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THE UPPER DEVONIAN DEPOSITS IN THE NORTHERN PART OF LEON (CANTABRIAN MOUNTAINS, NORTHWESTERN SPAIN)

BY

G.B.S. VAN LOEVEZIJN*) AND J.G.M. RAVEN*)

ABSTRACT

During the Late Devonian, deposition in the Cantabrian Mountains was largely controlled by movements along faults. By way of intermitting subsidence of the area south of the Sabero-Gordón line and the connected progradation of the coast during the Frasnian and early Famennian, three regressive sequences were deposited. On account of these sequences the Nocedo Formation is divided into three units. Before the late Famennian transgression, after which the upper part of the Ermita Formation was deposited, the area was peneplained.

Six facies maps show the changes in palaeogeography during the Late Devonian.

INTRODUCTION

The Upper Devonian deposits of the Cantabrian Mountains (Fig. 1) have not been studied very well; there is neither a satisfactory subdivision into lithological units nor an understanding of the environment of deposition.

A subdivision of the Devonian in the Cantabrian Mountains was proposed by Comte (1959); most of his lithostratigraphical units were later accepted as formations. The Upper Devonian siliciclastic deposits are divided into two formations. The lower formation, the Nocedo Formation consists of an alternation of shales, siltstones, sandstones (quartzites) and limestones. The upper formation, the Ermita Formation consists of sandstones (quartzites) capped with a thin limestone. The Nocedo Formation has a considerable thickness (up to 600 m) and a variable lithology; in this publication it is subdivided into several units. The subdivision was originally proposed in internal papers (Raven, 1980a, b; van Loevezijn, 1982).

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BIOSTRATIGRAPHY

In order to make a biostratigraphical framework the limestones in the succession were sampled for conodonts. In this paper a provisional subdivision is made to support the subdivision into lithological units. The biostratigraphy will be discussed in detail by Raven (in prep.). In Fig. 2 the main results are shown.

FACIES DESCRIPTIONS AND INTERPRETATIONS

Various facies are distinguished and described on the basis of lithological, sedimentary and

*) Geologisch Instituut, Garenmarkt 1b, 2311 PG Leiden

palaeontological characteristics considered typical for certain environments of deposition.

Facies a

This facies consists of bioclastic limestones (wackestones) and carbonatic shales and siltstones. The sediment has a nodular appearance and is completely bioturbated. Some platy, horizontally laminated, sandy layers occur. Wave ripples occur frequently. Crinoids, brachiopods and bryozoans are the principal faunal components.

The depositional environment is characterized by low energetic conditions, most probably a protected environment (lagoon). The sandy layers are interpreted as washovers which originated by storms.

Facies b

The deposits of facies b consist of fossiliferous limestones (packstones and grainstones). The bedding is well developed in layers several centimeters thick with sharp contacts. Characteristic for this environment are the abundant crossbedded sets. Remarkable is the palaeontological content: enormous quantities of crinoid ossicles and furthermore some bryozoans, brachiopods, solitary and compound corals, and stromatoporoids. The bioclasts contain some hematite which gives the sediment a red colour. The facies is characterized by bioclastic sediments although large quantities of siliciclastics may occur within the limestones.

Facies b was deposited in a shoal environment in agitated water. It forms the shallowest part of the open platform. The hematite in the pores of the bioclasts is an indication for high energetic reworking (Ruhrmann, 1971). The frequently occurring herringbone crossbedding is indicative for a tidal environment.

Facies c1

This facies consists of thick conglomerate beds with sandstone intervals in between. The sands are clean, medium to coarse-grained quartzarenites and quartzites. The majority of the pebbles of the conglomerate are composed of vein quartz. Also pebbles and boulders of shale, sandstone (with gastropods and brachiopods) and lenses of hematite occur in the conglomerate. The boulders may be up to 20 cm in diameter. At Puente de las Palomas the conglomerate is coloured dark red by the high content of hematite. Sedimentary structures are restricted to grading of the beds, the coarse-grained base cuts into the underlying beds. Therefore the boundary surfaces between the beds are very irregular. Apart from the gastropods and brachiopods present in some boulders no fossils were found in the conglomerate. In the intercalated sands very few off-prints of crinoid ossicles occur. Facies c1 interfingers laterally with facies c2.

The sediment was transported by a mass flow and was deposited in the form of nearcoastal fan-deltas, probably as a result of tectonic activity and upheaval of the source area immediately north of the Sabero-Gordón line.

Facies c2

This facies consists mainly of grey and white quartzarenites and quartzites, locally with microconglomerates. Some of the sands have a calcite cement. Locally the sands may be coloured red by hematite. Intercalations of siltstone and shale are rare. Bedding is well developed and the contacts between the layers are sharp. The sediment may be slightly bioturbated but anorganic sedimentary structures are dominant: parallel lamination, wave ripples, current ripples and channels are common. Fossil remains are rather rare: some off-prints of crinoids, brachiopods and solitary corals are present.

