sedimentaria, estratigrafía y paleontología, actividades didácticas, cooperación Ibérica.

1. CHOOSING FIELDWORK TO TEACH AND LEARN GEOLOGY

There is a common idea amongst many teachers and related participants in the educational process that fieldwork is an important strategy for the practical learning of Geology. Moreover, it can be considered as a valuable approach to complement the daily lessons, where many theoretical concepts arise to the student with a certain degree of complexity and abstraction (e.g., Pedrinaci et al., 1994; Marques et al., 1996; Marques & Praia, 2009). The geological discovery of didactic landscapes and outcrops for educational purposes is not a recent invention of modern pedagogues. It has been regularly used by teachers with naturalistic sensibility and spirit of observation for many years, as an addition to the practical hands-on of minerals, rocks, fossils and models available at the school laboratory of Natural Science (e.g., Bargalló, 1934) as well as in a museological context or in centers for experimental Science. By this way, outdoor trips and practices stand out as a relevant and somewhat specific facet of the art of teaching Earth Sciences, which has much contributed to the academic development of many generations of students pursuing the consecutive schooling degrees.

During the last decades, these activities have been gradually implemented in the Portuguese and Spanish basic and high-school educational settings and have constituted very appealing strategies with quite positive results in the holistic construction of student knowledge, especially if planned in line with the formal teaching taught in the classroom and contextualized with themes adopted by the national curricula of Natural Science.

It is known that the practical and experimental activities are of great importance in Geology, since they allow a proximal connection with objects, contexts and geological landscapes at different scales. They also help to mitigate abstractions inherent to taught concepts that involve time, space and dimensions of processes, allowing the student to solve problems that can reach higher cognitive levels. In parallel, they significantly contribute to the acquisition of competences on: (1) the history of Earth and Life; (2) the cycle of rocks and the organization of the Earth system; (3) the external and internal geodynamics; (4) the nature and structure of the planet; (5) the occurrence and typology of geological hazards; (6) the diversity of raw materials and geological resources; and (7) the natural heritage and geodiversity as a conservationist perspective for future generations.

It is also recurrent their development within the transversality that characterizes the interconnection between Science, Technology, Society and Environment (STSE), as a methodological way to contribute to citizenship education and to inspire responsible attitudes in the student, in a perspective of literacy improvement and approach to scientific knowledge and sustainable development.

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In this sense, fieldwork strategies allow a close access to geological scenarios that otherwise, would be far from the space of the Natural Science laboratory and only accessible through schematic representations, figurations, movies and analogic models. The quality of a field trip will be determined by its structure, learning materials, teaching method and by the ability to learn directly through a concrete interaction with the environment (e.g., Orion & Hofstein, 1994). For its effective implementation, it is advisable to follow a constructivist approach with a sequential methodologic development, as the one proposed in the works of Orion (1993, 2001). This kind of organized approach towards the field class practices have been widely tested and experimented for educational research purposes, with very overall positive results, mainly by increasing the familiarity of the learning setting or by reducing “novelty space” factors of the field trip.

This encouraging background justifies why they are being used today by many Portuguese and Spanish teachers, which manage to overcome many logistic difficulties, including the large extension of the curricula and some lack of knowledge concerning the local and regional geology, and make field activities with their students a reality. It is interesting to realise that the same kind of sensibilities and problems are found in both sides of the border, side to side with many resemblances between the curricula of Earth Science adopted in the two countries, and a geological environment with many contexts in common.

Our purpose is to explore this proximity through the development of cooperation strategies between Iberian teachers, where fieldwork in the Cenomanian of Figueira da Foz (Portugal) and Tamaña (Spain) (Fig. 1) will be used as a tool to share experiences amongst them and their students. Knowing that many field trips involve concepts of stratigraphy, sedimentary rocks, structures and fossils, our proposal focuses on the selection of Portuguese and Spanish outcrops with analogous stratigraphic contexts of the same age, and closely related facies, fossils and palaeoenvironments. The development of practical activities in this outdoor background, will allow students to transpose their local observations to regional and interregional scales, as a way to understand better the principles of stratigraphy and didactic aspects of the palaeogeographical and geodynamic evolution of Iberia.

2. CHOOSING THE IBERIAN CENOMANIAN AS A SHARED STRATEGY

The Cenomanian Stage (Upper Cretaceous, ca. 100.5 to 93.9 M.y.) is one of the most interesting intervals of Earth history for educational purposes. Besides its highly diverse palaeoenvironments inhabited by dinosaurs and many other "exotic" living beings that inspire children’s imagination, together with a worldwide natural garden where the first flowering plants made their first appearance, this major subdivision of Late Mesozoic times was characterized by a strong greenhouse effect and very effective sea-level rises of eustatic origin, which resulted in worldwide marine transgressions and flooding of large areas of the continental shelves.