The sands were deposited in a nearcoastal environment above wave base where the energy is moderately high to high. This is indicated by the sedimentary structures and the clean-washed, moderately well to well sorted sediments.

Facies d

This facies is characterized by completely bioturbated sandy shales and siltstones. The bedding is irregular. The sediment has a nodular appearance. Anorganic sedimentary structures are rarely present. The palaeontological content is remarkable: brachiopods occur in large quantities as well as bryozoans and crinoids.

Facies d was deposited in a low-energetic environment below wave base. This facies forms the transition from the nearcoastal deposited facies c and the holomarine facies e.

Facies e

This facies consists of an alternation of shale and sandstone. The bedding is well developed as cm thick beds with sharp boundary surfaces. Many of the sandstone beds are graded. Locally the Bouma-sequence was recognized. Loadcasts, flute marks, groove marks, ball-and-pillow structures and slumps occur frequently. The bioturbate structures are restricted mainly to horizontal traces of deposit feeders. The palaeontological content is remarkable: small goniatites (up to 1 cm in diameter) are the main component of the fauna, further some small brachiopods, bivalves and tentaculites occur.

The fauna, which is composed mainly of pelagic organisms, the bioturbate structures, and the shales with intercalations of persistent graded sandstone beds, are indicative for deposits of the middle and outer shelf.

In the Upper Devonian deposits south of the Sabero-Gordón line, it is possible to recognize three regressive sequences. These are reflected by characteristic vertical facies sequences composed of some of the facies described above but occurring in reversed order: e-d-c-b-a. On account of these sequences the Nocedo Formation may be divided into three units. Units A and B are informal units which conform to the first and second sequence respectively, the third sequence exists of the Fueyo Member of the Nocedo Formation and the lower part of the Ermita Formation. The upper part of the Ermita Formation was deposited during and after a transgression.

CORRELATIONS

East-West correlation (Fig. 3)

The deposits in the west are characterized by a relatively great thickness and a complete stratigraphical sequence. They were largely deposited in a holomarine environment (facies e). In the east most of the sediments were deposited in a nearcoastal environment, due to the slight subsidence. Holomarine deposits occur only in the Fueyo Member. In the easternmost part of this stable area a carbonate platform with reefs developed in unit B. Near the Pardomino High the facies pattern is strongly affected by epeirogenetic movements, therefore the units of the Nocedo Formation are thinner and unit B of the Nocedo Formation is locally incomplete or absent.

North-South correlation (Fig. 4)

The Sabero-Gordón line largely defines the facies pattern. South of this line the Ermita Formation lies conformably on the completely developed Nocedo Formation. There a great part of the sediments of this formation was deposited in a holomarine environment. North of the line the Ermita Formation lies discordantly on the underlying sediments. There the Nocedo Formation is incomplete: unit B and the Fueyo Member are absent. The Nocedo Formation consists of calcareous nearcoastal and lagoonal deposits belonging to unit A. The difference between both areas as well in facies as in thickness of the sediments is caused by the lesser subsidence in the northern area.

THE PIEDRASECHA FORMATION (Fig. 5)

Between Barrios de Luna and Mirantes de Luna the Portilla Formation consists of thick reef deposits, but towards the east, in the southern Alba syncline, it disappears suddenly. Van Staalduinen (1973) explained this with the interfingering of the Huergas, the Portilla, the Nocedo and the Ermita Formation with the Piedrasecha Formation. The detailed sections measured in this area (van Loevezijn, 1982), however, prove that above the Santa Lucía Formation only Nocedo and Ermita are present, including all the lithostratigraphical units which were recognized in other areas south of the Sabero-Gordón line. Therefore it is not necessary to distinguish a separate Piedrasecha Formation.

Evidence from fossils proves that the Portilla Formation does not interfinger with the Nocedo Formation. In fact the Nocedo lies immediately on the Santa Lucía Formation. The top of the Santa Lucía is an irregular surface formed by karst weathering (Buggisch et al., 1982). On top of it there is a thin shale (10 m thick) containing numerous cephalopods. Buggisch et al. (1982) found the same cephalopods in the Huergas Formation west of Sagüera. According to these authors they indicate a late Eifelian to Givetian age for the shales. In the same layer J.P.S. Goeijenbier (Rijswijk) found tentaculites indicating a late Givetian age (pers. comm., 1980). There must be a considerable hiatus between these shales and the overlying Nocedo Formation. But because the shale bed is thin and lithologically indistinguishable from the shales at the base of the Nocedo, it is included in unit A of that formation.

In the shales at the base of the Nocedo near Sagüera several slumps were recognized. North of the village a small limestone slump occurs at the base of the formation. Near Portilla de Luna an olistostrome (sensu Abbate et al., 1970) occurs, consisting of pebbly mudstone. It was traced laterally towards Sagüera where it pinches out against the top of the Portilla. Just above this pebbly mudstone some large limestone blocks are present. These originated from the Portilla carbonate platform as indicated by the facies and by the presence of the conodont *Polygnathus timorensis* Klapper, Philip & Jackson, 1970. The mass-gravity transport was caused by the difference in depth between the area west (north) of Sagüera where the carbonate platform was preserved and east (south) where this platform was absent. After the infill of the palaeorelief sedimentation was equal in both areas (Fig. 5).

FACIES MAPS

Van Adrichem Boogaert (1967) made a first biostratigraphically based palaeogeographic synthesis of the Late Devonian in the Cantabrian Mountains. As a result of detailed sedimentological and biostratigraphical research it is possible to give a more detailed outline of the depositional history for the southern areas. No palinspastic corrections were made for the displacement along faults and nappes. The Esla Nappe was originally situated south of the Sabero-Gordón line.

The first map (Fig. 6a) shows the reef platform which was present in this area during the early Frasnian (Upper *hermanni-cristatus* Zone). Probably north of the León line a low emerged area was present. The abundant reef growth in the southern areas indicates that erosion was slight or absent. In the northern part of the area south of the León line and at the Pardomino High there is little or no deposition. South of this area and east of the Pardomino High there is a carbonate platform with coral-stromatoporoid reefs. Only in the southern limb of the Alla syncline shales are present. The slumps and the olistostrome near Sagüera and Portilla de Luna indicate that in this area there was a steeper depositional slope.

The second map (Fig. 6b) represents the base of the Nocedo Formation, deposited during the Lowermost to Lower *asymmetricus* Zone. Again no deposits are known from the northern areas. Probably uplift was stronger, causing erosion, and these eroded materials were laid down in the southern areas north of the Sabero-Gordón line in a lagoonal environment and south of it in a transition and holomarine environment. Near the Pardomino High and in a narrow zone along the Sabero-Gordón line sands are present. At this time the Pardomino High was eroded.

The third map (Fig. 6c) represents the Lower to Middle *asymmetricus* Zone. At this time a carbonate platform was present once again. In most sections this deposit forms the top of unit A of the Nocedo Formation. In some sections (Huergas de Gordón, Santa Olaja de la Varga) younger deposits of unit A are present on top of the limestone. At Huergas de Gordón a part of these were formed in a lagoonal environment. Probably erosion removed these deposits from the other sections. The presence of the carbonate platform indicates that erosion was less intensive than earlier during the *asymmetricus* Zone. The limestone consists mainly of crinoidal grainstones, locally with corals and stromatoporoids (at la Ercina, Huergas de Gordón, La Cueta). No reefs of this age are known. Locally the limestone is absent: southeast of the Pardomino High and in the southwestern area sandstones were deposited. The arrow indicates the prevailing current direction calculated from measurements of large scale crossbedding in the sections at Barrios de Gordón, Huergas de Gordón, Portilla de Luna and Sagüera. At these locations the crossbedding is bipolar indicating that the sands were deposited in a shallow intertidal environment.

The fourth map (Fig. 6d) represents the base of unit B (Lower *gigas* Zone). In the northern area there was little or no deposition, south of the Sabero-Gordón line subsidence was rapid. Shales alternating with siltstones and sandstones were deposited, the sand was provided from the littoral zone by turbidity currents generated by storms.

The fifth map (Fig. 6e) represents the Upper to Uppermost *gigas* Zone (latest Frasnian) when the upper part of unit B of the Nocedo Formation was formed. At this time erosion was strong north of the Bernesga and Somiedo areas. Two mass flows formed fan-deltas south of the Sabero-Gordón line. Close to this line there occur coarse pebbles (up to over 20 cm); away from the sources the grain size rapidly decreases. The shape of the fans indicates a longshore current from east to west. South of the fan shales were deposited. More to the east the deposits are sandy and contain a rich brachiopod fauna. The presence of these sands is due to the erosion of the Pardomino High. In the Esla area a carbonate platform existed with stromatoporoid-coral reefs. The base of the Fueyo Member (early Famennian) has a development like the base of unit B (Fig. 6d).

The sixth map (Fig. 6f) shows the distribution of the younger Famennian deposits. After an important transgression intertidal sands were deposited in the whole area except in the south where sedimentation continues in the transition zone. At the end of the Famennian once again a carbonate platform is formed but now the coast is far away and depth of deposition is greater.

The three regressive sequences are the result of a tilting of the studied area: subsidence in the south is always accompanied by upheaval and erosion in the northern area and deposition in the southern area. When the relief is very low a carbonate platform may develop, sometimes with stromatoporoid-coral reefs. The late Famennian transgression was caused by a eustatic sea-level rise. From the maps it becomes apparent that subsidence was usually stronger in the Bernesga area than in the Esla and Somiedo areas.

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