During the Cenomanian, the emerged lands of the Iberian microplate were reduced to a minimal extend, and several basins with warm-water Tethyan carbonate platforms were developed through its continental margins and northeast interior. As best examples of these warm shallow seas, the West Portuguese Carbonate Platform and the Iberian Basin stand out, because of their geographical extension, diversity of facies and faunas (Segura et al., 2014). The former of these tectono-sedimentary units locates in the onshore sectors of the West Iberian Margin, across the Estremadura and Beira Litoral ranges of west central Portugal, and the second one corresponds to the Iberian Through, an intraplate basin located between the Hesperian and the Ebro massifs, whose materials nowadays occupy large areas of the northern, central and southeastern Spain.

Both Portuguese and Spanish basins record an impressive set of carbonate and mixed carbonate-siliciclastic rocks exposed in dozens of outcrops with abundant invertebrate assemblages, yielding a large diversity of macro and microfossils, and many ichno- and vertebrate sites. This
setting will allow Iberian teams of geologists and palaeontologists to cooperate in successful activities. By this way, several topics as the following could be explored for educative intervention:

*Low deformed tabular strata with wide lateral persistence of marine facies.* This allows ideal conditions for the field observation of sedimentary rocks, structures and bedding, together with activities based on the interpretation of basic stratigraphic principles (*e.g.*, superposition, lateral continuity, original horizontality, inclusion and cross-cutting relations) and unconformities (*e.g.*, angular unconformity, disconformity and paraconformity); *Relative abundance of ammonites and other groups of stratigraphic fossils common to both basins.* These materials can be used to demonstrate the principle of faunal succession, evolutionary patterns and the irreversibility of fossil record, as well as the basic exercise of stratigraphic correlation.

*High abundance and diversity of common benthic invertebrates, many of them with close living representatives.* This is typical of the carbonate platform beds, and it allows a diversity of field activities based on the collection and taxonomic classification of fossils with the help of rudimentary dichotomic keys. It can also allow to explore the concepts of fossil of facies, taxonomic uniformitarianism, analogy and functional morphology adapted to the reconstruction of palaeoenvironments and to the palaeoecological analysis of ancient communities and ecosystems.

Besides these attributes, several outcrops of the West Portuguese Carbonate Platform and the Iberian Through are especially relevant for the introduction of activities related to history of Science and geological heritage, which are preconized in the curricula and school manuals, and proved to be useful for the understanding of concepts and theories. In fact, some of these field exposures have been studied for more than a century and a half, since the beginning of stratigraphic studies in the Iberian countries, and a few faunas are known since the Enlightenment (Callapez *et al.*, 2013). Additionally, some of these Portuguese and Spanish outcrops are in course of being classified as geosites for heritage purposes, due to their remarkable attributes and singularities, as in the two following examples.

### 3. CHOOSING FIGUEIRA DA FOZ AND TAMAJÓN AS DIDACTIC SECTIONS

The Portuguese section of Figueira da Foz (Fig. 1B, D) is located near the coastal town of the same name, in front of the Mondego river estuary and very close to the entrances of the A14 and A17 highways. Local accessibility is excellent, including a direct access to Coimbra and Aveiro, as well as to the main itineraries to the Vilar Formoso-Fuentes de Oñoro border, and then to Salamanca and Madrid, at the distance of six hours by bus. The main available exposures are found in two old quarries (Salmanha), where the Cenomanian marine beds are recorded by the Costa d’Arnes Formation (Rocha *et al.*, 1981). The 65 meters thick of the stratigraphic succession consists of 14 fossiliferous units (beds “B” to “O”) with diverse ammonite faunas and highly abundant fossils of benthic invertebrates with Tethyan affinities, ranging from the middle Cenomanian to the lower Turonian (*e.g.*, Soares, 1980; Callapez, 1998, 2008; Barroso-Barcenilla *et al.*, 2011).
Figure 1. Geographical and Geological context of Figueira da Foz (Beira Litoral, Portugal) and Tamajón (Guadalajara, Spain). A – Geographical location of both sections in the context of Iberia. B-C – Geological maps of Figueira da Foz and Tamajón, showing the main stratigraphic intervals and tectonic structures. D – Local view of the upper Cenomanian fossiliferous beds outcropping in the Salamanca quarry (Figueira da Foz), taken during a didactic field trip. E – Panoramic view NE-SW of the middle Cenomanian-lower Turonian succession of Tamajón, with its main lithostratigraphic units.
From a historical point of view, this “classical” section has been early studied since 1849, by Daniel Sharpe (1806-1856). However, its knowledge is inseparable of the Swiss geologist Paul Choffat (1849-1919) from the Portuguese Geological Survey, who fully described the stratigraphic beds and fossils, including a remarkable recognition of the Vascceras ammonite faunas, representative of the Vascoceratidae, one of the main Upper Cretaceous cephalopod families (Choffat, 1898; Barroso-Barcenilla et al., 2015).

The Spanish section of Tamajón (Figure 1C, E) is located in Guadalajara, approximately 1 hour away from the northeast of Madrid, and combines high scientific, educational and divulgative values (Barroso-Barcenilla et al., 2016, in press). Its Cenomanian interval reaches 40 meters thick, being included into the Utrillas (Aguilar et al., 1971), Villa de Vés (Vilas et al., 1982) and Picofrentes (Floquet et al., 1982) formations.

The Utrillas Formation shows a sandy ferruginous crust, corresponding to the base of a middle-upper Cenomanian coastal channel, an extraordinary concentration of vertebrate tracks, among which numerous sets of two to five isolated digit impressions (“swim tracks”) and, at least, two trackways referred to crocodyliforms, and a single tridactyl footprint probably produced by a theropod dinosaur. It exhibits also several long epichnial grooves revealing sharp direction changes (up to 90°) which seem to correspond to the fish fin trace Undichna unisulca (Segura et al., 2016). The upper Cenomanian part of the Picofrentes Formation shows a high richness and diversity of molluscs and other invertebrates (see below), together with osteichitian and chondrichthyian fishes, and marine reptiles, among many other fossil remains (Meléndez-Hevia, 1984; Barroso-Barcenilla et al., 2016, in press).

The palaeontological setting of both sections has yielded several dozens of species, including land plants and algal remains, scleractinian corals, bryozoans, brachiopods (a single taxon), molluscs (many bivalves, gastropods and ammonites, and a single nautiloid), serpulid annelids, echinoderms (regular and irregular echinoids), and fish remains (Figure 2). They include the index fossils Neolobites vibrayeus and Vascoceras gamai (Figure 2J-K), beside many other fossils of facies suitable for palaeoenvironmental reconstructions. Many representatives of these faunas are also conserved in Portuguese and Spanish institutions and partially available in public exhibitions.

4. CHOOSING SHARED OUTDOOR ACTIVITIES

The planning of these activities in both sections should be adapted to the age and scholar degree of the visiting students, and based on the idea of “structured observation”, where students can make their own visual exploration, and pick-up and handle samples at consecutive scales. This includes: (1) the magnifying glass to identify microstructures; (2) the hand samples of minerals, lithologies, structures and fossils; (3) the outcrop dimension to identify local stratification (beds and planes), dip, lateral and vertical succession, continuity and changes, unconformities, joints, faults and other structural features; and (4) the landscape scale where landforms and megastructures can be perceived with the help of topographic and geological maps. These geological observations could be complemented with other items more related with raw materials and geological resources, as well as the anthropic imprint and its environmental consequences.

Special emphasis also should be given to aspects shared by both sections. This includes comparison activities between analogous litho- and biofacies with the same palaeoenvironmental significance, which allow teachers and students to understand that despite distance, both geographical areas where occupied by the same kind of marine and biotic contexts, during the Cenomanian highstand sea-level episodes that flooded a large part of Iberia. At the same time, cephalopod representatives, such as Neolobites, Vascceras and Angulithes could be used as a didactic
example of application of the “stratigraphic” or “age” fossil concept, revealing that both sections record contemporaneous events of Earth history. Additionally, the importance of both sections for geological heritage should be explored, including a universe of topics related to STSE and history of Science.

5. CONCLUSIONS

As a branch of Natural Science where the main purpose is the study of the Earth system and its evolution through deep time, Geology has an epistemological framework where many concepts show degrees of abstraction that are better understood in the reality of outdoor environments. By this reason, fieldwork activities have always played an important role in the educational learning of this discipline.

There is a wide-range of possibilities available for the implementation of outdoor strategies with fieldwork activities based on geological contexts. Its application by teachers and students of different grades can be assumed as a valuable contribution to reach a consistent and lasting learning, especially if adapted to scholar curricula and planned in line with formal teaching with practical hands-on minerals, rocks, fossils and models.

Many fieldwork activities developed by Iberian students explore local or regional contexts with sedimentary rocks and fossils, where a variety of stratigraphic concepts are focused, together with aspects of sedimentology, petrology, palaeontology and structural geology. Besides many stratigraphic and palaeogeographical aspects common to both countries, their educational community share the same kind of sensibilities and problems, as the adopted curricula of Earth Sciences have much in common.

In a scenery where real and virtual communication is much easier than some years ago, we purpose to explore this proximity through the development of cooperation strategies between Iberian teachers. As an example of geological contexts and fieldwork activities common to both countries, the Cenomanian units of Figueira da Foz (Portugal) and Tamajón (Spain) will allow to share experiences amongst them and their students. These outcrops have analogous stratigraphic contexts, sharing the same relative age, closely related facies, fossils and palaeoenvironments. They can be used to develop practical activities that transpose local observations to regional and interregional scales, to understand better the principles of stratigraphy and didactic aspects of the palaeogeographical and geodynamic evolution of Iberia.

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